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INTEREST RATE RISK IN BANKING BOOKS (IRRBB): A REVIEW OF NON-PARALLEL YIELD CURVE SHOCKS AND CAPITAL OPTIMIZATION STRATEGIES IN U.S. BANKS

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ABSTRACT

Interest Rate Risk in the Banking Book (IRRBB) focusing on cliff implications of non-parallel yield curve shocks as well as capital optimization methods at American banks. The review provides a theoretical background to IRRBB, and four key types of non-parallel yield curve movements that banks may be subject to (yield curve steepening, flattening, twisting and butterfly shifts), discusses the potential impact of these shocks on banks' earnings, Economic Value of Equity (EVE), Net Interest Income (NII), liquidity, regulatory capital as well as how these risks interact with existing advanced Asset-Liability Management (ALM) frameworks designed to support effective mitigation measures. Based on current literature and regulatory outlook, the study reveals that methods of measuring interest rate risk based on parallel shifts in the yield curve are becoming more inadequate as there is little to no resemblance to modern banking environments. Integrated risk management, behavioral deposit modelling, dynamic balance sheet optimization, stress testing and derivative-based hedging strategies can increase banking resilience as well as the ability to preserve capital and comply with regulatory requirements. The study suggests that forward looking and technology driven IRRBB management frameworks are needed to improve financial stability, and appropriate long-term sustainability of U.S. banks, because interest rates that stay volatile for long can adversely impact both economic health and medium-term bank profitability in the face of shocks affecting macroeconomic conditions.

Keywords: Interest Rate in The Banking Book, Non-Parallel Yield Curve Shocks, Capital Optimization, Asset-Liability Management, US Banking Sector.

1 INTRODUCTION

In the changing finance world, Interest Rate Risk in the Banking Book (IRRBB) was one of the most significant financial risks to a modern banking institution since aggressive U.S. Federal Reserve monetary tightening started in response to economic overexposure to inflation pressures from mid-2022 onwards. IRRBB, in contrast to trading book risk, which is driven by short-term market price valuation changes, arises from the movement of market interest rates affecting the earnings, cash flows and economic value of a bank's assets, liabilities and off-balance-sheet exposures (Tata, 2025), which impacts NII (net interest income), EVE (economic value of equity), capital adequacy, liquidity, long-term

profitability. In the past, banks generally used business and financial (B&F) to measure their IRRBB under the prior unchanged yield curve assumption. Business and Financial (B&F) is rarely considered an accurate approximation of IRRBB in practice since interest rates hardly move parallel across maturities. Not only do yield curves shift from constant direct lead to complex risk diversification, but it also causes exposures for institutions such as steepening, flattening, twisting and butterfly shifts (Majka, 2025) but also limits that are clearly not correctly captured by conventional duration re-measurement methods and gap management metrics. This non-neutral (steepening) non-parallel shocks in the yield curve creates important anchoring of financial intermediation on lending and capital market processes. This shapes how banks effectively price loans, securities portfolios, customer deposits, other interest-sensitive instruments, balance sheet resilience, income, etc.

As shown by the banking crisis where a rapidly increasing rate environment caused large mark-to-market losses, clearing capital-position vulnerabilities due to structural weaknesses in many regional banks' asset-liability management practices proved difficult (Chiaramonte, 2018). Additionally, deposit franchise assumptions based on historical experience often prove incorrect during policy reversals with multiple reasons contributing among which the most important lies in defending a deposit. Changing customer behavior makes it hard for banks to hedge effectively while also lowering systemic risk through a reduction in the betas increase and thus non-parallel yield curve shifts leaving institutions evermore open to shocks.

2 LITERATURE REVIEW

2.1 Theoretical Background Theory on Interest Rate Risk in the Banking Book (IRRBB)

Interest rate risk in the banking book (IRRBB) is known as one of the most fundamental risks faced by contemporary financial institutions due to their basic function of maturity transformation (Lubinska, 2021) whereby banks fund long-term assets with short-term liabilities, thus making both earnings and capital sensitive to fluctuations in market interest rates. In contrast to trading book risk arising mainly from short-term market price fluctuations, IRRBB directly influences the banking book through repricing risk, basis risk, yield curve risk, option risk and credit spread risk in the banking book (CSRBB) (Mathur, 2015). This is susceptible to significantly influencing a bank's Net Interest Income (NII), Economic Value of Equity (EVE) liquidity position and capital adequacy. Finally, Lubinska (2020) claim that structural timing mismatches between fixed-rate assets and floating-rate liabilities are still the main causes of IRRBB, especially in scenarios when countries face large monetary policy changes. Similarly, the stability of banks' earnings is directly influenced by changes in term structure of interest rates as it has an impact on interest margins and market value of financial instruments.

Traditional maturity gap analysis for measuring interest rate risk is insufficient because the financial innovation and complexity of modern banking products make it difficult to measure risks accurately. Ramlall (2018) also highlight that prolonged interest rate volatility may substantially diminish bank capital where banks do not apply forward-looking risk measurement methods in their balance sheet management. International regulators have therefore increased supervisory expectations, which now require banks to establish robust governance and stress testing frameworks as well as standardized interest rate shock scenarios to enhance their IRRBB measurement and capital resilience (Pliszka, 2021). Thus, theoretical literature defines IRRBB as a complex financial risk that necessitates sophisticated measurement frameworks to safeguard banking sector stability during changing macroeconomic conditions.

2.2 Non-Parallel Yield Curve Shocks and Balance Sheet Vulnerabilities

The conventional view that interest rates move in aligned parallel shifts has been gradually undermined by several empirical studies revealing a substantial incidence of non-parallel shifts among the yield curves, consisting of steepening, flattening, twisting and butterfly shifts and thus a different impact for earnings and capital positions of banks. Such non-parallel yield curve movements result in the redistribution of interest rate exposure among the various maturity segments, increasing repricing risk, basis risk, and yield curve risk beyond what traditional duration and static gap models can predict (Lubinska, 2022). Non-parallel shocks drastically change economic value of equity (EVE), irrespective of short-run net interest income (NII) remaining relatively constant, thus traditional earnings-based indicators on their own cannot adequately account for structural fragilities. In an analogous manner, Olusegun (2025) show that yield curve dynamics are closely interlinked with liquidity conditions and macroeconomic expectations, reinforcing banking system fragility in a tightening monetary cycle.

Additionally, out-of-synch movements aggravate embedded optionality as the influence of customer loan prepayments, mortgage refinancing, and deposit withdrawals creates more uncertainty in balance sheet management. The asymmetric shifts of yield curves reveal shortcomings in standard immunization approaches, as various maturity buckets respond differently to changing market conditions. Consequently, recent literature recommends incorporating several yield curve scenarios in IRRBB stress testing models to enhance banks' ability at finding balance sheet

vulnerabilities and deploying capital appropriately (Eichhorn, et al., 2021). Overall, these studies suggest that the bank resilience to time-varying interest rates hinges on non-parallel equilibrium yield curve dynamics.

2.3 Empirical Evidence from the U.S. Banking Sector and Deposit Behavior

Recent empirical evidence from the United States banking sector suggests that poor monitoring of IRRBB can have severe negative implications for overall financial stability, especially when monetary policy tightening is implemented hastily (Gortsos, 2023). The U.S. regional banking crisis of 2023 demonstrated how large unrealized losses can accumulate in portfolios of long-term securities when interest rates rise rapidly, which exposed more vulnerabilities in duration management, liquidity planning, and capital preservation (Trapanese, et al., 2024). Increasing policy rates had a significant impact on customer deposit behavior through an increase in deposit betas, with customers moving money from low-interest transactional accounts to higher returning investment alternatives. Trapanese et al (2024) note an especially deteriorating stability of retail deposit franchises during periods of aggressive monetary tightening, undermining the effectiveness of traditional balance sheet hedging strategies.

Interaction between liquidity risk and interest rate risk further manifested systemic vulnerabilities in U.S. bank balance sheet during this period according to Ji (2025). Thus, empirical evidence indicates that behavioral assumptions related to customer deposits and funding structures should be incorporated into IRRBB measurement models for enhanced capital planning and supervisory oversight (Lubinska, 2021). In general, the literature thus shows that effective modelling of deposit behavior and interest rate sensitivity is now a critical part of ensuring resilience in the U.S. banking system.

2.4 Capital Optimization Strategies and Advanced Asset-Liability Management.

The heightened volatility in interest rates has called for banks to adopt sophisticated capital optimization methodologies that go beyond a simplistic maturity gap view and embrace integrated ALM frameworks capable of managing earnings at risk, liquidity and regulatory capital simultaneously. This emergence of modern ALM practices includes but is not limited to the application of tools such as duration gap analysis, Economic Value of Equity (EVE) sensitivity analysis, Net Interest Income (NII) simulations (Lubinska, 2020). Dynamic balance sheet modelling, interest rate derivatives along with stress testing and scenario analysis to improve institutional resilience under non-parallel yield curve shocks in recent years. Dynamic hedging strategies with interest rate swaps and other derivatives can drastically increase banks' ability to smooth earnings in unpredictable monetary environments (McPhail, 2023). Equally, including credit, liquidity risk and interest risks in integrated optimization frameworks lead to the right economic capital allocation while also enhancing long-term profitability. However, empirical studies by Boztepe et al (2025) show that behavioral balance sheet models with a detailed representation of how customer demand for deposits influence the bank's choice between retaining or replacing liabilities leading to capital optimization outperform static modelling approaches in their predictive power.

Increasing implemented regulations where extensive testing of stress tests, as well as model validation procedures, are mandated to comply with Basel III Pillar 2 expectations from banks. The literature, while substantial, points to further gaps in research with respect to the inclusion of AI, ML and predictive analytics into integrated modelling and capital optimization frameworks for IRRBB. Thus, this study suggests that a step further in future research is warranted towards modelling the risk of exposure from non-parallel yield curve shocks and behavioral uncertainty as well as regulatory capital optimization.

3 RESULTS

3.1 Interest Rate Risk in the Banking Book (IRRBB) Remains a Critical Driver of Banking Stability and Capital Adequacy

As a result, the literature review reveals that Interest Rate Risk in the Banking Book (IRRBB) remains one of the important drivers of financial stability, profitability and regulatory capital adequacy of commercial banks and perhaps most acutely in U.S. banking sector. The results show that when banks are mismatched in their interest rate-sensitive assets and liabilities, they become exposed to inherent risks in Net Interest Income (NII) and the Economic Value of Equity (EVE) that result from repricing risk, basis risk, yield curve risk, option risk and credit spread risk (Shekhar, 2025). It also illustrates that with the evolution of market dynamics and financial innovation; traditional maturity gap analysis is not suitable to measure these increasingly multifaceted sources of interest rate risk. This in turn has also prompted regulatory authorities such as BCBS, the Federal Reserve and Office of the Comptroller of Currency (OCC) to call on banks to implement more robust frameworks for IRRBB measurement, governance, stress testing and scenario analysis (Abubakar, 2025).

The results also highlight from a wider angle the importance of effective IRRBB management through higher resilience by capital preservation, improved liquidity management, and better long-term viability. Taking together, these findings suggest that IRRBB has transitioned from an operational balance sheet management challenge to a critical strategic regulatory and enterprise risk management focus area (Ibrahim, et al., 2025). All in all, the evidence shows that strong IRRBB management is essential for the resilience of the banking sector and financial stability.

3.2 Non-Parallel Yield Curve Shock Significantly Increase Structural Balance Sheet Vulnerabilities

Non-parallel yield curve shifts as one of the most difficult aspects of contemporary interest rate risk, since it causes asymmetric movements among the various maturity segments of banks' balance sheets. The results show that standard duration matching and static gap analysis often understate the structural vulnerabilities on the ground that they rely on mean reversion to organize curve-shifts across maturities. As a result, banks that only depend on classic immunization methods are more prone to errors in their EVE risk and perspective earnings sensitivity estimates when monetary policy goes through turbulent cycles (Ige, 2025).

The review also shows that localized yield curve shifts speed up loan prepayment, change the behavior of customer deposits and have a large impact on the valuation of securities portfolios, which eventually increases uncertainty in managing the balance sheet (Moro-Visconti, 2026). They imply that structural banking risk is more accurately estimated using comprehensive multi-factor yield curve simulations rather than single-factor interest rate models. This suggests that a range of non-parallel yield curve scenarios are appropriate for use in regulatory stress testing and asset-liability management modelling. In short, robust non-parallel yield curve dynamics are crucial to help strengthen banks' risk identification, capital planning and strategic decision-making (Haque, 2026).

3.3 Changing Deposit Behavior and Integrated Risk Management are Essential for Banking Resilience

The review also states that changing behavior of customer deposits has developed into a key driver of banking resilience as monetary tightening turned aggressive, especially following the 2023 U.S. regional banking crisis. As shown in the literature, traditional asset-liability management models severely overstate the durability of retail deposit franchises by modeling that customers will react sluggishly to increasing market interest rates (Shekhar, 2025). Rather, higher deposit betas induced depositors to quickly migrate funds from low-yielding deposits into high-yield investments, creating even stronger liquidity strains that eroded traditional hedging measures. Moreover, they show that these behavioral changes have hastened the extent of unrealized losses on held-to-maturity and available-for-sale securities portfolios to the extent of causing dwindling amounts of regulatory capital and institutional liquidity (Marsh, et al., 2023).

In addition, the literature suggests that separating interest rate risk measurement from credit risk creates major vulnerabilities in capital planning as higher interest rates lead to an increase both in probabilities of default by borrowers and funding costs. Therefore, contemporary banking organizations need to manage risks in an integrated manner by employing interest rate risk and credit risk modelling as well as liquidity risk modelling and behavioral deposit modelling under one framework in simulated testing environment (Meshkova, et al., 2018). Integrating those approaches improves the economic allocation of capital, promotes stronger compliance with supervisory oversight, and provides greater institutional resilience in times of financial stress. In general, the results illustrate that behavioral finance aspects and holistic risk management are unavoidable building blocks of successful IRRBB management.

3.4 Advanced Capital Optimization and Dynamic Hedging Strengthen Regulatory Compliance and Long-Term Performance.

Previous studies found consistent evidence that advanced capital optimization strategies have resulted in improved banks' regulatory capital run-off stability, earnings stabilization and long-term financial performance during interest rate instability (Acharya, et al., 2024). Interest rate swaps, options and other derivative instruments for dynamic hedging help banks minimize their exposure to arguably non-parallel yield curve shocks while stabilizing earnings and avoiding needless asset liquidation. The review further illustrates that portfolio optimization models which incorporate all aspects of risk, such as credit risk, liquidity risk and interest rate risk are better at allocating capital than the traditional silo approach to each of these types of risks (Subramanian, et al., 2022). In addition, banks are subject to more rigorous stress testing and model validation by regulators in meeting supervisory levels on IRRBB management under Basel III Pillar 2 (Acharya, et al., 2024).

These advances notwithstanding, literature reveals opportunities to enhance capital optimization by augmenting existing data with artificial intelligence, machine learning, predictive analytics, and real-time behavioral modelling (George, et al., 2024). Such developments will take place in conjunction with an increased ability to support more accurate risk forecasting, as well as achieving greater strategic balance sheet management in a macroeconomic environment that is becoming ever less certain. In summary, the results examine how sophisticated capital optimization

as well as very dynamic hedging strategies are key to maintaining adequate capital levels, regulatory compliance, and enhancing long-term stability for US banking institutions.

Table 1: Summary of the Major Findings of the Study.

Finding Area	Major Findings	Implications for U.S. Banks
IRRBB and Banking Stability	IRRBB remains a major determinant of banks' financial stability, profitability, liquidity, and capital adequacy. Traditional maturity gap analysis is insufficient for managing modern interest rate risks, requiring stronger governance and comprehensive IRRBB frameworks.	Banks should strengthen enterprise-wide IRRBB governance, implement robust stress testing, and adopt integrated risk management practices to improve resilience and regulatory compliance.
Non-Parallel Yield Curve Shocks	Non-parallel yield curve movements, including flattening, twisting, and butterfly shifts, expose significant repricing, bias, and yield curve risks that conventional models frequently underestimate.	Banks should incorporate multiple yield curve scenarios and dynamic simulations models into Asset-Liability Management (ALM) to improve risk identification, capital planning, and strategic decision-making.
Deposit Behavior and Integrated Risk Management	The 2023 U.S. banking crisis revealed that changing customer deposit behavior, rising deposit betas, and interaction between interest rate risk, liquidity risk, and credit risk significantly weaken traditional risk management models.	Financial institutions should integrate behavioral deposit modelling with credit, liquidity, and interest rate risks within unified enterprise risk management frameworks to enhance financial resilience and reduce systemic vulnerabilities.
Capital Optimization and Advanced ALM	Dynamic capital optimization, derivative-based hedging, stress testing, Economic Value of Equity (EVE) analysis, Net Interest Income (NII) simulations, and advanced Asset-Liability Management (ALM) frameworks significantly improve banks' ability to manage IRRBB and maintain regulatory capital.	Banks should invest in advanced ALM systems, dynamic hedging strategies, and technology-driven risk management to strengthen capital adequacy, improve long-term profitability, and ensure compliance with Basel III Pillar 2 requirements.

4 DISCUSSIONS

4.1 Reconceptualizing Interest Rate Risk and Yield Curve Management in Modern Banking.

The results confirm that IRRBB is no longer a traditional asset-liability management problem but should be treated as an enterprise risk strategic issue impacting stability, profitability and regulatory compliance (Kallur, 2016). This review highlights that the traditional assumption of a parallel yield curve is growing less sufficient due to interest rates rarely moving in lockstep across the maturity spectrum. In particular, the structural changes in some banks balance sheet exposed to non-parallel yield curve movements like steepening, flattening and twisting, or butterfly shifts have proven to be even more harmful than how traditional mismatch liability structures based on duration matching and static gap analysis. This evidence bolsters the case for more dynamic, forward-looking risk-management approaches employed via Asset–Liability Committees (ALCOs) that can capture multiple dimensions of yield curve behavior (Haque, 2026).

Finally, good scenario analysis and stress testing need to be part of IRRBB frameworks as they help banks detect latent repricing and basis risk exposures ahead of looming threats on earnings and capital. Relatedly, these findings also support the proposal by the Basel Committee for banks to use multiple standardized interest rate shock scenarios on both sides of the balance sheet as opposed to only a parallel shift assumption (Chen, 2025). As a result, today's banking institutions must re-conceptualize yield curve risk as a concise but multidimensional phenomenon for which there is ample need for advanced analytical tools and continual oversight. The organizational change can enhance institutional resilience while optimizing the efficiency of large-scale risk management within a progressively unstable monetary environment.

4.2 Behavioral Deposit Dynamics and Balance Sheet Resilience.

The results also show that the shifts in customer deposit behavior have been transformed into one of the main driving forces behind banks' resilience during tighter monetary policy regimes, especially since 2023 U.S. banking crisis. The

literature indicates that traditional asset-liability management models relied heavily on the assumption of slow depositor responses to increasing market interest rates, resulting in substantial overestimates of the stability of retail deposit franchises. However, though deposit betas have been kept low due to the vast decrease in the interest rate environment following app groups, technological advances made possible by digital banking coupled with increased financial literacy and lucrative alternative investment opportunities (Gomber, et al., 2018). This has given customers the complete ability to shift funds quickly into higher yielding coordinated asset classes.

This change in behavior undermines traditional funding assumptions, amplifies liquidity strains and intensifies the mark-to-market losses on fixed-income portfolios. Thus, banks should substitute static behavioral deposit assumptions with dynamic behavioral deposit models that adapt over time to evolving market conditions and customer preferences (Ahmed, et al., 2023). These types of models will enhance both liquidity forecasting, capital planning, and interest rate risk measurement as well as reducing the odds of funding shocks hitting them out-of-the-blue. It is suggested that behavioral finance has become an integral part of successful IRRBB management and strategic balance sheet planning. Using behavioral analytics in ALM frameworks will bolster normality of banking through economic shocks arising from future monetary uncertainty (Binhamad, 2025).

4.3 Integrated Risk Management Enhances Capital Planning and Financial Stability

The crucial lesson from these findings is that management of banking risks should no longer involve credit risk, interest rate risk and liquidity intermixed in isolation as during market stress, they are becoming more interdependent. Research shows not only do higher interest rates lower the market value of those specific assets but rising debt-servicing burden on borrowers lead to a rise in default probabilities and overall asset quality deterioration (Sulistyono, 2026). As a result, banks that account for these risks in isolation may grossly understate their economic capital needs and overall susceptibility to financial shocks. The results do provide some evidence that integrated enterprise risk management frameworks, with unified simulation models and full-blown stress testing, that simultaneously take multiple elements of risk into account are beneficial (Edwards, et al., 2024).

These integrated approaches enhance capital allocation decisions by accounting for the interactions between shifting interest rates, customer behavior, liquidity strains, and credit quality. In addition, integrated risk management improves regulatory compliance by giving supervisors a better understanding of the resilience of institutions under adverse economic scenarios (Adeniran, et al., 2024). This also indicates it is essential to improve collaboration between market risk, credit risk, treasury and asset-liability management functions for strategic decision-making (Fallah et al., 2026). At its core, integrated risk management is a more holistic and proactive approach to securing financial stability and long-term banking success.

4.4 Dynamic Capital Optimization and Advanced Hedging Strategies Enhance Long-Term Performance

The results further show how utilizing sophisticated capital optimization strategies is crucial in reinforcing banks' resilience against constant interest rate volatility, whilst enhancing sustainable profitability and regulatory compliance. With an ever-changing monetary environment, traditional balance sheet matching techniques are no longer enough: Interest rates do change but far quicker than conventional maturity matched assets can be exchanged with reference to banks risk profile (Guzel, 2021). Therefore, modern Asset-Liability Management (ALM) frameworks combine Economic Value of Equity (EVE) analysis, Net Interest Income simulation and dynamic balance sheet optimization with interest rate derivatives trading techniques into holistic stress testing aimed at optimizing the strategic use of capital by banks (Saeidinezhad, 2024). Moreover, interest rate swaps, options, caps and floors, and other derivatives instruments give the banks much more flexibility to hedge implicit exposures with non-parallel yield curve movements than relying on extensive asset sales or disruptive lending activity.

In addition, these optimization techniques can help with compliance with Basel III Pillar 2 supervisory expectation in terms of supporting model validation, governance and capital planning process. It further explored how capital optimization model can leverage artificial intelligence, machine learning and predictive analytics to bring game changing improvements for interest-rate forecasting and strategic planning (Adewale, et al., 2023). Jameaba (2022) anticipated that the advances such technological innovations will enable banks to quickly spot a risk in advance, architecture their balance sheets for better effectiveness and uphold high levels of long- term durability. Dynamic capital optimization and sophisticated hedging must therefore be considered the bedrock of sustainable banking in the face of macroeconomic uncertainty.

5 CONCLUSION

Interest Rate Risk in the Banking Book (IRRBB) continues to be one of the potentially largest sources of financial risk threatening the safety, soundness and long-term viability of many U.S. banking institutions. The challenge posed by the increasing complexity of interest rate movements, driven primarily by non-parallel yield curve shocks such as

steepening, flattening, twisting and butterfly shifts, has been borne witness to this review. It was shown that traditional interest rate risk measurement techniques based on parallel shift assumptions and static gap analysis have become progressively less effective. It was also found that these complex yield curve dynamics have a critical impact on the Net Interest Income (NII), Economic Value of Equity (EVE), liquidity management, regulatory capital and resilience of banking sector as illustrated in 2023 U.S. banking crisis. This provided shocking evidence about the disastrous consequences of poor duration management, unrealistic behavioral assumptions regarding customer deposits, and ineffective asset-liability management practices.

The review also identified the need for banking institutions to implement integrated Asset-Liability Management(ALM) frameworks that seamlessly integrate dynamic balance sheet optimization with comprehensive stress testing, multi-factor scenario analysis, behavioral deposit modelling, Economic Value of Equity, sensitivity analysis, Net Interest Income simulations, and derivative-based hedging strategies that both bolster capital preservation mechanisms as well as strengthen strategic decision-making. Also, if interest rate risk is incorporated with liquidity and credit risk and behavioral considerations, a greater overall picture of banks' total risk exposure, which can also provide support to firms in meeting their Pillar 2 supervisory expectations on behaviors of Basel III. The study therefore concludes that U.S. banks' resilience in the future will increasingly rely on their ability to replace traditional static risk management practices with forward-looking, technology-enabled, integrated capital optimization frameworks able to accurately estimate non-parallel yield curve risks adapt to evolving customer behavior (preserving regulatory capital requirements) and improving financial stability for sustainable long-term profitability in a continuously uncertain and volatile rate environment.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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