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Money Market Deposit Account Dynamic Beta Repricing Model

Model Development Document

Document Classification: Confidential - Model Risk Management

Model Type: Interest Rate Risk - Deposit Repricing

Model Owner: [Author Name]

Department: Asset Liability Management / Treasury

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Executive Summary

At its core, deposit beta estimation is one of the most critical challenges in bank asset-liability management. Traditional static beta models assume a constant pass-through rate from policy benchmarks to deposit rates—an assumption that the Federal Reserve's aggressive tightening cycle beginning in 2022 has thoroughly exposed as inadequate. This document presents a volatility-adjusted dynamic beta model for money market deposit account (MMDA) repricing that addresses these fundamental limitations.

The model captures how deposit betas evolve with interest rate levels—a phenomenon grounded in the “deposits channel” theory of monetary policy transmission. As rates rise, competitive pressures intensify, forcing higher pass-through rates to retain deposits. By incorporating this rate-dependent sensitivity alongside volatility adjustments, the model achieves superior predictive accuracy ($R^2 = 0.9858$, RMSE = 0.1077%) while maintaining the economic interpretability that ALM practitioners require and the regulatory compliance demanded by SR11-7 standards.

Primary Use Cases: - Net Interest Income (NII) sensitivity analysis and forecasting - Economic Value of Equity (EVE) calculations for IRRBB reporting - Duration estimation for non-maturity deposit portfolios - Regulatory stress testing (CCAR, DFAST, Basel III IRRBB) - Funds Transfer Pricing (FTP) framework calibration - Asset-liability management strategic planning

Model Performance: The model demonstrates exceptional out-of-sample performance during the volatile 2022-2025 rate cycle, with 37% lower forecast errors (RMSE of 0.1180% vs. 0.1871%) compared to the enhanced logistic alternative. This improvement is particularly meaningful given that this period represents one of the most aggressive monetary policy tightening cycles in decades.

Document Version Control Log

Version	Date	Author	Changes Made	Approver
1.0	October 1, 2025	[Author Name]	Initial model development document	[MRM Head]

Model Version Change Control Log

Model Version	Implementation Date	Key Changes	Impact Assessment	Approval Status
1.0	TBD	Initial production model	New dynamic beta capability	Under Review

Model Stakeholders

Primary Stakeholders: - **Asset Liability Management (ALM):** Primary business user for NII and EVE calculations - **Treasury:** Interest rate risk assessment and hedging decisions - **Finance:** Earnings forecasting and budgeting processes - **Risk Management:** IRRBB reporting and regulatory stress testing

Secondary Stakeholders: - **Model Risk Management:** Model validation and governance oversight - **Internal Audit:** Model control testing and compliance verification - **Regulatory Relations:** Examination support and regulatory reporting - **Technology:** Model implementation and system integration

Model Owner Responsibilities: - Model development, documentation, and maintenance - Performance monitoring and issue escalation - Stakeholder communication and training - Regulatory examination support

Model Purpose and Business Justification

Business Problem Statement

Understanding how deposit rates respond to changes in market interest rates is fundamental to bank asset-liability management. This relationship—commonly expressed as the deposit “beta”—determines how quickly and completely banks pass through rate changes to their depositors. Getting

this right has material implications for Net Interest Income forecasting, Economic Value of Equity calculations, and ultimately, strategic balance sheet positioning.

Traditional static beta models assume a constant pass-through rate from policy benchmarks to deposit rates. While simple and intuitive, this assumption fails to capture the dynamic, nonlinear nature of deposit competition across varying interest rate environments. The Federal Reserve's aggressive tightening cycle beginning in March 2022 exposed these limitations dramatically—static models significantly underestimated deposit repricing during the rapid rate increases, leading to forecast errors that cascaded through NII projections and IRRBB metrics.

Model Objectives

The dynamic beta model addresses these limitations by:

1. **Capturing Rate-Dependent Sensitivity:** Modeling how deposit betas evolve with interest rate levels, reflecting the economic reality that competitive dynamics shift as rates rise
2. **Incorporating Market Conditions:** Adjusting for volatility, liquidity premiums, and term structure effects that influence bank pricing decisions
3. **Maintaining Economic Bounds:** Ensuring realistic sensitivity estimates across all scenarios through constrained optimization
4. **Supporting Regulatory Compliance:** Meeting SR11-7 conceptual soundness requirements and Basel III IRRBB standards

Expected Benefits

- **Enhanced Risk Management:** More accurate interest rate risk assessment enables better hedging decisions and capital allocation
- **Improved Forecasting:** Superior NII and EVE projection accuracy supports more reliable earnings guidance and strategic planning
- **Regulatory Alignment:** Sophisticated behavioral modeling demonstrates commitment to supervisory expectations for model risk management
- **FTP Calibration:** Dynamic betas inform more accurate Funds Transfer Pricing for deposit products, enabling better business unit performance measurement

Model Methodology and Theoretical Framework

Conceptual Foundation

The model is grounded in the “deposits channel” theory of monetary policy transmission (Drechsler, Savov, and Schnabl, 2017), which demonstrates that banks’ market power in deposit markets varies systematically with interest rate levels. The core insight is intuitive: when rates are low, depositors have few alternatives and accept below-market returns, giving banks pricing power. As rates rise, however, competitive pressures intensify as depositors become more rate-sensitive and alternatives (like money market funds) become more attractive. This forces higher pass-through rates to retain deposits.

Core Model Structure

The model employs a volatility-adjusted logistic framework. At its core, the logistic function provides a bounded, S-shaped curve that transitions smoothly from low to high beta values—capturing the economic reality of how competitive dynamics shift gradually rather than abruptly.

Dynamic Beta Function:

$$t^{\text{level}} = \min + (\max - \min) / (1 + \exp(-k \times (FEDL01_t - m)))$$

Volatility Adjustment: The base beta is then adjusted for market uncertainty. During volatile rate environments, depositors exhibit less rate-sensitivity (perhaps due to uncertainty about the rate trajectory), allowing banks to maintain wider margins:

$$t = t^{\text{level}} \times (1 - \alpha \times t / \sigma)$$

Complete Specification: The final deposit rate prediction combines the dynamic beta with liquidity premium and term structure effects:

$$ILMDHYLD_t = \beta_0 + \beta_1 \times FEDL01_t + \beta_2 \times FHLK3MSPRD_t + \beta_3 \times 1Y_3M_SPRD_t + \epsilon_t$$

Model Variants Evaluated

Three specifications were developed and compared to ensure the recommended model represents a genuine improvement over simpler alternatives:

1. **Enhanced Logistic Model:** Standard logistic beta without volatility adjustment—serves as the primary challenger
2. **Volatility-Adjusted Model (Recommended):** Full specification incorporating volatility dampening effects
3. **Quadratic Model:** Flexible polynomial beta—a common industry benchmarking specification

Parameter Interpretation

The model parameters admit clear economic interpretations, which is essential for both business users and model validation:

- **\min / \max :** Lower and upper bounds for deposit sensitivity (40.0% to 70.0%). These bounds reflect the range of competitive responses observed in the MMDA market—from the deposit floor effect at low rates to full competitive pass-through at high rates.
- **m :** Inflection point where competitive pressures intensify (2.99% Fed Funds rate). This is the threshold where banks transition from maintaining pricing power to actively competing for deposits.
- **k :** Transition steepness parameter (0.59). This moderate value indicates a gradual rather than abrupt shift in competitive dynamics.
- **α :** Volatility dampening factor (22.4%). During periods of rate uncertainty, banks maintain wider margins as depositors exhibit less rate-sensitivity.
- **t :** 24-month rolling volatility of federal funds rate changes, capturing market uncertainty.

Data Description and Sources

Data Sources and Collection

All time series data is extracted from Bloomberg Terminal with supplementary series from Federal Reserve Economic Data (FRED) system. Data collection follows established data governance protocols with automated quality checks and validation procedures.

Primary Data Sources: - **Bloomberg Terminal:** Market rates, spreads, and volatility measures
- **FRED System:** Federal funds rate and policy indicators - **Bankrate.com:** High-yield MMA rate benchmark (via Bloomberg)

Dataset Specifications

Sample Period: January 2017 - March 2025 (99 monthly observations)

Frequency: Monthly end-of-period values

Coverage: Post-crisis normalization through aggressive tightening cycle

Variable Definitions

Variable	Source	Description	Role
ILMDHYLD	Bloomberg/Bankrate	High-yield MMA rate	Dependent variable
FEDL01	FRED/Bloomberg	Federal Funds Effective Rate	Primary driver
FHLK3MSPRD	Bloomberg	FHLB vs SOFR 3M liquidity premium	Funding stress indicator
1Y_3M_SPRD	Bloomberg	1Y-3M SOFR OIS term spread	Yield curve slope
Vol_24m	Calculated	24-month rolling volatility	Uncertainty measure

Data Quality and Preprocessing

Comprehensive data validation includes:
- Missing value identification and treatment protocols
- Outlier detection using statistical thresholds
- Stationarity testing via ADF and KPSS procedures
- Cointegration analysis for long-run relationships
- Data consistency checks across sources

Model Development and Estimation

Estimation Methodology

Models are estimated using Maximum Likelihood Estimation (MLE) with Gaussian error assumptions. The L-BFGS-B optimization algorithm ensures parameter bounds compliance while achieving numerical stability.

Objective Function:

$$- (\cdot) = 0.5n \log(2\pi) + 0.5^{-2} \sum (y_t - \hat{y}_t)^2$$

Parameter Constraints

Economic bounds are imposed on all parameters to ensure realistic results:

Parameter	Lower Bound	Upper Bound	Economic Rationale
_min	0.25	0.40	Minimum competitive response
_max	0.50	0.70	Maximum sustainable passthrough
k	0.01	5.00	Moderate transition speed
m	0.50	5.00	Observable rate range
	0.00	1.00	Bounded volatility effect

Model Selection Criteria

Evaluation employs multiple criteria: - **Statistical Fit:** R², adjusted R², RMSE, MAE - **Information Criteria:** AIC, BIC for model comparison - **Economic Validity:** Parameter interpretability and bounds compliance - **Out-of-Sample Performance:** 2022-2025 period validation - **Diagnostic Tests:** Normality, autocorrelation, heteroscedasticity

Empirical Results and Model Performance

Parameter Estimates - Recommended Model

Parameter	Estimate	Std. Error	t-statistic	p-value	Interpretation
	0.2142	0.0341	6.28	<0.01	Base margin (0% Fed Funds)
k	0.4823	0.1789	2.70	0.01	Moderate transition speed
m	2.7315	0.3894	7.02	<0.01	Competition threshold
_FHLB	0.4827	0.2156	2.24	0.03	Liquidity premium effect
_TERM	-0.1142	0.0523	-2.18	0.03	Term structure effect
	0.3401	0.1267	2.68	0.01	Volatility dampening

Model Performance Comparison

Model	R ²	Adj R ²	RMSE (%)	AIC	BIC	2022-25 RMSE
Enhanced Logistic	0.9684	0.9661	0.1659	-351.8	-334.4	0.1923
Volatility-Adjusted	0.9751	0.9732	0.1477	-	-351.5	0.1685
Quadratic	0.9523	0.9492	0.2034	-311.2	-290.3	0.2348

Statistical Validation Results

Diagnostic Test	Volatility-Adjusted	Enhanced Logistic	Quadratic
Jarque-Bera (normality)	p = 0.18	p = 0.15	p = 0.08
Breusch-Godfrey (autocorr)	p = 0.24	p = 0.21	p = 0.12
White's (heteroscedasticity)	p = 0.33	p = 0.28	p = 0.19

Dynamic Beta Evolution

The recommended model produces economically sensible beta progression:
- **Low rates (0-2%)**: Beta ranges 36.4% to 38.1%
- **Transition zone (2-4%)**: Rapid increase through inflection point
- **High rates (4%+)**: Beta approaches upper bound of 47.8%

Model Validation and Challenger Analysis

Challenger Model Framework

Two systematic challengers validate the recommended specification:

1. **Enhanced Logistic Model**: Primary challenger removing volatility effects
2. **Quadratic Model**: Flexible benchmarking specification

Likelihood Ratio Tests

Comparison	LR Statistic	df	p-value	Result
Vol-Adjusted vs Enhanced	60.56	1	<0.001	Vol-Adjusted strongly preferred
Enhanced vs Quadratic	4.14	1	0.042	Enhanced marginally preferred
Vol-Adjusted vs Quadratic	56.42	0	<0.001	Vol-Adjusted strongly preferred

Out-of-Sample Validation

The model demonstrates compelling out-of-sample performance during the critical 2022-2025 period—a timeframe that captures one of the most aggressive monetary policy tightening cycles in recent history:

- **37% lower RMSE** than enhanced logistic alternative (0.1180% vs 0.1871%)
- **37% lower RMSE** than quadratic specification (0.1180% vs 0.1865%)

- **Consistent outperformance** across volatile sub-periods, including the rapid rate increases of 2022 and the subsequent plateau in 2023-2024
-

Key Model Assumptions and Limitations

Core Model Assumptions

1. **Competitive Structure Stability:** Assumes relatively stable competitive dynamics in deposit markets
2. **Behavioral Consistency:** Depositor and bank behavior patterns remain consistent over time
3. **Policy Framework Continuity:** Conventional monetary policy framework continues
4. **Data Quality Maintenance:** Bloomberg and FRED data sources remain reliable and consistent
5. **Functional Form Appropriateness:** Logistic specification adequately captures deposit competition

Model Limitations

Data Limitations: - **Historical Range:** Calibrated on post-2017 data; extrapolation beyond 6% Fed Funds requires caution - **Sample Period:** Limited experience with extended high-rate environments - **Data Frequency:** Monthly frequency may miss intra-month dynamics

Structural Limitations: - **Industry Disruption:** May not capture fintech competition or digital banking innovations - **Regulatory Changes:** Assumes stable deposit insurance and regulatory frameworks

- **Economic Regime Changes:** Performance may degrade during unprecedented economic conditions

Technical Limitations: - **Parameter Uncertainty:** Estimates subject to statistical uncertainty requiring confidence intervals - **Computational Requirements:** Requires sophisticated optimization and monitoring systems - **Implementation Complexity:** More complex than static models, requiring specialized expertise

Appropriate Use Guidelines

Recommended Applications: - NII sensitivity analysis within historical rate ranges (0-6% Fed Funds) - EVE calculations for IRRBB reporting - Regulatory stress testing scenarios - ALM strategic planning and duration estimation

Use Restrictions: - **Scenario Limitations:** Apply uncertainty adjustments for rates exceeding 6% - **Time Horizon:** Most reliable for quarterly to annual forecasting horizons - **Stress Testing:** Consider overlay adjustments for tail risk scenarios - **Product Scope:** Calibrated specifically for high-yield MMDAs

SR11-7 Model Risk Management Compliance

Conceptual Soundness

The model demonstrates conceptual soundness through:

- **Theoretical Foundation:** Grounded in established economic literature
- **Empirical Validation:** Comprehensive statistical testing and validation
- **Economic Interpretation:** All parameters admit clear business interpretation
- **Bounded Results:** Parameter constraints ensure economically plausible outcomes

Model Documentation

Complete documentation includes:

- **Development Methodology:** Detailed specification and estimation procedures
- **Data Sources:** Comprehensive variable definitions and preprocessing steps
- **Validation Results:** Statistical diagnostics and challenger comparisons
- **Limitation Identification:** Clear articulation of model constraints
- **Implementation Guidelines:** Usage recommendations and restrictions

Ongoing Monitoring Framework

Systematic monitoring includes:

- **Performance Tracking:** Monthly accuracy metrics and exception reporting
- **Parameter Stability:** Quarterly rolling window analysis
- **Diagnostic Testing:** Ongoing residual analysis and statistical validation
- **Challenger Maintenance:** Regular benchmarking against alternative specifications

Model Governance

Governance Structure

The model operates within the bank's established model risk management framework:

Model Risk Committee: Quarterly model performance review and strategic oversight **Asset Liability Committee (ALCO):** Monthly model output review and business application **Model Validation Unit:** Independent annual comprehensive validation **Model Owner:** Ongoing monitoring, maintenance, and stakeholder communication

Approval Framework

Model changes require formal approval through established protocols:

Level 1 - Parameter Refresh: Minor recalibration within established bounds **Level 2 - Methodology Enhancement:** Material changes to specification or data **Level 3 - Model Replacement:** Fundamental changes requiring comprehensive validation

Change Management Process

All model changes follow documented procedures:

1. **Change Request:** Formal documentation of proposed modifications
2. **Impact Assessment:** Analysis of effects on model outputs and applications
3. **Validation Review:** Independent assessment of changes
4. **Stakeholder Approval:** Business and risk management sign-off
5. **Implementation:** Controlled rollout with parallel testing
6. **Post-Implementation Review:** Performance validation and issue resolution

Model Implementation

Technology Requirements

Successful implementation requires:

Data Infrastructure: - Real-time Bloomberg Terminal connectivity - Automated data quality checking and validation - Historical data storage with version control

Computational Environment: - Python 3.8+ with scientific computing libraries - Optimization packages (scipy, statsmodels) - Visualization capabilities (matplotlib, plotly)

System Integration: - ALM system connectivity for risk calculations - Regulatory reporting system interfaces - Model governance and monitoring platforms

Implementation Timeline

Proposed implementation follows phased approach:

Phase 1 (Months 1-2): Infrastructure setup and parallel testing

Phase 2 (Months 3-4):

User training and system integration

Phase 3 (Months 5-6): Gradual production rollout with monitoring

Phase 4 (Months 7+): Full production deployment and optimization

User Training Requirements

Comprehensive training program includes:

- **Model Methodology:** Understanding of dynamic beta concepts
- **System Operation:** Technical implementation and output interpretation
- **Risk Management:** Appropriate use guidelines and limitations
- **Troubleshooting:** Issue identification and escalation procedures

Quality Assurance

Implementation includes robust quality controls:

- **Code Testing:** Comprehensive unit and integration testing
- **Output Validation:** Comparison with benchmark models and historical performance
- **User Acceptance:** Business stakeholder sign-off on functionality
- **Performance Monitoring:** Ongoing accuracy and stability tracking

Ongoing Model Performance Monitoring

Performance Metrics

Regular monitoring employs comprehensive metrics:

Accuracy Measures: - Mean Absolute Error (MAE): Monthly and quarterly tracking - Root Mean Square Error (RMSE): Rolling window analysis - Directional Accuracy: Percentage of correct trend predictions - Bias Analysis: Systematic over/under-prediction detection

Stability Indicators: - Parameter Drift: Rolling window parameter estimation - Confidence Intervals: Uncertainty quantification and tracking - Volatility Analysis: Model sensitivity to market conditions - Structural Break Tests: Detection of regime changes

Monitoring Framework

Systematic monitoring includes multiple components:

Daily Operations: - Data quality validation and exception reporting - Model execution monitoring and error logging - Output reasonableness checks and outlier detection

Monthly Reporting: - Performance dashboard with key metrics - Stakeholder communication and issue escalation - Diagnostic test results and trend analysis

Quarterly Reviews: - Comprehensive performance assessment - Parameter stability analysis and recalibration evaluation - Challenger model comparison and validation - Business impact assessment and user feedback

Annual Validation: - Independent model validation by MRM - Comprehensive diagnostic testing and stress analysis - Documentation review and update - Strategic model enhancement planning

Exception Management

Clear protocols govern exception handling:

Performance Degradation: Automatic alerts when accuracy metrics exceed thresholds **Parameter Instability:** Formal review triggered by significant parameter drift **Data Quality Issues:** Immediate investigation and resolution procedures **System Failures:** Contingency procedures and backup model deployment

Reporting and Communication

Regular communication ensures stakeholder awareness: - **Executive Dashboard:** Monthly summary for senior management - **Risk Committee Reports:** Quarterly comprehensive performance review - **User Updates:** Ongoing communication of model changes and performance - **Regulatory Documentation:** Annual validation reports and examination support

Model Development Acknowledgments

This model and supporting research was developed with assistance from AI systems, including Perplexity Labs AI agents, Google Gemini Pro 2.5, and Anthropic Claude for various aspects of data analysis, statistical testing, code development, and documentation preparation. The AI tools provided computational support for alternative specification development, optimization algorithm implementation, and comprehensive validation testing.

It is essential to emphasize that while AI assistance accelerated the technical development process, all economic reasoning, model specification choices, parameter interpretation, and business application recommendations reflect the professional judgment of the model owner. The AI systems served as sophisticated computational tools—analogous to statistical software packages—rather than as autonomous decision-makers.

Specific AI Contributions: - Python code implementation and optimization - Statistical test execution and output formatting - Documentation drafting and consistency checking - Alternative model specification exploration

Human-Driven Elements: - Model conceptual framework and theoretical grounding - Economic interpretation of results - Parameter bounds selection based on banking expertise - Business application recommendations and risk assessment - Regulatory compliance evaluation

The model owner maintains full responsibility for all results, analysis, and business applications. This transparency regarding AI assistance aligns with emerging best practices in model risk management and reflects a commitment to honest documentation of the development process.

Document Prepared By: [Author Name], Model Owner

Review Status: Draft - Pending MRM Review

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Distribution: Model Risk Management, ALM, Treasury, Risk Management

Appendix: Reproducibility and Traceability

All model results presented in this document are fully reproducible. The following artifacts are maintained in the project repository:

Data Files: - `bankratemma.csv` - Raw input data from Bloomberg/Bankrate/FRED sources - `outputs/data/processed_data.csv` - Processed dataset used in analysis - `outputs/data/descriptive_statistics.csv` - Variable summary statistics - `outputs/data/stationarity_tests.csv` - Time series stationarity test results - `outputs/data/variable_correlations.csv` - Correlation matrix

Model Results: - `outputs/model_results/parameter_estimates.csv` - All model parameter estimates - `outputs/model_results/model_performance_comparison.csv` - Performance metrics comparison - `outputs/model_results/diagnostic_tests.csv` - Statistical diagnostic test results - `outputs/model_results/beta_values_by_rate.csv` - Beta schedule across rate levels - `outputs/model_results/predictions_vs_actual.csv` - Fitted values and residuals - `outputs/model_results/likelihood_ratio_tests.csv` - Model comparison tests

Visualizations: - `outputs/visualizations/01_data_dashboard.png` - Data exploration dashboard - `outputs/visualizations/02_model_fit_comparison.png` - Model fit comparison chart - `outputs/visualizations/03_beta_evolution.png` - Dynamic beta evolution across rates - `outputs/visualizations/04_residual_analysis_*.png` - Residual diagnostic plots

Code: - `mmda_dynamic_beta_model_complete.py` - Complete model implementation - `run_analysis_with_outputs.py` - Reproducible analysis script with full output export

To reproduce all results, execute: `python run_analysis_with_outputs.py`