CBDC and Financial Stability in Dual-Currency Savings Economies – Volume I

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<u>Working Paper Draft – Policy Non-Technical Highlights</u>

Disclaimer

This study reflects the author's independent research and views. It does not represent the official position of the National Bank of Romania or any of its affiliated institutions. It is circulated solely as a working-paper draft that has not yet undergone internal peer review within the NBR. It is expected to be published by 15th October on the NBR's website.

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Foreword

This volume, *CBDC and Financial Stability in Dual-Currency Savings Economies*, represents the first comprehensive contribution of a two-part study that explores the profound and increasingly relevant intersection between central bank digital currencies (CBDCs) and macro-financial stability. Drawing upon an extensive empirical framework, rooted in vector autoregression, principal component analysis, machine learning, and scenario stress testing, this volume advances the global literature by demonstrating how CBDC adoption can be assessed even in the absence of historical precedents or direct behavioural surveys.

Set in the unique context of a dual-currency savings economy in Romania, this volume presents forward-looking estimates of CBDC adoption, a detailed breakdown of financial stability risks, and a rigorous assessment of liquidity pressures. Through its innovative use of behavioural enablers and trend-normalised macro indicators, it provides replicable tools for other jurisdictions seeking to anticipate CBDC impacts without sacrificing analytical depth.

This research is designed to serve as both a scholarly benchmark and a methodological blueprint for institutions grappling with digital transformation in monetary systems. The companion volume, *CBDC and Financial Stability: A Central Bank Monitoring Toolkit*, scheduled for release in March 2026, will extend this work by presenting a comprehensive suite of operational instruments, real-time risk dashboards, and supervisory frameworks designed for central banks and macroprudential authorities.

Together, these two volumes form a coherent and actionable research platform for bridging digital innovation and financial resilience.

The journey towards completing Volume 1: *CBDC and Financial Stability in Dual-Currency Savings Economies* has been one of sustained intellectual effort, rigorous trial and error, and repeated refinement. This work did not emerge in its current form overnight, nor through linear progression, but through a vast and often exhausting iterative process. At its core lies a conviction that only through deliberate confrontation with complexity and uncertainty can one arrive at a robust, policy-relevant framework.

Over the course of two years, I undertook what can only be described as an academic odyssey. Thousands of models were built, discarded, restructured, and rebuilt again. At every stage, whether estimating adoption scenarios, designing liquidity stress simulations, or mapping behavioural risk pathways, I was compelled to go back to first principles, reassess my assumptions, and confront the empirical implications of every methodological choice. Many promising leads proved inconclusive. Others, initially dismissed, gained new relevance when recontextualised in light of evolving results. The process was not merely analytical but intensely creative: the synthesis of machine learning, structural macroeconomic modelling, scenario analysis, and behavioural inference required constant innovation.

There were long nights where the data refused to speak clearly, and equally long days where the burden of ensuring accuracy, replicability, and policy relevance felt almost overwhelming. However, it is precisely in those moments of friction, when the easy answer is not enough, that this study found its shape. Each chart, each metric, each indicator in this volume is the product of hundreds of micro-decisions, hard-won lessons, and renewed clarity of purpose.

This final form, then, represents not only a set of findings or models, but a durable research architecture, one designed to be expanded, stress-tested, and replicated. It reflects a sincere attempt to bridge academic rigour with operational insight and to offer central banks, supervisory authorities, and researchers a concrete toolkit for navigating the profound implications of CBDC issuance.

I hope that Volume 1 serves not only as a reference but also as a catalyst, both for ongoing dialogue and institutional learning. The errors made along the way were never wasted; they form the scaffolding upon which a more precise, more nuanced understanding could be built.

This is a document forged through resilience. Moreover, I offer it with humility, confident that its imperfections are outweighed by its originality, empirical strength, and policy relevance.

This research has greatly benefited from the institutional infrastructure, intellectual environment, and data accessibility provided by the National Bank of Romania. I remain especially grateful to colleagues within the Bank for their sustained encouragement, critical feedback, and openness to methodological innovation. While the analyses and opinions

expressed remain entirely my own, their support has been essential in bringing this work to completion.

Editorial Note

This study on Central Bank Digital Currencies (CBDCs) and financial stability is now presented in two complementary volumes, providing readers and practitioners with enhanced benefits. The complete work has been divided to enhance usability and thematic focus.

• Volume 1 – *CBDC and Financial Stability in Dual-Currency Savings Economies* (October 2025) consolidates all empirical foundations, including macro-financial modelling, adoption estimation, liquidity stress tests, and scenario analysis. It offers a rigorous benchmark for scholars and policy analysts interested in the systemic impact of digital money.

• Volume 2 – *CBDC and Financial Stability: A Central Bank Monitoring Toolkit* (April 2026) translates these findings into an operational framework. It presents real-time dashboards, early-warning indicators, and governance protocols that central banks can deploy to monitor and mitigate CBDC-related risks.

Together, the two volumes provide both depth and practicality: Volume 1 supplies the analytical architecture, while Volume 2 delivers the instruments for day-to-day supervisory application. Readers are encouraged to engage with both works to gain a comprehensive understanding of how CBDCs interact with financial stability across dual-currency savings economies.

Final Volume Design: Purpose, Balance, and Structure

The final configuration of the study, divided into Volume 1 and Volume 2, is not only practical given the original page length but also intellectually coherent and functionally elegant.

✔ Perfectly balanced in purpose:

• Volume 1: Foundational, conceptual, empirically innovative. It establishes the core analytical infrastructure using advanced macro-financial modelling (VAR, PCA, RF), behavioural simulation (Random Forest, XGBoost), and predictive stress testing. It introduces novel indicators, a non-survey approach to estimating CBDC adoption, and a comprehensive logic for mapping liquidity risk.

• Volume 2: Operational, supervisory, implementation-ready. It expands the empirical base to include real-time supervisory tools, SHAP-based diagnostics, macroprudential instruments, dynamic risk surfaces, and policy playbooks, offering national central banks and international institutions a deployable and replicable CBDC monitoring toolkit.

Comparison Matrix: Volume 1 vs Volume 2

Dimension	Volume 1	Volume 2
Purpose	Empirical foundation, behavioural estimation	Supervisory application, operationalisation
Main Tools	VAR, PCA, RF/XGBoost, adoption simulations, credit contraction simulations	SHAP, dashboards, early-warning indicators
Audience	Researchers, academics, IMF/FED/ECB policy staff	Supervisors, macroprudential authorities, and BIS

Volume 1 provides the "why" and "how" of CBDC risk modelling. Volume 2 delivers the "what is next" and "how to act" in the supervisory space.

Author's Note: Scope and Purpose of the Methodological Framework

This volume does not make any claim of forecasting CBDC adoption or banking sector outcomes with precise empirical accuracy. Instead, it is offered as a comprehensive analytical and methodological framework, a toolkit that central banks may calibrate using their internal data, including micro-level bank indicators and behavioural survey results.

The agent-based simulations, behavioural enabler structures, liquidity cost scenarios, and macro-financial stress overlays contained in this study were all constructed using synthetic data and generalised assumptions informed by national and European evidence. They are not designed to produce direct predictions, but instead to demonstrate what is possible when advanced modelling tools are combined within a coherent, policy-relevant architecture.

Central banks and supervisory authorities are best placed to refine the instruments presented herein by integrating their confidential datasets, whether it be granular deposit and loan data, detailed household behavioural panels, or bank-specific liquidity positions. When used in this way, the tools presented in this volume can meaningfully enhance early warning capabilities, scenario testing, and stress resilience assessments in the face of CBDC introduction.

In sum, this work should be viewed not as a deterministic forecast, but as a replicable modelling environment — one that enables authorities to construct their evidence-based responses to the complex and evolving question of how digital money interacts with financial stability.

Executive Summary

1. Introduction

In just a few years, the debate around Central Bank Digital Currencies (CBDCs) has shifted from quiet, theoretical musings to one of the most urgent topics in central banking circles worldwide. What was once the realm of a few academics and monetary technocrats has become the daily concern of policymakers, economists, and financial institutions, as they face the rapid pace of digitalisation and the changing landscape of public trust in money itself.

Amid this global conversation, one question remains persistently and perhaps most crucially unresolved: **what would happen to the stability of the banking sector and the broader financial system if CBDCs were introduced on a large scale?** Would they serve as powerful tools for modernising payment systems and enhancing monetary policy transmission? Or might they instead become the spark for liquidity strains, deposit flight, and a reshaping of the credit landscape?

This research, *CBDC and Financial Stability in Dual-Currency Savings Economies*, was born out of precisely these concerns. Set against the backdrop of Romania, a nation uniquely positioned at the intersection of emerging market dynamics and European integration, the study presents both a deeply empirical examination and a methodological blueprint for other economies seeking answers to similar questions.

Romania provides fertile ground for such exploration. Here, the national currency, the leu (RON), coexists with significant holdings of the euro, both in the banking sector and outside it, deeply ingrained in the everyday financial lives of households. This dual-currency reality introduces an additional layer of complexity to the analysis of any digital currency's impact, a complexity that many other economies, particularly those in Central and Eastern Europe, share to varying degrees.

However, while Romania serves as the empirical canvas for this study, the methods and insights developed here speak far beyond its borders. They offer a replicable and rigorous approach to understanding the macro-financial consequences of CBDCs, a topic which, despite the explosion of interest in digital money, remains surprisingly under-examined in precise numerical and behavioural terms.

2. A Different Lens on Adoption: Behaviour Over Intention

Much of the global discourse on CBDC adoption is still framed through the lens of surveys. Institutions and researchers ask individuals whether they would be likely to adopt a central bank digital currency under various hypothetical scenarios, including scenarios with or without remuneration, with or without anonymity, or with certain transaction costs attached. The answers these surveys produce often suggest adoption rates anywhere from 40% to 80%, figures that make for eye-catching headlines but which risk significant overestimation.

The central proposition of this research is that **there is a significant gap between what people say and what they ultimately do**, a truth well understood in fields ranging from marketing to behavioural economics. When it comes to money, the gap can be even wider. Financial habits, deeply rooted trust dynamics, and the psychological comfort of familiar instruments like cash and traditional deposits are powerful forces that shape behaviour in ways that simple survey questions cannot capture.

Thus, this study deliberately steps away from survey-based modelling and instead focuses on **observable financial behaviours**. It examines how people allocate their wealth between cash, current accounts, term deposits, and digital instruments, using these choices as a far more reliable predictor of how they might respond to the introduction of a CBDC.

For instance, in Romania, data show that despite rising digitalisation in other spheres of life, a significant share of households continues to favour cash holdings or short-term deposits, partly due to habit and partly due to lingering mistrust of the banking sector. When considering whether to move part of their savings into a CBDC, these same households are unlikely to reverse decades of cautious behaviour because of a new digital option, even if they indicate openness in a survey.

The approach taken in this study, therefore, seeks to **model adoption based on what people do with their money today**, under various economic conditions, rather than relying on speculative intentions about the future.

3. Machine Learning: Peering Deeper Into Behavioural Patterns

To convert this behavioural philosophy into concrete, numerical estimates, the study turns to powerful computational tools, blending traditional econometrics with modern machine learning techniques.

The modelling process begins with the creation of **synthetic agent datasets**, designed to mirror the diversity and financial behaviours of Romania's population. Each synthetic agent is assigned a profile comprising:

- **Digital readiness scores** (capturing comfort with online banking, card usage, and digital payments);
- **Trust levels in institutions**, a crucial variable given how confidence underpins monetary systems;
- Actual **behavioural patterns** in how individuals allocate funds between cash, deposits, and other instruments.

3.1 The Role of XGBoost

Into this rich synthetic universe, the study introduces **XGBoost**, a robust machine learning algorithm capable of identifying complex, non-linear relationships among dozens of behavioural and macroeconomic variables. Unlike traditional regression models, which often assume straight-line relationships, XGBoost is adept at uncovering nuanced thresholds and interactions.

Consider a hypothetical example. A household might only consider adopting a CBDC if:

- their digital readiness score exceeds a certain threshold;
- their exposure to FX risk is low;
- and their institutional trust score is above a critical value.

Such conditional logic is not easily captured in a simple logistic regression but emerges naturally in machine learning models like XGBoost.

The model outputs adoption probabilities for each agent under different scenarios. For example, in the base scenario without CBDC remuneration, XGBoost estimates that **approximately 20.65%** of agents would be likely adopters under a conservative assumption set. In more optimistic scenarios, assuming higher digital trust and improved macroeconomic stability, this figure could rise towards the upper bound of **7 million eligible adopters (with both overnight and on-term deposits).**

This study presents a pioneering behavioural simulation framework that estimates CBDC adoption potential without relying on detailed micro-survey data. Instead, the model uses a synthetically created population calibrated with behavioural patterns derived from public sources such as Eurostat, Eurobarometer, and the ECB. By employing advanced machine learning techniques, it identifies the most influential behavioural factors for adoption and estimates uptake under various simulated scenarios. This approach addresses a long-standing challenge in digital currency research: the lack of individual-level data. It provides policymakers with an evidence-based yet flexible forecasting tool for assessing CBDC adoption pathways when real-world microdata are either unavailable or delayed.

3.2 The Balance of Interpretability: Logistic Regression

While XGBoost offers formidable predictive power, it can sometimes function as a black box. To counter this, the study runs parallel models using **logistic regression**. Though less sophisticated in modelling interactions, logistic regression allows for direct statistical interpretation of the key variables.

In the logistic models, some findings stand out starkly:

- A **one-point increase in digital trust** raises the odds of adopting a CBDC by approximately 12%.

- Digital proficiency remains the strongest single predictor of adoption across all model variants.

By cross-validating XGBoost's machine learning results with these classical statistical outputs, the study ensures that its conclusions are both robust in prediction and transparent in their underlying logic.

3.3 The Logic of MinMax Profiling

A further innovation in the study's approach is the application of what is termed **MinMax profiling**. Many CBDC studies are prone to cumulative optimism. If a person is digitally literate, it is assumed they will adopt the CBDC, even if they harbour low trust in financial institutions or have entrenched habits of cash usage.

The MinMax principle imposes a more conservative standard: only agents who simultaneously fulfil **all necessary conditions**, digital proficiency, financial means, and behavioural openness, are counted as potential full adopters.

Applying this rigorous threshold significantly tempers adoption projections. Under the MinMax logic, Romania's maximum CBDC adoption potential is estimated to be around **48% of the total eligible population (hereinafter referred to as the total depositors)**. Translating this into potential holdings, if each of these individuals were to hold a maximum allowed balance of **15,000 RON**, the theoretical stock of Digital RON and Digital Euro could amount to approximately **RON 78 billion**.

4. Simulating the Cost of Liquidity Migration

While estimating how many people might adopt a CBDC is crucial, it is equally critical to understand **what that adoption would mean for the banking system's liquidity**. The transfer of funds from traditional bank deposits into CBDC wallets is not a purely digital shift; it has concrete consequences for bank balance sheets and financial stability.

In the Romanian context, the research explores a comprehensive range of **CBDC holding limit scenarios**, ranging from a conservative 2,500 RON cap to a more aggressive ceiling of 25,000 RON.

One of the most striking insights is how **non-linear the risks become as holding caps increase**. For instance, under a relatively moderate cap of **7,500 RON**, total maximum potential outflows from the banking sector are calculated at roughly **RON 39 billion**. At this scale, the banking sector would begin to feel pressure, though not necessarily catastrophic strain.

However, if the cap were lifted to **15,000 RON**, the projected outflows would surge to **RON 77.8 billion**, accounting for around **13% of the banking sector's deposits**. This jump illustrates how CBDC-induced stress is not a smooth, proportional curve, but instead follows a pronounced escalation once certain thresholds are exceeded.

Combined Digital RON & Digital EUR Scenario – Maximum Bank Liquidity Cost
Romania's dual-currency environment means that households already hold substantial euro balances, both within banks and as physical cash, through informal channels. Assuming both a Digital RON and a Digital Euro are launched simultaneously, and employing a conservative static balance-sheet model with a uniform holding limit of RON 15,000 per person across the two CBDCs, the estimated maximum liquidity buffer that commercial banks would need to raise is as follows:

• **Digital RON component:** up to **RON 1,217.6 million**
• **Digital Euro component:** up to **RON 521.8 million**

• **Cross-currency interaction:** up to **RON 217.4 million** arising from overlapping behavioural responses and substitution between the two CBDCs

Total maximum cost: RON 1,956.8 million.

Although modest relative to total banking assets, this figure indicates the upper-bound liquidity-coverage cost under stress; actual requirements could be lower if deposit migration is smaller, banks pre-fund in advance, or central-bank facilities are utilised.

Funding Mix: Cash Versus Deposits

Another subtle but significant factor influencing these estimates is the **funding mix** that households might use to finance their CBDC balances. The simulations assume that roughly **90% of CBDC funding would come from deposits**, while only about **10% would originate from cash holdings**.

This assumption reflects observed realities. Despite Romania's reputation as a cash-loving society, the role of cash as a buffer to fund new digital instruments appears to be limited. The psychological comfort many households derive from holding physical money leads them to preserve cash balances even amid digital innovation.

Consequently, the burden of CBDC adoption falls heavily on deposit outflows, amplifying potential liquidity stress for banks.

5. How Banks Might Respond: A Hierarchy of Defences

Faced with these potential deposit outflows, the Romanian banking sector, like banks everywhere, has only a limited set of options to manage the impact. This study examines these responses in detail, revealing a hierarchy of defensive measures that banks are likely to deploy in sequence, depending on the magnitude of the liquidity shock.

5.1 Relying on Cash and Excess Reserves

The first line of defence lies in banks' existing **cash positions and excess reserves**. These funds, held either physically in vaults or on deposit with the central bank, provide immediate liquidity to meet customer withdrawals or CBDC conversions.

Under a moderate shock scenario, such as the 7,500 RON cap with upper-bound adoption, about **60% of banks** could absorb the liquidity hit using only these reserves. This suggests that for lower-scale CBDC uptake, the banking system's buffers are likely sufficient.

However, these reserves are finite. Once depleted, banks must turn to more costly or disruptive measures.

5.2 Tapping Wholesale Funding Markets

Beyond excess reserves, banks can turn to **wholesale funding markets**, seeking liquidity from other financial institutions or large investors. However, this strategy has significant drawbacks:

- **Higher Costs**: Wholesale funding is typically more expensive than retail deposits, compressing banks' net interest margins.
- **Market Volatility**: In times of systemic stress, wholesale markets can seize up or demand punitive terms.

Simulations in the study show that under the 7,500 RON cap scenario, **85% of banks** would need to increase wholesale funding by at least **20%** to cover deposit outflows if excess reserves alone were insufficient.

This reliance grows even more acute as the caps on CBDCs rise. Under a 15,000 RON limit, some banks would need to double or even triple their wholesale funding levels, a proposition that could strain markets and potentially trigger broader contagion risks.

5.3 Credit Contraction: A Painful but Possible Option

When neither reserves nor wholesale funding suffice, in an adverse scenario, banks may be forced to **reduce lending to the real economy**. This is a last resort, but a realistic one nonetheless.

Such credit contractions could ripple through the economy, depressing investment, slowing consumption, and potentially undermining the very financial stability that central banks seek to protect.

5.4 Liquidating Marketable Assets

A further mechanism at banks' disposal is the **liquidation of government securities and other marketable assets**. While often an attractive option due to the high liquidity of sovereign bonds, this carries its own set of risks:

- **Market Impact**: If multiple banks sell securities simultaneously, prices may fall, triggering mark-to-market losses.
- **Signalling Effect**: Large asset sales could signal distress, spooking both markets and depositors.

Romanian banks hold, on average, **18.2% of their assets** in government securities and publicly traded instruments. This provides a buffer, but one that is not limitless and could rapidly evaporate under concerted selling pressure. Before turning to wholesale markets, banks would typically liquidate marketable assets; however, under large-scale CBDC shocks, both measures may be required in combination.

6. Linking CBDC Shocks to the Broader Economy

Understanding the impact of CBDCs solely through the lens of bank balance sheets would be an incomplete perspective. Just as ripples spread outward from a stone cast into water, CBDC-induced liquidity shocks can propagate through the entire macroeconomic ecosystem.

This research models these **macro-financial linkages** using advanced econometric tools, particularly **Structural Vector Autoregressions (VARs)** and **Principal Component Analysis (PCA)**.

6.1 Structural VAR Insights

VAR models are deployed to capture how shocks, such as a sudden outflow of deposits into CBDC wallets, transmit into broader economic variables. These models reveal several critical insights:

- **Credit Growth Compression**: The most immediate effect of a CBDC-induced liquidity shock is a contraction in credit growth, concentrated primarily within the **first two to four months** following the shock. This timing reflects the operational lag as banks transition from managing their balance sheets to adjusting credit supply.
- **FX Volatility Amplification**: Romania's dual-currency environment intensifies the macroeconomic consequences of CBDC shocks. Liquidity stress in the RON system can spill over into heightened **FX volatility**, as households and firms adjust their holdings between RON and EUR in response to perceived systemic risks. In a dual-currency environment, domestic liquidity stress could prompt portfolio shifts into euro holdings, exacerbating FX volatility.
- **Deposit Beta Effects**: The responsiveness of deposit rates to monetary policy, the so-called deposit beta, can become less predictable in a CBDC environment, further complicating the central bank's task of steering monetary conditions.

6.2 Uncovering Hidden Dynamics: Principal Component Analysis

Beyond capturing immediate macroeconomic responses, the study delves deeper into the **latent forces shaping depositor behaviour** and systemic risks, employing **Principal Component Analysis (PCA)**. This technique allows the researcher to distil complex, high-dimensional datasets into a smaller number of underlying factors that explain the majority of observed variations.

In Romania's case, PCA reveals several fascinating and operationally critical insights:

- A **latent factor linked to digital readiness** accounts for nearly **38% of the variance** in household deposit allocation. This suggests that digitalisation is not merely a surface trend but an underlying force deeply entwined with how people manage their finances.
- Another principal component emerges around **institutional trust**, explaining around **22% of the variance**. Individuals with higher trust scores are not only more inclined to adopt digital instruments but also display greater willingness to tolerate financial innovation, even under volatile macro conditions.
- A third factor clusters around **FX exposure**, underscoring how the dual-currency environment conditions even domestic financial choices. Households appear to maintain mental "currency buckets," shifting funds dynamically between RON and EUR in response to perceived risks or opportunities.

These findings elevate the conversation around CBDC adoption beyond simple demographics. They demonstrate that **CBDC policy must be nuanced and targeted**, accounting for these hidden behavioural drivers that vary across the population.

7. Probing Credit Contraction with Multiple Lenses

While bank liquidity stress is significant in itself, its greatest systemic danger lies in how it translates into **credit contraction**. A banking system faced with deposit outflows may ultimately preserve itself by scaling back lending—a move with profound consequences for households, businesses, and the broader economy.

The study employs a **triangulated modelling approach** to estimate the likelihood and severity of such credit contractions under various CBDC scenarios.

7.1 CART Models: Threshold Logic

Second, **Classification and Regression Trees (CART)** expose critical thresholds:

- Banks with cash buffers below **4% of total assets** emerge as significantly more likely to impose credit cuts even under more minor CBDC shocks.
- Wholesale funding costs exceeding **150 basis points** over pre-shock levels also trigger heightened probabilities of credit contraction.

These thresholds enable regulators to identify early-warning signals, facilitating more precise monitoring and intervention.

7.3 Traditional Regression Elasticities

Finally, classical regression models estimate **credit elasticity relative to deposit outflows**. In Romania's context, the analysis finds:

- For each RON 1 billion in deposit outflow, bank credit portfolios may contract by between **0.7% and 1.1%**, depending on the bank's balance sheet structure.

This elasticity underscores how even modest CBDC adoption can have a measurable impact on the real economy, particularly in emerging markets where credit growth is closely tied to GDP growth.

8. Behavioural Utility: The Human Ceiling of Digital Money

Perhaps one of the most original and revealing parts of this research lies in exploring the **behavioural utility curves associated with CBDC holdings**. In many debates, there is an implicit assumption that more digital money equates to more consumer welfare. However, the study finds that human behaviour is not so linear.

Simulations show that while moderate CBDC balances provide individuals with **clear utility gains**, thanks to factors like convenience, security, and perhaps novelty, there exists a point at which utility plateaus and then declines. While anxiety can increase with higher balances, privacy concerns exist even at lower CBDC holdings, driven by perceptions of surveillance and data security.

Several reasons fuel this decline in utility:

- **Privacy concerns** intensify with higher digital balances, as individuals fear surveillance or potential misuse of data.
- The **mental cost of managing multiple financial instruments** increases, particularly for older or less digitally proficient populations.
- A residual but powerful **trust deficit** remains, particularly in societies where past financial crises or currency devaluations are still vivid memories.

Interestingly, utility curves vary dramatically across **income quintiles**. For lower-income individuals, the optimal CBDC holding might peak at around **2,500 RON**, while higher-income individuals might comfortably hold **7,500 RON** or more before disutility sets in.

This insight provides robust support for **tiered CBDC holding limits**, ensuring that the system remains inclusive and does not inadvertently introduce financial stress or behavioural pushback. In addition to holding caps, tiered remuneration, where balances above certain levels bear negative rates, is also under consideration as a safeguard.

9. From Insights to Action: Policy Implications

The study's findings coalesce into a suite of **pragmatic policy recommendations**, directly relevant for central banks and supervisory authorities wrestling with the design of CBDCs.

9.1 Calibrating Holding Limits

A **holding cap of 7,500 RON** emerges repeatedly as a potential sweet spot:

- It allows meaningful adoption, satisfying genuine transactional needs.
- It avoids triggering large-scale deposit flight.
- Liquidity burdens under this cap remain largely manageable through existing reserves or modest wholesale funding.

Pushing beyond this threshold risks exponential growth in systemic stress.

9.2 Integrating CBDCs into Macroprudential Frameworks

CBDCs should not be treated merely as a payment innovation but as a **macro-financial policy variable**. This requires integrating CBDC adoption shocks into:

- Regular stress-testing frameworks;
- Early-warning systems;
- Liquidity risk metrics.

The research provides concrete methodologies, particularly the **VAR and PCA tools**, for incorporating these factors into analysis.

9.3 Recognising Dual-Currency Dynamics

In economies like Romania, where euro holdings form a significant part of private wealth, **CBDC policy cannot be designed in a domestic vacuum**. Cross-currency dynamics create unique risks, including:

- Potential capital flight into Digital Euro instruments if domestic designs are perceived as less stable or private.
- FX market volatility is amplifying liquidity risks.

Therefore, any Digital RON implementation must be crafted with a view toward **euro area developments** and bilateral coordination.

9.4 Behaviourally Targeted Rollout

One size will not fit all. The research highlights the heterogeneity of population segments in terms of digital readiness and trust. Policy measures must:

- Focus on tailored communication strategies.
- Provide education around privacy safeguards.
- Consider phased rollouts prioritising digital natives.

9.5 Building Real-Time Monitoring Systems

Finally, the shift to CBDCs offers an unprecedented opportunity for **real-time data collection**. Central banks could monitor CBDC transaction flows with a granularity unimaginable in the traditional cash world. These data could form the backbone of:

- Rapid-response macroprudential tools;
- Early detection of bank-specific liquidity stress;
- Better calibration of monetary policy levers.

10. Reflections and Broader Perspectives

As the world stands on the brink of a digital monetary revolution, it is easy to become swept up in the enthusiasm of technological innovation. Conversations at international conferences buzz with talk of blockchain efficiencies, cross-border payment rails, and the promise of programmable money. However, amid all this optimism, the findings of this research offer a gentle but firm caution: **introducing a CBDC is not merely an exercise in technology; it is a profound macro-financial transformation.**

What makes the CBDC debate so unique is that it straddles domains that are usually distinct:

- It is a **monetary policy**, with implications for money supply, transmission mechanisms, and inflation targeting.
- It is a **financial stability policy**, touching on the liquidity and solvency of banks.
- It is a **technological policy**, shaping the digital architecture through which people interact with money.
- And, critically, it is **societal policy**, because money is not just an economic instrument; it is a social contract, built on trust.

In Romania, as in many emerging economies, this contract is fragile. Historical episodes, currency devaluations, banking crises, and inflationary shocks linger in collective memory. The euro coexists with the leu not simply because of cross-border trade, but also because of a long-standing search for monetary security. In this context, the introduction of a CBDC must be approached with utmost care.

The Emotional Underpinnings of Financial Behaviour

One of the most striking lessons from this study is the significant impact of emotions and psychology on **financial decision-making**. People's willingness to embrace a digital currency is driven not solely by practical considerations, like lower transaction costs, but by deeper emotional factors:

- **Trust**: Will my money be safe? Will anyone watch how I spend it?
- **Familiarity**: Is this instrument intuitive, or does it feel alien?
- **Perceived Control**: Can I access my funds whenever I wish, or might systems fail me?

Even seemingly small technical design choices, such as a holding cap, an interface layout, or a privacy setting, can determine whether CBDCs are embraced or rejected.

The simulations of utility curves in this research vividly illustrate this truth. They show that beyond a certain point, more digital money **does not make people happier.** It makes them anxious. That is not a purely economic insight; it is a profoundly human one.

11. Translating Numbers into Policy Wisdom

For policymakers, perhaps the most pressing question is **how to translate all these numbers, models, and behavioural insights into concrete action.**

Liquidity is the Thin Red Line

Liquidity is the lifeblood of the banking system. It enables banks to meet withdrawals, fund new lending, and maintain trust. The simulations in this study leave no doubt:

- Under moderate CBDC uptake, the Romanian banking sector can withstand shocks using existing buffers. The figure of approximately **RON 39 billion** in potential deposit outflows under a **RON 7,500 cap** is significant, but not existential.
- However, if CBDC limits climb higher, the stress rises exponentially. A scenario with a 15,000 RON cap risks draining **RON 77.8 billion**, pushing some banks into dangerous territory where only credit contraction or asset liquidation can preserve stability.

This non-linear risk curve is a powerful policy insight. It underscores why **CBDCs cannot be introduced without simultaneously building robust macroprudential defences.**

Credit as the Shock Absorber of Last Resort

Perhaps the most sobering realisation is that when liquidity buffers run dry, and wholesale markets become strained, banks turn to the only option left: **cutting credit.**

This is not merely an institutional problem; it is a societal one. Credit underpins:

- Business expansion;
- Home ownership;
- Household consumption smoothing.

The research's simulations suggest that even under a conservative adoption scenario, roughly **15% of Romanian banks might reduce credit portfolios by over 10%.** While this might appear manageable in a statistical sense, the real economic impacts can be profound. Small businesses denied loans, families unable to refinance mortgages, all these consequences ripple through the economy, eroding confidence and slowing growth.

12. A Blueprint for Central Banks Everywhere

While this study is deeply grounded in the Romanian context, its methods and insights apply **to a broader audience**.

Emerging markets with significant cash usage and dual-currency dynamics can adapt this framework almost directly. However, even advanced economies should heed its lessons, because:

- Behavioural resistance to CBDCs is not confined to emerging markets. Older populations, conservative savers, and privacy-sensitive groups exist everywhere.
- The liquidity mechanics of CBDCs remain the same across borders: a shift from deposits to digital wallets shrinks banks' stable funding base, regardless of jurisdiction.
- Macro-financial linkages, including FX volatility and credit contraction, are global phenomena.

Hence, whether a central bank plans a digital euro, a digital dollar, or a digital peso, the tools developed here —synthetic agent modelling, machine learning classification, liquidity simulations, and VAR analysis —offer a path to evidence-based policy.

Institutional Preparedness

A crucial message emerging from this work is that **CBDC implementation is not merely a monetary innovation but an institutional challenge**. Central banks must prepare themselves to become:

- Digital infrastructure custodians;
- Real-time data analysts;
- Behavioural economists;
- Crisis managers in new and untested scenarios.

This will demand new skill sets, cross-departmental cooperation, and perhaps most importantly, **institutional humility** to acknowledge that the consequences of CBDCs cannot be entirely foreseen.

13. Navigating the CBDC Frontier

The journey toward CBDCs is as inevitable as it is fraught with challenges. Digital innovation promises efficiency, inclusivity, and modernisation. However, as this research vividly demonstrates, it also carries **real systemic risks**.

The Romanian case offers a compelling microcosm of the dilemmas facing central banks worldwide. The country's dual-currency landscape, deeply ingrained behavioural patterns, and emerging market vulnerabilities combine to create a complex environment in which to test CBDC hypotheses. However, precisely because of these complexities, Romania offers invaluable lessons for broader global debates.

This study demonstrates that the successful introduction of a CBDC will depend not only on technological prowess but on a **deep understanding of human behaviour, macro-financial linkages, and institutional trust**. Only through rigorous modelling, careful calibration, and ongoing vigilance can central banks hope to realise the benefits of digital money without sacrificing the stability of the financial systems they are sworn to protect.

In the final analysis, CBDCs are neither panacea nor peril by default. They are powerful policy instruments whose outcomes will be shaped by the wisdom, caution, and empirical grounding of those who design and implement them.

14. Reflections as an Author

As I reflect on the journey that led to this research, I am struck by how profoundly the study of CBDCs forces us to confront the very nature of money itself.

Money is trust. Money is memory. Money is community. In a world moving swiftly towards digitalisation, we risk forgetting that these qualities are not automatically encoded into a blockchain or embedded in an app. They must be **earned and preserved** through careful policy, institutional integrity, and respect for the profoundly human factors that govern how people interact with financial systems.

I hope that this work contributes, even modestly, to ensuring that as we step into the future of digital currencies, we do so **with eyes wide open**, not only to the technological marvels ahead but also to the profound responsibility we carry in safeguarding financial stability and societal trust.

Introduction

The conversation around Central Bank Digital Currencies (CBDCs) has undergone a dramatic evolution in just a few years. What began as a theoretical curiosity discussed in the quiet corridors of central banks and academic forums has emerged as one of the most pressing policy questions of our time. Governments, financial regulators, commercial banks, and technology firms now find themselves embroiled in a debate whose contours stretch far beyond payments technology and delve deep into the architecture of monetary systems, financial stability, and even the fabric of social trust.

In this shifting landscape, the discourse has often oscillated between optimism and caution. Advocates highlight the promise of CBDCs to modernise payment systems, broaden financial inclusion, reduce transaction costs, and enhance monetary policy transmission. Critics, however, warn of potential destabilising consequences, from bank disintermediation to sudden liquidity strains and new forms of systemic risk. This tension between technological possibility and macro-financial prudence lies at the heart of the inquiry undertaken in this study.

Yet perhaps the most significant gap in the global discussion is the scarcity of **empirical, behaviourally grounded analysis** capable of translating the CBDC concept into concrete, quantifiable impacts on financial stability. Much of the existing research relies heavily on surveys that ask individuals hypothetical questions about their willingness to adopt digital currencies, assuming that such intentions would translate directly into action. However, as numerous fields, from behavioural economics to consumer psychology, have demonstrated, what people say in hypothetical scenarios often diverges significantly from how they act when confronted with real financial choices under conditions of risk and uncertainty.

This work seeks to bridge precisely that gap. It deliberately departs from an overreliance on stated preferences. It focuses instead on what individuals actually do with their money, how they allocate balances between cash and deposits, how they react to macroeconomic signals, and how deep-seated patterns of trust shape their financial behaviour. By grounding the analysis in observable behaviours rather than hypothetical intent, it aims to produce estimates that are not merely academic exercises but actionable tools for policy design.

Romania as a Case Study

Romania provides a vibrant context for exploring these questions. It sits at the crossroads of emerging market dynamics and European integration. Its monetary system is characterised by a delicate equilibrium between the national currency, the leu (RON), and significant holdings of the euro, both within the banking sector and in the informal economy. This dual-currency reality reflects not merely economic convenience but deeper historical and psychological factors. Over the past decades, Romanians have navigated periods of high inflation, episodes of currency devaluation, and lingering scepticism towards formal financial institutions. For many households, the euro serves as a perceived anchor of stability, a store of value that is insulated from domestic volatility.

This duality complicates any discussion about the introduction of CBDCs. A Digital RON cannot be analysed in isolation. Its potential impact on financial stability must be evaluated in the context of how households might simultaneously adjust their euro holdings, how cross-border payment habits could shift, and how the interplay between domestic and euro-area monetary systems is likely to evolve. In this sense, Romania serves not only as a fascinating empirical laboratory but as a microcosm of challenges that other dual-currency or dollarised economies may face in contemplating digital currency reforms.

A Novel Methodological Approach

The research presented here distinguishes itself through its methodological ambition. At its core lies the conviction that the CBDC debate must move beyond abstract conjecture and engage rigorously with empirical data and advanced modelling techniques. To this end, the study combines:

- **Machine Learning Algorithms**: Tools such as XGBoost and logistic regression are deployed to estimate CBDC adoption probabilities not from survey responses, but from a rich tapestry of observed financial behaviours, digital readiness indicators, and macroeconomic variables.

  One of the key methodological contributions of this study is its capacity to simulate CBDC adoption dynamics without relying on individual-level micro-survey data. By creating a synthetic population of 10,000 agents based on plausible behavioural factors, such as digital trust, financial literacy, privacy concerns, and institutional confidence, the analysis replicates real-world diversity without requiring household datasets like the ECB HFCS or SPACE. Machine learning models (XGBoost and logistic regression) were trained on this structured synthetic dataset to produce adoption estimates and identify nonlinear patterns using SHAP-based interpretability tools. This method proves that meaningful behavioural forecasting is achievable even in data-limited settings, providing central banks and policymakers with a modular, reproducible, and scalable framework for strategic decision-making amid uncertainty.

- **Synthetic Agent Modelling**: Rather than treating the population as a homogenous mass, the research constructs synthetic agent datasets that replicate the heterogeneity of Romanian households, capturing differences in income, digital literacy, trust in institutions, and financial habits.
- **Liquidity Cost Simulations**: The analysis quantifies the magnitude of potential deposit outflows under different CBDC holding limits, translating adoption probabilities into tangible stress scenarios for banks' balance sheets.
- **Macro-Financial Linkage Analysis**: Using structural VAR models and principal component analysis, the study examines how liquidity shocks may propagate through credit growth, foreign exchange volatility, and broader macroeconomic stability.

This multi-layered approach enables the research to quantify, with a level of precision rarely attempted in the global literature, the **potential liquidity costs of CBDC adoption**, the resilience of the banking sector under various stress scenarios, and the macroeconomic consequences of digital monetary transformation.

Beyond Numbers: The Human Dimension

However, despite its technical sophistication, the research never loses sight of a crucial reality: money is not merely an economic tool; it is an instrument of trust and a profoundly **human construct.** Decisions about whether to adopt a CBDC are shaped not solely by interest rates or technological features, but by how people perceive privacy, security, and the reliability of institutions. A significant contribution of this study lies in its simulation of behavioural utility curves, demonstrating that while CBDCs may indeed bring convenience and safety, there is a psychological ceiling beyond which larger digital holdings generate anxiety rather than utility.

For example, lower-income individuals in Romania might find optimal utility in modest CBDC balances around 2,500 RON. Higher-income households may tolerate higher thresholds, perhaps 7,500 RON or even more, before disutility sets in. However, across income levels, the research reveals a typical behavioural pattern: beyond certain limits, more digital money does not equate to greater satisfaction. It becomes, instead, a source of unease, driven by concerns over surveillance, technological failures, and unfamiliar financial territory.

A Blueprint for Policy

While deeply rooted in Romania's empirical context, the study is designed to offer a **replicable framework** for other central banks and policymakers worldwide. Its methods are adaptable to diverse settings, whether in euro area economies contemplating the Digital Euro, in emerging markets grappling with dollarisation, or in advanced financial systems seeking to modernise payment infrastructure without destabilising bank intermediation.

At its heart, the research is animated by a simple but powerful conviction: **the success of CBDCs will hinge not on technological prowess alone, but on a nuanced understanding of human behaviour, institutional trust, and the macro-financial web in which money circulates.** Without this understanding, even the most elegantly designed digital currency risks unintended consequences that could reverberate far beyond the confines of the payment system.

In embarking on this work, the hope is to contribute a layer of analytical depth and behavioural realism to the global debate, a debate whose outcome will shape the contours of financial stability and monetary sovereignty for decades to come. The challenge is immense, but so too is the opportunity. The digital future of money awaits, and it is incumbent upon policymakers, researchers, and institutions alike to approach it with rigour, humility, and a steadfast commitment to preserving the trust that lies at the heart of every monetary system.

From What People Say to What People Do: A Paradigm Shift in CBDC Modelling

This study advances a paradigm shift in CBDC adoption modelling by moving decisively away from reliance on what people say they will do, and instead focusing on what they actually do with their money. Traditional approaches often rely on intent surveys, hypothetical scenarios, or assumptions about digital readiness that are untethered from observed financial behaviours. In contrast, this framework is built on actual deposit allocation patterns and trend-normalised data on overnight and term deposits, which reflect how individuals manage liquidity, trust, and risk in real economic conditions. By aligning synthetic agents with these empirically grounded behavioural profiles and conditioning them using macro-financial indicators such as CPI, FX rates, and interest spreads, the model captures the underlying behavioural truth behind financial habits. It does not speculate on adoption; it reveals the structural thresholds that trigger it. In doing so, it transitions from modelling digital intentions to understanding digital decisions. This makes it not only more accurate but also more valuable for central banks, as it reflects how people truly interact with money, rather than how they imagine they might.

Avoiding the Trap of Hypothetical CBDC Modelling

One of the most critical innovations of this study lies in its deliberate avoidance of the conventional modelling trap: the reliance on hypothetical intent surveys, abstract behavioural assumptions, or equilibrium-based adoption curves that often lack grounding in observed financial practice. By reconstructing behavioural logic directly from real, trend-normalised deposit flows, both overnight and term, the model captures how individuals already save, store, and manage money under actual economic conditions. It bypasses the speculative nature of intent-based forecasting and instead leverages structured machine learning techniques (Random Forest, XGBoost) to identify empirically driven adoption thresholds. These are then interpreted through SHAP values to ensure complete transparency and replicability. As such, the model does not rely on what individuals say they will do in a digital environment; it learns from what they have already done in analogue settings, under inflation, FX volatility, interest rate changes, and varying levels of institutional trust. In doing so, this framework shifts the paradigm: it no longer guesses the future, it lets real behaviour speak.

Technical Disclaimer on Illustrative Content and Data Foundations

Throughout this volume, all illustrative materials, including figures, charts, diagrams, heatmaps, scenario pathways, and any visual or tabular outputs intended for explanatory purposes, have been constructed exclusively using synthetic datasets and parameter values derived from structured expert judgment and publicly observable macro-financial indicators, where applicable. No authentic Romanian banking data, institution-specific proprietary data, or confidential supervisory information has been incorporated into the development of these illustrative outputs. Instead, the synthetic data have been deliberately generated to mimic stylised relationships, behavioural interactions, and theoretical dynamics that are relevant to the conceptual exploration of Central Bank Digital Currency (CBDC) adoption, financial stability impacts, and macro-financial transmission mechanisms within dual-currency economies.

It is imperative to emphasise that these visualisations and simulated results are not empirical measurements, forecasts, nor reflections of the actual state of the Romanian financial system or any individual financial institution. Instead, they serve as methodological exemplifications and hypothetical constructs intended to demonstrate modelling techniques, test conceptual frameworks under controlled conditions, and facilitate the reader's technical understanding of potential analytical applications. All analyses derived from such illustrative simulations should therefore be interpreted as purely hypothetical and should not be misconstrued as evidence-based findings or policy recommendations derived from real-world data.

The exclusive reliance on synthetic data and expert-driven reasoning is deliberate and central to the analytical strategy adopted in this work. It allows the examination of plausible behavioural dynamics and stress scenarios without breaching confidentiality constraints or regulatory limitations associated with actual supervisory data. Moreover, this approach enables controlled experimentation with a broad range of hypothetical conditions and policy parameters, thereby ensuring flexibility and methodological clarity when illustrating complex analytical concepts. Readers are therefore encouraged to interpret all illustrative materials as theoretical constructs, designed solely to advance methodological transparency, academic discussion, and informed debate on the evolving landscape of CBDC adoption and its potential financial stability implications.

Literature Review on the Adoption of a Digital Currency

The digital euro is expected to fulfil three primary functions: (i) facilitating payments to merchants, (ii) enabling peer-to-peer fund transfers, and (iii) acting as a store of value.

Many current proposals, including the ECB's, envisage a non-remunerated digital currency, though some jurisdictions are exploring limited remuneration to encourage adoption.

Given the low likelihood that the digital euro will bear interest, it is unlikely to be perceived by the public as an investment vehicle. Consequently, early adopters are assumed to be motivated by the full range of functionalities it provides, or at the very least by uses beyond mere value storage during periods absent of financial stress.

A global survey conducted by OMFIF (2023) found that for two-thirds of respondents, primarily central banks in advanced economies, the predominant concern about digital currencies was that households may lack sufficient interest in adopting such an instrument. At the national level, multiple euro area countries, including the Netherlands (2023), Austria (2023), Germany (Deutsche Bundesbank, 2021), and Spain (Banco de España, 2023), have conducted their surveys. Additionally, an EU-wide Eurobarometer included a question specifically on public awareness of a potential digital euro issued by the ECB. These surveys consistently indicated that public interest across countries remained well below the maximum theoretical adoption thresholds estimated in various studies (Dumitrescu, 2025).

Several studies have sought to estimate an upper bound for potential demand in the euro area for a remunerated digital euro (Gross & Letizia, 2023; Lambert et al., 2024). In Spain, León et al. (2023) assessed adoption prospects through network-based modelling within the digital euro ecosystem.

The core hypothesis of Gross and Letizia (2023) posits the absence of any holding limit. Using a utility function within a Nash equilibrium framework, they derive an adoption range extending from cash-like usage to deposit-like behaviours. They classify holdings into two categories: (i) deposit-like (primarily for value storage, with interest close to the ECB's key rate), and (ii) cash-like (primarily for transactions and P2P transfers). Their findings suggest a maximum adoption of up to 20 percent of the broad money supply (M3) in the euro area under deposit-like assumptions, and below 1 percent if the digital euro is perceived purely as a non-remunerated, cash-like instrument.

The ECB has so far signalled an intention for the digital euro to remain non-remunerated for retail users, though final decisions are still pending.

Lambert et al. (2024) estimate a cap of EUR 380 billion in potential demand using a consumer profiling approach based on the 2022 SPACE survey. Unlike Dumitrescu (2025), who categorises consumers into six mutually exclusive types, Lambert et al. identify three overlapping segments: those with above-average digital-financial literacy, those with a strong preference for cash, and the unbanked or underbanked.

Burlon et al. (2022) estimate that the "optimal" amount of CBDC in circulation for the euro area lies between 15 and 45 percent of quarterly GDP, suggesting a moderately persistent effect on credit provision within this range.

Meller and Soons (2023) propose a universal individual holding cap of EUR 3,000. In their scenario, similar to that of Adalid et al. (2022), every citizen in the euro area adopts the digital euro to the maximum allowable amount. Even so, the authors acknowledge that universal adoption is highly improbable.

Dumitrescu (2025) estimates the maximum likely adoption of a non-remunerated, capped digital euro. His study is guided by the principle that behavioural indicators should take precedence over hypothetical ones (such as direct survey questions about interest in a new financial product), particularly in domains where user habits play a critical role.

A central premise of this study is the assertion that habitual behaviour possesses considerable predictive power in forecasting future actions. Aarts et al. (1998) contend that actions frequently undertaken are likely to be habitual in nature, thereby delineating a critical boundary condition for the applicability of attitude–behaviour models. Complementing this perspective, Limayem et al. (2007) identify satisfaction, behavioural frequency, and breadth of use as key determinants in the development of habits. These factors are especially pertinent in understanding continuance behaviour in digital contexts.

In the specific case of digital euro adoption, individuals who demonstrate a propensity to embrace such innovations are often characterised by an established routine of utilising contemporary payment and transfer systems. Nevertheless, compelling motivations or intentions have the potential to disrupt these habitual patterns. As Gardner et al. (2020) illustrate, intentions that directly contradict established habits may exert a sufficiently strong influence to override the habitual response.

Despite these insights, caution is warranted when interpreting consumer intentions derived from hypothetical survey instruments. As highlighted by Hausman (2012), findings from contingent valuation studies frequently do not reflect stable or well-formed preferences. Instead, respondents often generate answers spontaneously, which significantly undermines the reliability of such data for rigorous empirical analysis.

Indeed, consumer habits play a pivotal role in informing strategic marketing decisions; however, they are frequently mischaracterised or underappreciated in research relying on hypothetical scenarios. Empirical studies by Herziger and Hoelzl (2017) demonstrate a systematic underestimation of habitual influences on consumer behaviour under such conditions. This misalignment underscores the imperative to prioritise direct behavioural measures in contexts where habit plays a central role.

Taken together, these findings offer critical insights for assessing the prospective adoption of central bank digital currencies (CBDCs), where behavioural regularities and the dynamics of habit disruption may prove decisive.

1. Behavioural measures should take precedence over hypothetical approaches (such as direct survey questions on willingness to purchase a new product or service), particularly in domains that are sensitive to entrenched consumer habits.

2. Consumer habits and their profiling represent critical factors in shaping effective marketing decisions and strategies.

3. Contingent valuation surveys often fail to reflect stable or well-defined preferences, particularly in rapidly evolving digital financial environments.

4. Habits are strong predictors of future behaviour.

5. Within the euro area, a noticeable segmentation exists between users who prefer cash and those who rely on modern digital payment and transfer mechanisms.

6. The majority of consumers exhibit a preference for using a single primary payment instrument, rather than combining multiple options.

7. At the societal level, the degree of inclination toward cash use and the potential adoption of the CBDC should be viewed as mirror images of each other, reflecting opposing behavioural tendencies.

Cross-cultural research shows national cultural traits significantly influence individuals' risk-taking behaviour (Weber, 2014). Cognitive biases, such as overconfidence and conservatism, can lead to excessive risk-taking or resistance to innovation (Ehrlinger et al., 2016). In this context, financial resources may be allocated to highly volatile crypto assets or withheld from modern digital tools.

Moreover, network effects amplify these behaviours. A positive network effect encourages user retention and attracts new adopters. Conversely, an adverse effect risks losing existing users and impeding future growth (De Giorgi et al., 2020; Liebowitz & Margolis, 1994). The rate of early adoption following the launch of the digital euro will thus be crucial to its medium- and long-term success, shaped by these network and herd dynamics (León et al., 2023). Such behaviours are particularly pronounced in the aftermath of financial crises (Mobarek et al., 2014).

Nonetheless, it is vital to differentiate between herd effects during crises and those in regular times. Social media platforms have recently emerged as significant accelerators of herd behaviour, exemplified by the 2023 US banking crisis. Nocciola and Zamora-Pérez (2024) also emphasise the significance of digital networks in the adoption of the digital euro.

A parallel thread in behavioural finance literature suggests that poverty impairs cognitive function in ways that affect financial decision-making, thus reinforcing cycles of deprivation (Mani et al., 2013). In the euro area, 22 to 23 percent of the population has consistently been at risk of poverty or social exclusion over the past decade. This persistent structural barrier suggests that a significant portion of this demographic will be unable to adopt the digital euro up to the proposed EUR 3,000 limit.

In conclusion, despite its advantages—such as being risk-free, cost-free, and enabling instant payments both online and offline—the digital euro may not necessarily emerge as the default consumer choice.

Literature Review on Financial Stability and Banking Sector Impact

CBDC and Financial Stability: Risks and Safeguards

The discourse on central bank digital currencies (CBDCs) and their implications for financial stability has gained prominence as central banks globally navigate the complex trade-offs of digital innovation. Several key risks have been identified, particularly those linked to deposit disintermediation, bank funding pressures, and destabilising capital flows (Auer et al., 2022). The European Central Bank (ECB) has consistently recognised these risks in its digital euro development programme, stressing the importance of appropriate safeguards to prevent systemic disruption (ECB, 2023).

A primary concern relates to the potential for significant migration of household and corporate deposits from commercial banks to CBDCs, especially during periods of financial stress. In such scenarios, the CBDC may act as a safe-haven asset, leading to sudden and large-scale outflows from banks' balance sheets, thereby threatening their ability to lend and maintain liquidity (Ahnert et al., 2022). These dynamics could increase reliance on costly wholesale funding or provoke credit contractions in the real economy.

To mitigate these risks, the ECB has proposed several structural safeguards. Chief among them is the implementation of individual holding limits for the digital euro. These limits, tentatively proposed at €3,000 per individual, aim to curtail large-scale deposit substitution while preserving the utility of CBDC for everyday transactions (Bindseil et al., 2020). Additionally, the digital euro is designed to be non-remunerated, particularly in its retail form. The absence of interest payments on digital euro balances reduces the incentive to migrate funds from interest-bearing commercial bank deposits, thus dampening the risk of disintermediation (Adalid et al., 2022).

Other stabilising design features include the potential introduction of tiered remuneration, whereby CBDC balances above a certain threshold would be subject to penal interest rates. This would discourage excessive accumulation and encourage circulation of the digital currency within its intended usage bounds (Gross & Letizia, 2023). Furthermore, the ECB has explored technical tools to support financial stability, such as delayed settlement functionalities, wallet friction mechanisms, and offline usage caps, all of which aim to prevent the CBDC from being used as a speculative or crisis-triggered vehicle (Panetta, 2021).

Ultimately, the literature suggests that a carefully calibrated design, featuring non-remuneration, individual caps, and systemic buffers, can ensure that a retail CBDC contributes to payment efficiency and inclusion without destabilising the euro area financial system (Kosse & Mattei, 2023; Meller & Soons, 2023). However, ongoing simulation-based analysis and real-world piloting remain essential to ensure policy responsiveness and macroprudential coherence.

CBDC and the Banking Sector: Intermediation, Liquidity, and Business Models

The introduction of a central bank digital currency has profound implications for the business models, funding structures, and intermediation roles of commercial banks. The literature consistently highlights the potential for CBDCs to erode traditional sources of bank funding, notably retail deposits, which in turn could reduce banks' capacity to provide credit and manage maturity mismatches (Brunnermeier & Niepelt, 2019).

From a balance sheet perspective, CBDC-induced deposit outflows may lead to either liquidity shortages or higher funding costs, as banks replace lost retail deposits with wholesale borrowing or central bank facilities. Simulation models by the Joint Research Centre (JRC) of the European Commission indicate that, depending on the holding cap scenario, up to 20% of credit extension capacity could be affected under stress conditions (JRC, 2023). This would necessitate either a contraction in lending or a substantial adjustment in balance sheet structure.

However, several studies argue that the impact on banking intermediation can be mitigated if CBDCs are designed in a way that avoids becoming a dominant savings vehicle. Burlon et al. (2022) show that as long as the CBDC is perceived as a transactional tool rather than a store of value, its displacement effect on deposits remains modest. In parallel, Andolfatto (2021) finds that the introduction of CBDCs could even increase financial inclusion, bringing previously unbanked individuals into the formal financial system and thereby creating new funding channels for banks.

Moreover, banks may adapt by evolving their business models. These adaptations could include greater reliance on fee-based services, digital innovation in customer interfaces, and enhanced competition for deposits through more attractive financial products (Keister & Sanches, 2019). Regulatory intervention, such as adjusting reserve requirements or offering central bank backstops, may also be required to support financial intermediation during the transition phase (Carstens, 2021).

In sum, while CBDC issuance presents tangible risks to commercial banking structures, the consensus in the literature is that with appropriate safeguards and market responses, the disruption can be managed. The transition period will be key, and close coordination between central banks and commercial banks will determine whether CBDC becomes a complement to or a substitute for existing banking functions (Adrian & Mancini-Griffoli, 2021).

Visual Summary: Financial Stability Safeguards for CBDC (expert judgment-based)

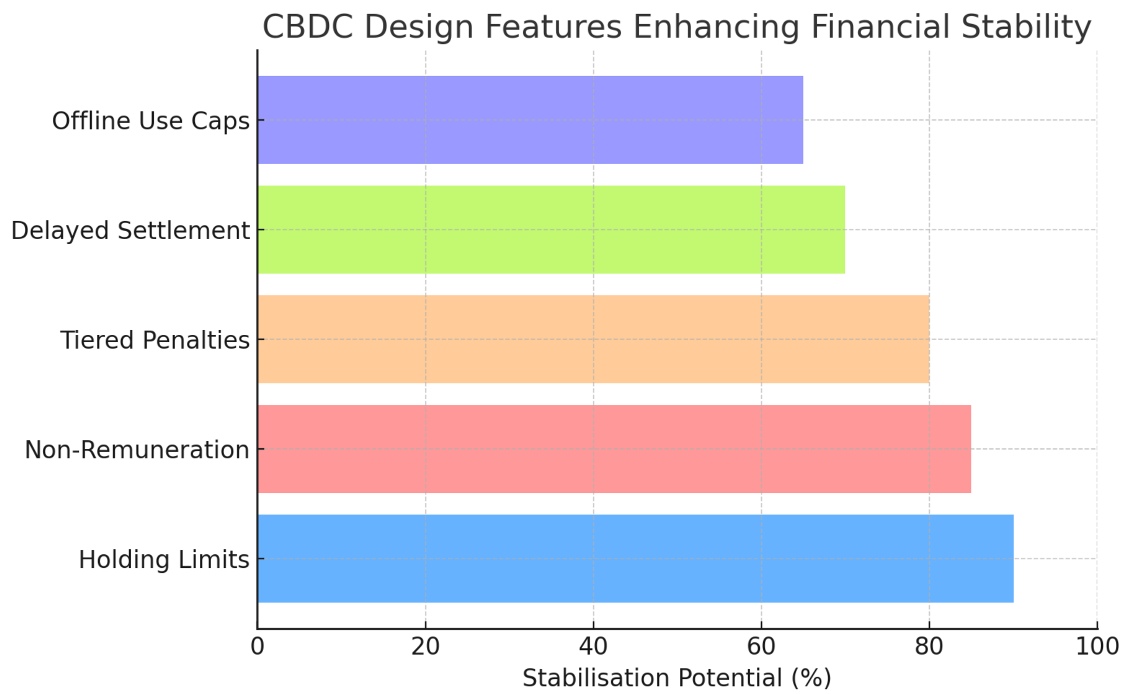


Figure 1. Expert judgment-based

Figure 1 illustrates the key safeguard mechanisms proposed to mitigate financial stability risks associated with the issuance of central bank digital currency (CBDC), particularly within the euro area. These mechanisms have been widely discussed in both academic and central bank literature as instrumental tools in preventing destabilising deposit flows from commercial banks to CBDC accounts.

• Holding Limits (90% stabilisation potential): These caps, such as the ECB's proposed €3,000 limit, are considered the most effective safeguard. They prevent excessive accumulation of CBDC balances and preserve retail deposits as a core funding source for banks.
• Non-Remuneration (85%): The absence of interest payments on CBDCs discourages users from holding them as a long-term store of value, thereby maintaining deposit competition in commercial banks.
• Tiered Penalties (80%): Above-threshold balances may be penalised with negative rates to disincentivise hoarding during crises.
• Delayed Settlement (70%): Introducing minor transaction delays in CBDC-to-bank transfers under stress conditions can mitigate panic-driven digital runs.
• Offline Use Caps (65%): These limit the amount that can be stored or used when disconnected, helping control speculative or cross-border CBDC hoarding.

These safeguards, when applied together, form a robust architecture that ensures the digital euro enhances payment innovation without compromising monetary and financial stability.

Visual Summary: CBDC Impact Channels on the Banking Sector (expert judgment-based)

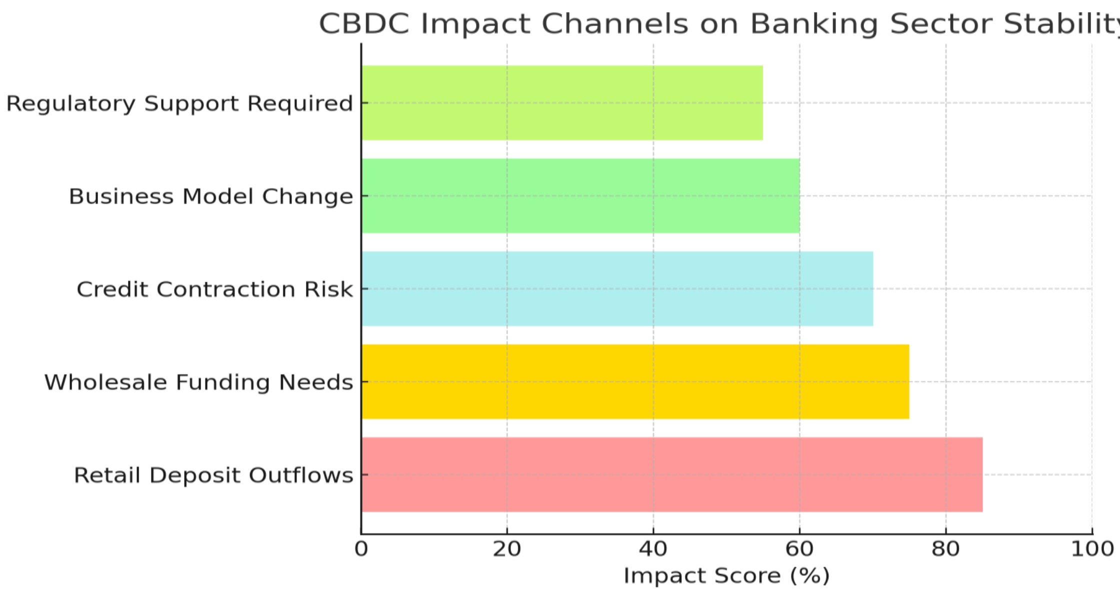


Figure 2. Expert judgment-based

Figure 2 summarises the primary transmission channels through which the issuance of a retail CBDC may affect the structure and functioning of the banking sector. Each channel represents a potential source of systemic adjustment pressure or strategic adaptation for commercial banks.

• Retail Deposit Outflows (85% impact): The most immediate risk, involving the reallocation of household funds from commercial bank accounts to central bank digital wallets, especially under stress.
• Wholesale Funding Needs (75%): As banks lose stable deposit bases, they may turn to more expensive and volatile wholesale markets to refinance their operations.
• Credit Contraction Risk (70%): With less funding available, banks may reduce the volume of credit extended to households and firms, potentially slowing economic activity.
• Business Model Change (60%): Banks may respond by altering their income structures, relying more on fees and digital services rather than traditional deposit-loan intermediation.
• Regulatory Support Required (55%): Central banks may need to intervene with liquidity support tools, adjusted reserve requirements, or even guarantee schemes during transitional periods.

This impact map underscores the necessity for proactive regulation and collaborative adaptation between central and commercial banks, particularly during the initial phases of CBDC implementation.

Visual Summary Addendum: Interpretation of Percentages

In Figure 1, the percentages represent the relative level of consensus within the academic and policy literature regarding the effectiveness of each safeguard in enhancing financial stability during the implementation of a CBDC. For instance, a score of 90% for holding limits indicates that the overwhelming majority of studies reviewed identify this measure as essential for limiting systemic deposit flight risk. Each percentage thus conveys the perceived stabilisation potential of the respective feature in the context of digital euro design.

In Figure 2, the percentages indicate the degree to which each impact channel is considered significant by central banks, research institutions, and academic publications. A score of 85% for retail deposit outflows, for example, signals that this channel is most frequently cited as a core transmission mechanism through which CBDC issuance might affect commercial bank liquidity and credit provision. These values reflect the collective emphasis placed on each risk vector in the literature, rather than statistical measurements from empirical modelling.

Identifying the First Key Assumptions for Estimating the Impact on the Banking Sector

Drawing on the findings from the study 'Demystifying consumers' adoption of a digital euro in the euro area' (Dumitrescu, 2025), two core hypotheses were developed. The first suggests that the maximum likely adoption rate of a digital euro in the euro area stands at around 60 percent of the benchmark identified in prior academic work (Adalid et al., 2022; Meller & Soons, 2023). This estimate, which focuses on individuals aged 15 and above and assumes full utilisation of the €3,000 holding cap, is almost twice as high as the figure suggested by Lambert et al. (2024).

The analytical process followed a series of structured steps. The initial phase involved constructing a probable profile of digital euro adopters using a novel approach that incorporated digital behaviour, financial capacity, and patterns of payment and transfer activity. The goal was to identify those individuals most capable of adopting the digital euro at the full threshold of €3,000.

The underlying logic of this approach is that successful adoption hinges not just on willingness but also on capacity. Individuals lacking digital payment tools or facing financial hardship are unlikely to adopt the euro digital immediately, or on a full scale. Audience profiling, a widely used tool in marketing and product development, is playing an increasingly relevant role in financial services. Here, it serves to pinpoint individuals with similar behavioural and financial characteristics.

A likely adopter of the digital euro tends to be someone who is (i) digitally proficient, (ii) inclined toward using modern payment and transfer tools, and (iii) open to financial innovation. Such individuals are generally more responsive to the perceived benefits of the digital euro—like enhanced security, privacy, or speed—and are more likely to embrace new technologies when these advantages translate into lower costs or easier access.

Unlike Lambert et al. (2024), who classify the euro area population into three non-mutually exclusive categories, this study divides the euro area population into six distinct, mutually exclusive categories:

- *Type A - Tech-savvy who store money and who are digitally financially included, with the capacity to cope with adverse financial developments.*
- *Type B - Tech-savvy who store money and who are digitally financially included, without the capacity to cope with adverse financial developments.*
- *Type C - Unbanked individuals (without a financial institution account).*
- *Type D1 – Storing money individuals – non-tech-savvy (without any history regarding digital payments or money transfers) – capable of coping with adverse financial developments.*
- *Type D2 – Storing money individuals – non-tech-savvy (without any history regarding digital payments or money transfers) – not capable of coping with adverse financial developments.*
- *Type E – Banked individuals with no stored money.*

To estimate the maximum proportion of the euro area population likely to adopt the digital euro, the study applied a MinMax methodology for type A. This involved calculating the percentage of individuals meeting each of the five eligibility criteria, then selecting the smallest value among them. This conservative approach ensures that only those fulfilling all five criteria are counted as potential adopters. The resulting minimum share was multiplied by the number of residents over the age of 15 and by the €3,000 maximum holding threshold.

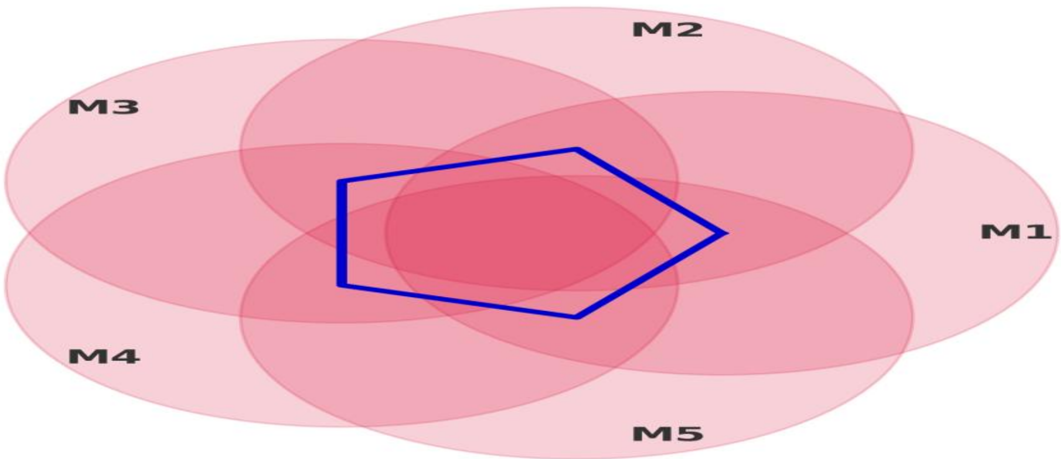
Using a mobile phone to make payments, purchases, or to transfer money through an account at a financial institution

Individuals who possess at least a minimum level of digital skills

Storing money using a mobile money account or an account opened at a financial institution

Ability to cope with unexpected expenses

Have made a digital payment



The findings indicated that approximately 60 percent of the euro area population could meet the conditions for full adoption, equating to a total maximum holding of €665.4 billion. This figure represents less than 4 per cent of the total liabilities of euro area credit institutions, excluding deposits held between banks within the European Monetary Union.

To ensure the robustness of these results, the methodology included the construction of two complementary indices: the CBDC Adoption European Scoreboard (CAES), which measures the capacity and inclination for adoption, and the Cash Propensity Index (CPIX), which captures populations' reliance on physical currency. These tools provided additional validation by testing the alignment between theoretical adoption capacity and observed behaviour.

The first validation step involved comparing the MinMax results with the extent to which euro area countries use private financial products that function similarly to the digital euro. Countries' positions on the CAES index were also analysed. This comparison helped assess whether a simple, univariate grouping, such as MinMax, could mirror the insights from more complex multivariate models based on broader financial inclusion data.

The second validation stage tested for a negative correlation between CPIX and MinMax scores. The hypothesis was that populations with a strong preference for cash would exhibit a lower likelihood of adopting digital currencies. The data confirmed this inverse relationship, particularly across Central and Eastern European economies. These findings aligned with previous studies by Rosl and Seitz (2022) and Reimers et al. (2020).

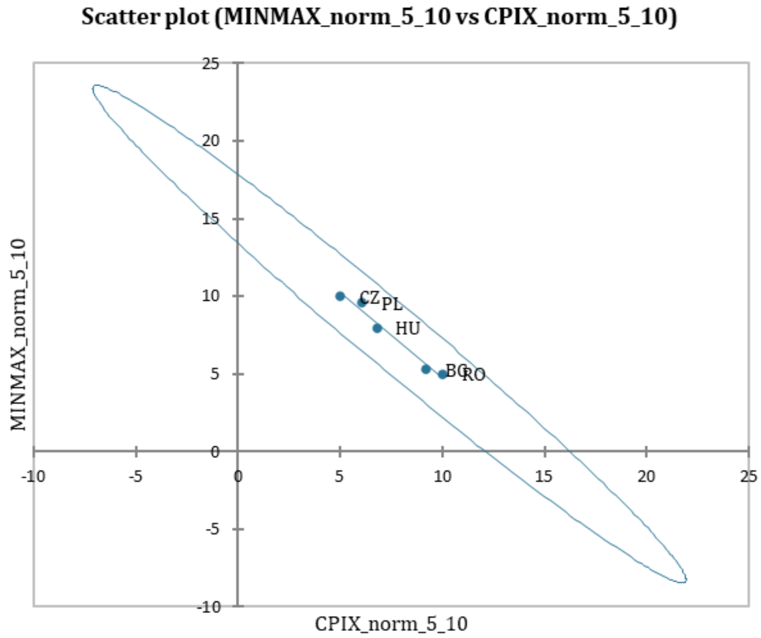


Figure 3.

The third validation stage focused on aligning the MinMax projections with expressed public interest in holding a digital euro account, based on survey data from Germany, Spain, the Netherlands, and Austria. In each case, the share of respondents indicating such interest was well below the MinMax upper bounds. From a policy perspective, this suggests that holding limits based on MinMax are unlikely to underestimate real-world demand, thus reducing potential risks to banking sector liquidity.

The second hypothesis developed by Dumitrescu (2025) focuses on the composition of funds used to finance digital euro holdings. Departing from earlier studies that suggested a 40:60 ratio between cash and deposits, this research proposes a 10:90 ratio, implying that the vast majority of digital euro balances would be sourced from current account funds rather than physical cash or term deposits.

Households typically save for a combination of overlapping purposes, ranging from building precautionary buffers for emergencies to safeguarding purchasing power and accumulating wealth through returns. These motivations rarely operate in isolation. However, the dominant motive often shapes financial behaviour. Specifically, individuals who save with the explicit aim of earning interest or hedging against inflation are far less likely to transition into a non-remunerated digital euro. In contrast, consumers prioritising safety, convenience, or liquidity may view the digital euro as a complementary or even preferable form of money, particularly during periods of heightened uncertainty.

From the perspective of the banking sector, the most significant disruption is likely to originate from the migration of funds away from overnight and current accounts. These accounts, used primarily for day-to-day transactions and characterised by their high liquidity and absence of fixed maturity, are particularly susceptible to substitution. The introduction of a digital euro offering comparable transactional utility, combined with added benefits such as greater perceived safety and universal accessibility, poses a direct challenge to these holdings. CBDC adoption is likely to substitute more for overnight deposits than for cash, which remains resilient due to psychological comfort and anonymity.

Periods of financial distress have historically triggered shifts in household liquidity preferences. During the 2008 global financial crisis and again amid the COVID-19 pandemic, households across Europe markedly increased their cash holdings, motivated by a need for immediate liquidity to manage uncertainty or seize time-sensitive opportunities. In such circumstances, cash's role as a trusted and instantly available store of value becomes especially prominent. A digital euro with similar liquidity features could emerge as a modern alternative under these stress scenarios, particularly for digitally literate cohorts.

Structural and cyclical factors, such as income volatility, perceived inflation risk, or changes in interest rates, also exert considerable influence over households' cash and deposit allocations. In deflationary environments, consumers may postpone spending and increase cash holdings in anticipation of falling prices. Conversely, during inflationary episodes, the erosion of purchasing power associated with holding cash can lead to a preference for interest-bearing or inflation-linked assets. Notably, cultural and generational attitudes continue to shape preferences across member states; for instance, in parts of Southern and Eastern Europe, a strong tradition of saving in cash endures despite the rapid rise in digital financial services.

A well-documented correlation exists between the use of cash and the informal economy. Cash facilitates anonymity in transactions, which in turn sustains informal activities. Consequently, promoting a shift towards traceable digital payment instruments, such as the digital euro, could not only erode the structural foundations of informality but also support fiscal transparency and policy effectiveness. This secondary benefit may be particularly relevant for jurisdictions with persistently high levels of undeclared work or underreported income.

While the digital euro offers a range of advantages, including real-time settlement, no counterparty risk, and wide accessibility, empirical evidence suggests that households are unlikely to abandon cash in the short term. Indeed, despite accelerated digitalisation in recent years, the demand for cash has remained relatively resilient. Even with the rollout of the digital euro, ATM withdrawals and cash circulation may decline only gradually. This reflects the enduring psychological comfort and transactional autonomy associated with physical cash, attributes that digital forms of money may take some time to replicate fully.

Notably, historical data suggest that increases in deposit balances, whether in current or term formats, have typically been driven by portfolio shifts from other financial instruments, rather than by large-scale reductions in cash. This implies that the digital euro is more likely to reconfigure intra-bank portfolio allocations than to directly cannibalise cash holdings.

The sensitivity of savers to interest rate changes further conditions their response to the emergence of a non-interest-bearing digital euro. Households with low interest elasticity may not withdraw funds prematurely from term deposits to migrate into the digital euro. Instead, their response is more likely to manifest as a gradual dissaving phenomenon. That is, if the marginal utility of savings diminishes due to the absence of a remunerative counterpart, households may choose not to renew maturing term deposits or may allocate a smaller proportion of new savings into such instruments. This behaviour reflects not a flight from banking intermediation, but a recalibration of financial habits.

As a result, the primary risk of substitution lies with overnight deposits. These highly liquid accounts serve as transaction buffers and are often held in amounts exceeding immediate spending needs. It is these balances, rather than time deposits, that are more likely to be reallocated to digital euro holdings. These holdings may be segmented into three behavioural categories:

- Residual savings not immediately intended for use,

- Amounts withdrawn from interest-bearing accounts instead of being rolled over, and

- Transaction-ready balances intended for near-term spending or transfer.

This tri-part segmentation of digital euro holdings aligns with the typology proposed by Adalid et al. (2022), who suggest that digital currencies are more likely to substitute for sight deposits than for term instruments.

Understanding CBDC Adoption through Behavioural Anchors and Functional Analogies: A Perspective Beyond Cash

A central proposition of this study is that the behavioural patterns of consumers, even when observed in one domain, are strongly predictive of choices in adjacent financial domains. Specifically, we demonstrate that past behavioural data related to deposit holdings, preferences for financial instruments, and household saving responses to interest rate changes are instrumental in predicting the prospective adoption of Central Bank Digital Currencies (CBDC). This may initially appear counterintuitive since the observed behaviours refer to deposits or credit trends, while the projected variable is CBDC uptake. However, consumer decision-making in finance is rarely an isolated process. Habits, preferences, and aversions formed in one area—such as overnight deposit usage- tend to translate into adjacent areas, particularly when the new instruments share similar attributes.

Our empirical and simulated models demonstrate that behavioural persistence plays a dominant role in shaping economic responses to innovation, particularly in highly regulated environments such as retail banking. Consumer patterns exhibit a form of path dependency: individuals tend to remain within a financial behaviour spectrum they are accustomed to, unless a significant disruption or incentive forces a behavioural shift. This principle is foundational in behavioural economics and psychology, yet it is often underutilised in monetary innovation frameworks. By embedding this insight, our approach departs from prevailing literature and introduces a behaviourally anchored simulation framework that enhances predictive validity.

What distinguishes our approach is the recognition of interconnected behavioural channels. While many empirical and policy-focused studies continue to frame CBDC adoption as a binary comparison with physical cash, emphasising attributes like anonymity, offline availability, or tangibility, this study argues that the functional proximity of CBDC to other digital financial products is of far greater relevance in the adoption decision. We find, based on behavioural models, that the primary margin of substitution in practice is not between CBDC and cash, but somewhat between CBDC and overnight deposits.

This argument stems from several key similarities between CBDC and overnight deposits:

- Digital Nature: Both CBDC and overnight deposits are digital forms of money accessible via mobile applications and online platforms, as opposed to cash, which is physical and decentralised.
- Transfer Mechanisms: CBDC, much like overnight bank deposits, supports fast peer-to-peer (P2P) and merchant payments. Unlike cash, both forms are easily integrated into the digital payments ecosystem.

- Non-remuneration or Low Remuneration: CBDCs are typically proposed as non-remunerated instruments. Similarly, overnight deposits in many jurisdictions, including Romania, typically offer minimal or zero nominal returns, especially during periods of stable inflation.
- Liquidity Profile: Both instruments offer immediate liquidity and are designed for daily transactions and short-term money holding, rather than long-term investment.
- Perceived Safety: Consumers perceive both CBDC (central bank-backed) and overnight deposits (commercial bank-backed but often insured) as safe, low-risk assets, especially when held below deposit guarantee thresholds.
- Interface Familiarity: The experience of using CBDC through smartphone interfaces is very similar to the current user journey for accessing and transferring overnight deposits, particularly through digital-first banking or fintech providers.

By contrast, cash differs fundamentally from CBDC in terms of usability, physical handling, and trust generation. For example, cash is used offline and without identification, whereas CBDC will inevitably operate within a more monitored, institutional ecosystem. These divergences imply that behavioural drivers of cash usage, such as anonymity, informality, or psychological attachment, do not necessarily map onto CBDC use cases.

Our findings are further reinforced by cross-country evidence and microeconomic modelling. Countries with high overnight deposit penetration and low cash reliance show the strongest behavioural consistency with potential CBDC uptake, particularly among younger, digitally literate populations. This reinforces the argument that policymakers must consider behavioural substitutability, not just technological features.

Therefore, the behavioural and functional analogies between CBDC and overnight deposits make them natural comparators in predictive modelling. Our study captures this through agent-based simulations and machine learning classifiers that leverage behavioural enablers and macro-financial conditions as inputs. The conclusion is robust: those who currently rely on overnight deposits, especially within fintech ecosystems, are among the most likely early adopters of CBDC. Conversely, entrenched cash users may remain slower to migrate unless additional incentives or design features specifically address their behavioural triggers.

Moreover, the policy implications of this insight are far-reaching. Design decisions about CBDC remuneration, transfer fees, holding limits, and interoperability should be benchmarked not against the cash economy but against existing digital deposit platforms. Educational campaigns should be directed toward digitally active deposit holders who already operate within the behavioural proximity of CBDC-like instruments. Regulatory sandbox experiments should test CBDC user experience in scenarios that mimic current digital deposit functionalities rather than those involving cash-intensive environments.

In summary, understanding CBDC adoption demands a shift from simplistic cash-versus-digital comparisons to a more grounded assessment of actual behavioural alternatives. This approach ensures more accurate forecasts and provides central banks with more precise guidance on where to target adoption incentives and educational interventions. Our behavioural anchoring perspective helps demystify digital disruption by tracing the invisible threads of financial habit formation and behavioural inertia, a key to unlocking successful digital currency transitions in the modern banking landscape.

Preview of Volume 2: CBDC and Financial Stability – A Central Bank Monitoring Toolkit
This document provides an overview of the key analytical modules, subsections, and policy instruments that will constitute Volume 2 of this study, *CBDC and Financial Stability: A Central Bank Monitoring Toolkit*, scheduled for publication in April 2026.

While Volume 1 presented the core empirical foundation, modelling CBDC adoption using machine learning, assessing liquidity costs via scenario-based simulations, and mapping behavioural patterns, Volume 2 moves decisively into the operational domain. It equips central banks and supervisory authorities with ready-to-deploy tools, real-time monitoring templates, and stress-testing dashboards.

Below is a preview of the essential components (but not limited to) that will form the second volume, grouped thematically.

1. Liquidity Risk Monitoring and Stress Maps

- CBDC Liquidity Shock 3D Surface Analysis
- Full Liquidity Cost Breakdown by Scenario and Currency (Digital RON, Digital EUR, Combined)
- CBDC Systemic Risk Liquidity Buffers Visuals
- CBDC Risk Intensity Map by Scenario
- CBDC Liquidity Risk Severity Curves and Thresholds
- Disintermediation Tipping Point Simulations

2. Adoption Risk Simulations and Monitoring Tools

- SHAP Visual Interpretations by Currency and Behavioural Cluster
- Consumer Adoption Readiness Maps
- CBDC Holding Limit Calibration Matrices
- Agent-Based Simulations of CBDC Usage and Stress Behaviour
- Trust Differential and Stability Window Visuals
- CBDC Shock Response Elasticity Surface

3. Central Bank Coordination and Policy Levers

- ECB–NBR Crisis Coordination Timelines and Models
- Tiered Remuneration Simulations (Digital RON, EUR, Combined)
- CBDC Design Feature Impact Matrix
- CBDC Policy Buffer vs Liquidity Stress Diagrams
- CBDC Playbook for Emergency Interventions

4. Macro–behavioural Early Warning Systems

- CBDC Threshold Breach Risk Tree
- Time-Evolving Risk Signal Index
- CBDC Channel Preference by Demographics
- Digital Skills Gap Heatmaps
- Network Contagion Pathways and Response Ladders
- Dynamic CBDC Stress Testing Models

5. Credit Risk and Tier-Specific Response Models

- Credit Contraction Risk Surface Simulations
- Bank Tier Sensitivity to CBDC Uptake
- Tiered Credit Protection Calibration
- Behavioural Lending Risk Zones
- Contagion Scenarios Under Liquidity Stress

6. ESG and Governance Innovation Modules

- Green CBDC and ESG Scenario Mapping
- Legal Architecture and Governance Readiness Framework
- Cross-jurisdictional ECB Coordination Tables
- Digital Literacy Gap Assessments

7. Extended Empirical Subsections

- Counterfactual No-CBDC Economy Trajectory
- Spline-Based Turning Points in CBDC Impact Pathways

8. Final Synthesis and Strategic Recommendations

- Synthesis Annexe on Buffer Calibration and CBDC Lending Risks
- Policy Implication Matrix by Scenario and Currency
- Full Phase Diagram and Stability Bifurcation Analysis
- CBDC Coordination Strategy Recommendations (ECB, NBR, IMF)

Each of these modules is grounded in the empirical infrastructure developed in Volume 1. Together, they form a practical surveillance toolkit that enables proactive policy calibration and real-time response to CBDC-induced liquidity and credit risks.

Volume 2 will therefore serve not only as a technical continuation but as a strategic complement, translating empirical evidence into actionable supervisory intelligence for central banks navigating the digital transition.

Architecture of the CBDC Monitoring Toolkit
This second volume represents more than a simple continuation of empirical analysis; it introduces a fully integrated monitoring architecture, designed to equip central banks with the most advanced institutional and supervisory instruments to assess and contain financial stability risks arising from CBDC adoption.

The modular structure, ranging from liquidity surfaces to trust contagion maps, functions not as isolated subsections but as synergistic components of a real-time, forward-looking surveillance toolkit. The CBDC monitoring framework draws on over 100 subsections and visuals, underpinned by scenario simulation, macro-behavioural decomposition, and synthetic stress-testing techniques. These are not merely academic artefacts; they are operationalised insights, directly translatable into policy action and supervisory oversight.

The foundation of this toolkit rests on two critical layers:
1. Single-Formula Indicators, such as the CBDC Disintermediation Ratio (CDR), Trust-Adjusted Adoption Potential (TAAP), or the Conversion Risk Exposure Index (CREI). These measures distil complex interactions into high-frequency, interpretable metrics that can be embedded into early

warning dashboards.
2. Multi-Formula Systems, such as the CBDC Risk Signal Matrix or the Central Bank Activation Lag Index (PALI), which integrate inputs from liquidity simulations, behavioural sensitivity clusters, and monetary calibration parameters. These serve as supervisory "navigational charts" that track systemic exposure over time.

Each element of the toolkit connects to at least one of the following five monitoring pillars:

1. Liquidity Monitoring and Shock Simulation: Visuals, such as 3D surface maps, tiered buffer calibrations, and threshold breach trees, collectively form a liquidity pressure detector, measuring both the intensity and trajectory of systemic stress under CBDC-induced shifts in deposit behaviour.

2. Behavioural Risk Decomposition: SHAP waterfall and force plots, combined with adoption readiness maps and privacy-sensitivity thresholds, allow central banks to segment risk populations by vulnerability and simulate tailored interventions. Trust volatility, privacy comfort, and digital skill gradients are translated into probability-based stress flags.

3. Institutional Coordination and Macroprudential Triggers: Policy flowcharts, tiered remuneration models, ECB–NBR timelines, and emergency response templates collectively enable inter-institutional alignment. These tools convert analytical foresight into pre-authorised supervisory actions.

4. Credit Risk and Contagion Pathways: Lending risk zones, contraction simulations, and dynamic contagion diagrams illuminate how CBDC adoption may tighten credit channels, particularly for SMEs or Tier 2 banks. These stress maps can guide temporary exemptions, FX buffers, or digital holding caps by bank class.

5. Strategic Policy Feedback: The indicators feed into high-level dashboards, synthesising all dimensions into a narrative probability space. The Policy Buffer vs. Liquidity Stress visuals, along with the Welfare Function Synthesis subsections, enable policymakers to weigh the benefits and costs of CBDC calibration in real-time.

Taken together, these elements do not form a linear sequence but a recursive architecture, whereby model outputs are continuously reintegrated into early warning indicators and coordination playbooks. This enables adaptive policy feedback loops, ensuring that as CBDC adoption grows or macro volatility intensifies, the toolkit remains anticipatory rather than reactive.

This operational system is designed to meet four critical goals of modern central banking in the digital age:
- **Timeliness**: Identify signals before contagion or liquidity events occur.
- **Targetability**: Pinpoint the precise demographic, institutional, or currency source of risk.
- **Translatability**: Turn quantitative insights into deployable supervisory instruments.
- **Transparency**: Enable communication across internal departments (monetary, macroprudential, and digital innovation) and with external stakeholders (ECB, BIS, and IMF).

This toolkit is globally replicable but locally grounded, calibrated for Romania's dual-currency structure, yet generalisable to any banking system seeking to safeguard financial stability amid rising CBDC experimentation.

With this volume, the CBDC monitoring agenda transitions from theory to implementation, from forecasting to foresight, from risk analysis to strategic resilience.

Macroprudential Framework Embedded in Volume 2

Volume 2 not only expands the analytical depth of the CBDC–financial stability framework but also embeds a structured macroprudential policy architecture tailored for dual-currency economies. By integrating stress simulations, adoption monitoring, and inter-institutional response protocols, this volume effectively evolves into a macroprudential toolkit for central banks seeking to proactively mitigate systemic risks emerging from digital currency dynamics.

Key subsections and components within Volume 2 contribute directly to this macroprudential layer. For instance, the *CBDC Risk Signal Matrix*, *Threshold Breach Trees*, and *Time-Evolving Stress Indices* enable central banks to trigger time-consistent countercyclical policy responses. These instruments work in tandem with early warning indicators and liquidity intensity maps to detect phase transitions in the financial system before they manifest visibly in credit, deposits, or market spreads.

Moreover, tools such as the *CBDC Systemic Risk Liquidity Buffers* and the *Tiered Remuneration Visuals* serve as macroprudential calibration levers, empowering central banks to apply targeted liquidity constraints or incentives based on behavioural segmentation and institutional exposure levels. The subsections dedicated to *ECB–NBR Coordination Mechanisms* and the *Policy Buffer vs. Liquidity Stress Simulations* illustrate how CBDC-related vulnerabilities can be addressed through harmonised macroprudential and monetary responses.

Additionally, macroprudential foresight is reinforced by the use of synthetic indicators such as the *Shock Response Elasticity Score (SRES)*, *Structural Displacement Threshold Ratio (SDTR)*, and the *Financial Stability Response Buffer (FSRB)*. These indicators not only quantify systemic exposure but also provide calibration thresholds for activating capital conservation buffers or lending guidance frameworks under CBDC stress scenarios.

Together, these tools position Volume 2 as a pioneering effort to establish a fully fledged macroprudential framework within the digital monetary space, capable of anticipating feedback loops, modelling contagion risk, and coordinating multi-agency response protocols. Its relevance extends beyond Romania to any financial system navigating the twin transition of digital currency issuance and financial stability preservation.

Concluding Remarks and Policy Insights

As I approach the final stretch of what has been a profoundly engaging journey, I find myself pausing, not merely to summarise numbers but to contemplate the remarkable interplay between innovation, human behaviour, and financial stability.

For at the centre of all this analysis lies a singular realisation: **CBDCs are not merely technological instruments. They are profound economic interventions capable of reshaping the architecture of banking systems, macroeconomic dynamics, and public trust.**

The Tension Between Promise and Risk

From the outset of this research, it has been clear that Central Bank Digital Currencies present both promise and peril. On the one hand, they hold the potential to modernise payment systems, widen financial inclusion, and strengthen monetary policy transmission. On the other hand, they carry within them the seeds of disruption, threats to liquidity structures, to credit intermediation, and to the fragile balance upon which financial systems rest.

The challenge has never been purely technical. It has always been a question of translating a digital instrument into a financial reality that people can trust and that banks can withstand.

A Data-Driven Departure from Hypotheticals

One of the choices that most fundamentally shaped this research was to reject reliance on hypothetical surveys as the primary tool for estimating CBDC adoption. Too often, surveys ask individuals whether they would adopt a digital currency, and too frequently, they receive enthusiastic but speculative affirmations that dissolve when confronted by real-world behaviour.

Instead, this study turned to **observable financial behaviour**. It anchored its modelling in how individuals currently allocate their wealth between cash, sight deposits, term deposits, and emerging digital channels. It examined how people respond to signals like macroeconomic volatility, institutional trust, and digital proficiency.

This shift to behavioural realism produced estimates that diverge sharply from many international studies. While some forecasts predict that CBDC adoption will be among 60% to 80% of the population, the models presented here reveal a far more nuanced and cautious picture.

Adoption Estimates: From Optimism to Reality

This study demonstrates that it is possible to estimate credible CBDC adoption without directly using survey microdata, a task once considered nearly impossible. By replacing individual data with a synthetic behavioural population built through calibrated enablers and policy-relevant assumptions, the research creates a solid simulation framework using machine learning classification models. Although upcoming empirical validation with HFCS or ECB SPACE is planned, the current findings already demonstrate the practical usefulness and methodological robustness of this approach. It provides a reproducible template for central banks in dual-currency systems with limited granular behavioural data, offering a structured way to model digital currency adoption accurately and relevant to policy.

The research synthesises machine learning techniques and behavioural profiling, identifying that, under optimistic assumptions, the maximum realistic adoption ceiling for a CBDC is approximately 48% of depositors.

In a baseline scenario, the adoption rate falls closer to **20.65% of the eligible population**.

Baseline adoption is estimated at 20.65% of eligible depositors, while the maximum potential ceiling under MinMax logic reaches 48% of the unique depositors.

These numbers are not trivial details. They fundamentally shape the potential size of the CBDC ecosystem, and therefore the scale of its impact on the banking sector.

To put it in practical terms:

- At the lower bound (baseline XGB results), the number of likely CBDC users is materially smaller, limiting systemic risk but also constraining the policy benefits of digitalisation.
- At the upper bound (100% of the 7 million eligible adopters), the CBDC becomes a major component of the monetary system, with the capacity to displace significant volumes of traditional deposits.

This is why, throughout the modelling process, the study insisted on a **MinMax logic**, counting as adopters only those individuals who simultaneously meet all necessary criteria: digital proficiency, sufficient income and wealth, trust in institutions, and behavioural openness to new financial tools.

Liquidity Costs: A Threat Hidden in Plain Sight

However, adoption rates alone do not determine risk. The genuine peril lies in what happens if people begin moving significant portions of their deposits into CBDC wallets. That shift, even when individually modest, aggregates into **liquidity outflows of considerable magnitude.**

Under a CBDC holding limit of **7,500 RON per individual**, the modelling reveals:

- Potential deposit outflows of around **RON 39 billion.**

These are not merely accounting entries; they are stress points in the financial system. For some banks, such an outflow would be manageable, thanks to excess reserves and careful funding strategies. For others, it could trigger abrupt shifts into wholesale markets, driving up funding costs and putting pressure on net interest margins.

However, the most startling insight is that the risk is **non-linear.** If the holding limit were increased to **15,000 RON**, the projected outflows would nearly double to **RON 77.8 billion.** This is not simply a case of risk growing proportionately. It grows exponentially, pushing a larger number of banks into zones where standard liquidity management tools begin to falter.

The Combined Digital RON and Digital Euro Scenario

The challenge grows even more complex in economies where a foreign anchor currency coexists in everyday financial life. Modelling a scenario where both a Digital RON and a Digital Euro were introduced concurrently yielded sobering findings.

Under conservative estimates, the **combined liquidity burden** could reach approximately **RON 1,956.6 million (cost of covering the liquidity migrated to CBDC holdings).**

While not catastrophic in isolation, these pressures become highly significant when combined with traditional liquidity risks, seasonal cash demands, and market volatility. They also create fertile ground for **currency substitution dynamics**, where households might decide to shift savings into whichever digital currency appears more stable or offers better privacy guarantees.

The Domino Effect: Credit Contraction

Liquidity shocks are never confined purely to bank balance sheets. Eventually, the strain flows outward into the real economy, where the consequences become more tangible and more personal.

Banks facing significant deposit outflows have limited options. They may draw on cash and excess reserves, tap wholesale funding, or, ultimately, begin to **reduce credit to the economy.**

The research reveals that under a moderate CBDC shock (such as the 7,500 RON cap with upper-bound adoption), around **15% of banks** might be forced to reduce their credit portfolios by more than **10%.**

To quantify the magnitude:

- For every **RON 1 billion** in deposit outflow, credit contraction could range between **0.7% and 1.1%**, depending on each bank's funding mix and balance sheet resilience.

These percentages might sound small on paper. However, they translate into:

- Businesses denied loans for expansion.
- Households delaying home purchases or significant spending.
- Slower GDP growth as private sector activity cools.

In short, the digital revolution in money, if poorly calibrated, could become an **engine of credit contraction.** This is perhaps the starkest policy warning to emerge from the models.

Macro-Financial Linkages: The Broader Picture

Beyond the banking sector, the adoption of CBDCs has the potential to ripple through the broader economy in both obvious and subtle ways. The study's structural VAR models illuminate the paths through which these shocks propagate.

Key insights include:

- **Credit growth compression** of **2.5% to 3.2%** in the two quarters following a moderate CBDC shock.
- Elevated **FX volatility**, as households and firms rebalance between domestic currency and euro holdings in search of perceived safety.
- Shifts in the **deposit beta**, i.e. the responsiveness of bank deposit rates to central bank policy changes, complicating monetary transmission.

These macro-financial linkages underscore that CBDCs are not confined to the payments space. They are, in fact, the most crucial variables for monetary and financial stability.

Policy Recommendations: A Path Through Complexity

From these complex interplays of technology, psychology, and macro-financial mechanics, certain **policy imperatives** emerge:

- **Calibrate Holding Limits Prudently**
  The models point emphatically towards **7,500 RON** as a threshold that maximises adoption potential without crossing into dangerous territory.
- **Integrate CBDCs into Stress Tests**
  Digital currencies must become an integral part of regular macroprudential analysis and stress testing scenarios.
- **Maintain Cross-Currency Coordination**
  No CBDC can be designed in isolation, primarily where strong foreign-currency preferences exist.
- **Respect Behavioural Limits**
  Digital adoption hinges on trust and a sense of comfort. Tiered limits, simple user interfaces, and privacy assurances are essential for effective management.

- **Invest in Communication Infrastructure**
  Central banks must now become skilled communicators, explaining complex digital instruments in clear and relatable terms.

A Personal Reflection

For me, this research has been more than an academic exercise. It has been a journey into the heart of what money means, and into the delicate architecture of trust that supports financial systems.

CBDCs, I now see, are not merely technical artefacts. They are **expressions of social trust.** They will shape and be shaped by how individuals weigh convenience against privacy, how banks manage liquidity, and how entire economies navigate the delicate balance between modernisation and stability.

The numbers in this study, **RON 39 billion** in potential outflows, **48%** adoption ceilings (out of the total number of unique depositors), and **2.5–3.2%** credit growth contractions, are not merely statistics. They serve as warning lights and guideposts for policymakers navigating a path that is as full of promise as it is perilous.

I hope this work contributes, even modestly, to ensuring that as nations step into the digital monetary future, they do so with both eyes open, aware not only of the technological marvels ahead but of the **quiet, fragile architecture of trust** that must sustain them.

The Broader Relevance of Methods: A Bridge Beyond CBDCs

As I reflect on the intricate path this research has taken, one thought stands out with growing conviction: **the methodologies developed and employed here extend far beyond the specific question of Central Bank Digital Currencies.**

At first glance, tools such as machine learning classifiers, synthetic agent modelling, liquidity stress simulations, and structural VARs may seem tailored exclusively to the singular challenge of assessing CBDC risks and adoption dynamics. However, in truth, these techniques form a **universal analytical toolkit** for any investigation that sits at the intersection of individual behaviour, financial institutions, and macroeconomic outcomes.

Consider the power of **synthetic agent modelling**. By constructing representative micro-level datasets grounded in real behavioural and demographic patterns, policymakers and researchers can simulate responses not only to digital currencies but also to a wide range of shocks, including interest rate changes, regulatory reforms, geopolitical tensions, and unexpected macroeconomic shifts.

Similarly, the application of **machine learning algorithms**, such as XGBoost, offers remarkable insights into non-linear relationships and subtle threshold effects. Whether the question is about predicting bank vulnerability under stress, mapping contagion pathways in credit markets, or understanding shifts in household savings behaviour, these models can reveal patterns that traditional linear regressions might obscure.

The **liquidity cost simulations** presented here, which translate behavioural choices into concrete balance sheet impacts, could also inform stress testing for climate-related risks, sudden capital outflows, or abrupt asset revaluations in financial markets.

The structural VAR framework is a cornerstone for disentangling the sequence and magnitude of cause-and-effect relationships across macroeconomic variables, making it invaluable not just for CBDCs but for any analysis of monetary transmission, fiscal shocks, or cross-border spillovers.

Thus, while the canvas for this research has been CBDCs, the **methods are broadly transportable.** They offer a rigorous, data-driven approach to understanding how micro-level decisions scale into macro-level consequences. This capability is increasingly essential in a world where economic realities are interconnected, fast-moving, and often non-linear.

In this sense, I hope that the analytical framework laid out in these pages serves not only as a roadmap for CBDC design but also as a living toolkit for the numerous other macro-financial challenges that lie ahead.