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“ANALYSIS OF ASSET & LIABILITY MANAGEMENT: THE SILICON VALLEY BANK CASE”

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Introduction

"Banking is fundamentally about managing risk, not avoiding it." — Alan Greenspan, Former Chairman of the U.S. Federal Reserve (2001).

This statement captures what separates resilient financial institutions from fragile ones: the ability to identify, quantify, and effectively manage risk. Among the most critical forms of risk in banking is the mismatch between a bank's assets and liabilities, known as Asset Liability Management (ALM). ALM is a strategic process by which banks manage interest rate exposures, liquidity constraints, and maturity mismatches to ensure long-term stability and profitability. ALM protects a bank's balance sheet from market volatility when executed properly. When neglected, it can become a catalyst for systemic failure.

The collapse of Silicon Valley Bank (SVB) in March 2023 illustrates the consequences of failing to uphold this principle. SVB's business model left it heavily exposed to rising interest rates: it invested many of its deposits in long-duration fixed-income securities without sufficient interest rate hedging while funding its balance sheet with an undiversified base of uninsured, volatile deposits. As interest rates rose and depositors grew uneasy, SVB could not absorb the losses or meet withdrawal demands, resulting in a catastrophic bank run. In essence, SVB did not fall victim to an unpredictable external shock; rather, it collapsed because it failed to manage the most basic banking risk of all: the mismatch between its assets and liabilities.

Such a failure—second only to that of Washington Mutual in U.S. history—had become nearly unthinkable due to the extended period of relative financial calm that followed the Global Financial Crisis (GFC). However, this episode is a sobering reminder of how opaque and complicated contemporary finance is. Until shortly before its downfall, SVB had undergone remarkable growth, both in reputation—emerging as a key financial partner for numerous successful start-ups in the technology and life sciences sectors—and in scale, rising to become the sixteenth largest banking institution in the United States. Despite its peculiar characteristics, it demonstrates a common issue in finance: Hidden weaknesses tend to accumulate during prosperous times. Banks and other institutions can make choices without fully considering future risks when all seems secure. Overconfidence can compound inherent challenges, which stay unnoticed until a sudden crisis reveals them.

A clear parallel can be drawn with the 2007–2008 financial crisis, which devastated the banking sector and led to the collapse of major institutions such as Bear Stearns and Lehman Brothers. In response to that global crisis, supervisory authorities turned to a tool with significant untapped potential (the stress test), which became a cornerstone of efforts to restore confidence in the banking system despite its limited use prior to the GFC.

This work examines the collapse of Silicon Valley Bank (SVB) through a regulatory lens. Unlike the Global Financial Crisis (GFC), which stemmed from the real estate market and was driven by poor lending standards, dubious securitisation practices, and the excessive leverage of investment banks (as highlighted by Cochrane (2014) and Duffie (2019)) the current crisis cannot be attributed to credit risk or investment banking activities. Instead, the downfall of SVB is primarily linked to its substantial investment portfolio, reportedly worth $120 billion, which consisted mainly of long-term mortgage-backed securities (MBS) issued by U.S. government agencies (Financial Times, February 2023). By entering this position during 2020—at a historically low yield-to-maturity of approximately 1.64%—and by classifying the assets as hold-to-maturity with minimal hedging, SVB's management exposed the bank to significant interest rate risk. This strategy resulted in a suboptimal return on capital relative to prevailing market conditions and led to substantial unrealised losses as interest rates rose.

The crisis raises several critical regulatory and supervisory questions: Why did SVB's risk management framework fail to identify and address these vulnerabilities? Did regulators miss warning signs? This study addresses these questions and explores persistent shortcomings in regulatory oversight and SVB's failure to uphold its fundamental responsibility of effective risk management through a detailed analysis of the bank's business model, balance sheet, and risk governance structure.

The study is structured as follows. Chapter I provides an in-depth overview of Asset Liability Management (ALM) in the banking sector, tracing its historical evolution from a basic risk tool to a central strategic function. It highlights how financial crises, deregulation, and interest rate volatility shaped ALM practices and explains its role in managing liquidity, interest rate, and market risks. The chapter also explores the structure and responsibilities of ALM departments, tools like stress testing, fund transfer pricing, and securitisation, and the growing importance of regulatory compliance and advanced analytics in ALM today.

Chapter II reviews the evolution of Asset Liability Management (ALM), highlighting key theoretical models—deterministic and stochastic—and their application in banking. It categorises ALM strategies into static, value-driven, and return-driven approaches, emphasising duration matching, immunisation, and scenario analysis. The chapter also examines the impact of Basel I, II, and III regulations on risk and capital management. It underscores the growing role of stress testing in assessing banks' resilience to financial shocks.

Chapter III explores the interest rate and liquidity risk management within Asset Liability Management (ALM). It outlines the nature, sources, and implications of interest rate risk, including mismatch, yield curve, basis, and option risk. It presents key models such as the repricing gap model, duration gap model, cash flow mapping, and internal transfer pricing. The chapter also examines liquidity risk, differentiating between short-term and structural liquidity, and introduces key tools for managing funding risk, including stock-based, cash flow, and hybrid approaches. Additionally, it highlights stress testing and key liquidity ratios used to assess a bank's resilience to shocks.

Lastly, Chapter IV examines the collapse of Silicon Valley Bank (SVB) in March 2023, driven by poor risk management, excessive exposure to interest rate changes, and weakened oversight following U.S. regulatory rollbacks (EGRRCPA and the 2019 Tailoring Rule). SVB heavily relied on uninsured deposits from the tech sector and invested in long-term securities vulnerable to rising rates. Supervisors failed to intervene despite warning signs, and CAMELS ratings overlooked key risks. In contrast, the chapter argues that the EU's stricter and more consistent regulatory framework, including stress testing for smaller banks, makes a similar collapse less likely in Europe.

CHAPTER I

AN OVERVIEW OF ALM IN THE BANKING SECTOR

Asset and Liability Management (ALM) has evolved significantly over the decades, shaped by changing financial environments, technological advancements, and regulatory reforms. Its history reflects the ongoing effort of financial institutions to manage risks associated with mismatches between assets and liabilities, particularly in the face of market volatility and economic uncertainty.

In recent years, ALM has gained significant popularity. Initially developed by English-speaking financial institutions in the 1970s as a method for actuarial and cash flow matching, ALM has since evolved into a crucial framework for banks. The three main reasons for this popularity and importance are: 1) advances in modelling tools have improved the accuracy of cash flow projections; 2) accounting standards are constantly evolving; and 3) financial reporting is increasingly regulated.

The goal of ALM is to coordinate assets and liabilities effectively to achieve the financial targets for a specified level of risk and under predefined constraints. The ALM department in a bank is, therefore, responsible for conducting analyses that provide recommendations on marketing strategies and asset allocation.

In the last fifty years, three main aspects have been important for the ALM's evolution and centrality in the banking sector: 1) inflation rates have started to rise from the early seventies with a consequent increase in nominal rates, leading to an alteration of the market conditions in which the banks operated; 2) at the turn of seventies and the eighties, interest rate movements became more volatile. This underlined the need for greater flexibility in the structure of bank balance sheets; 3) from the second half of the sixties, deregulation started to take hold, which increased dependence on market forces as an integral part of the control mechanisms.

Despite its importance, ALM in banks faces several challenges. Market volatility, regulatory changes, technological advancements, and globalisation all add complexity to the ALM process. For example, fluctuations in interest and exchange rates can significantly impact ALM strategies, while frequent regulation updates require constant adjustments. Moreover, integrating advanced technologies, such as artificial intelligence and machine learning, into ALM processes can be challenging but is essential for improving predictive capabilities and decision-making.

This chapter is structured as follows. Section 1.1 puts ALM in context by examining its history and its changes over the years. Section 1.2 continues by defining the ALM concept, generally in financial institutions and specifically in banks. Finally, Section 1.3 concludes with an operational analysis of the ALM department, its policies, functions, processes, reports, and instruments.

1.1 Brief History of ALM

Before the 1970s, the financial landscape was characterised by relative stability. Interest rates in developed countries remained relatively stable, leading to minimal losses from asset and liability mismatches. Banks and financial institutions typically invested the funds from their liabilities (such as deposits, life insurance policies, or annuities) in assets like loans, bonds, or real estate. Banks and other financial entities typically managed their portfolios by holding assets and liabilities to maturity and recording them at book value, thus minimising the need for sophisticated risk management strategies. (Corlosquet-Habart et al, 2015). This era of stability was supported by regulatory frameworks such as interest rate caps and the Bretton Woods system,[1] which pegged currencies to the U.S. dollar and gold, limiting exchange rate volatility. As a result, the concept of ALM, as it is understood today, had little relevance, as financial institutions were rarely exposed to significant interest rate or liquidity risks. Historically, ALM was a relatively simple process shaped by regulatory constraints and the saving and borrowing behaviours of bank customers. In the U.S. banking sector, for example, regulations dictated the terms of deposit accounts, imposed limits on the geographic reach of customer bases, and restricted the interest rates banks could offer. Within this framework, ALM mainly focused on asset management, where banks allocated depositor funds to create an asset portfolio that best aligned with their liability portfolio.

1.1.1 The 1970s

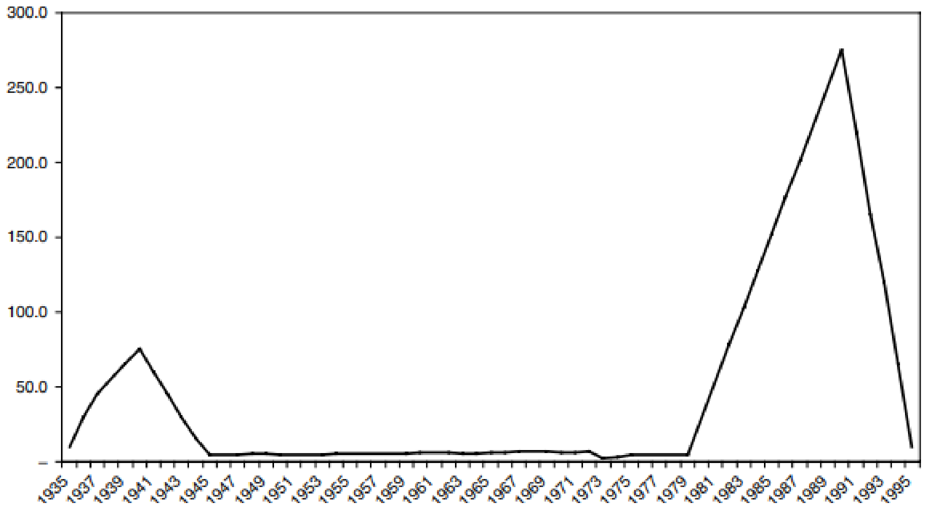
The 1970s marked a turning point for financial markets, driven by two major developments: the collapse of the Bretton Woods system in 1971 and the oil crises of 1973 and 1979. The shift to floating exchange rates introduced significant currency volatility, while inflationary pressures led to sharp fluctuations in interest rates. This volatility, which persisted until the early

[1] The Bretton Woods agreement was negotiated in July 1944 by delegates from 44 countries at the United Nations Monetary and Financial Conference held in Bretton Woods, New Hampshire. Under the Bretton Woods system, these countries agreed to fix the values of their currencies to gold and to maintain fixed exchange rates within a narrow interval of $\pm 1\%$. It came to an end in the early 1970s when President Richard M. Nixon announced that the U.S. would no longer exchange gold for U.S. currency.

1990s, had negative implications for financial institutions, including the U.S. Savings and Loan crisis in the 1980s and early 1990s, as well as the Japanese banking crisis during the 1990s (Sakovich, 2012). These economic shocks exposed the vulnerabilities of traditional banking practices, which were ill-equipped to handle the emerging risks.

The following figure shows the number of bank failures in the United States from 1934 to 1995.

Figure 1. Number of bank failures in the United States, 1934-1995



Source: Adam (2007)

Financial institutions began to realise the need for a structured approach to managing mismatches between their assets and liabilities' maturities and interest rate sensitivities. During this period, the term "Asset and Liability Management" entered common usage as banks sought to align their financial positions more effectively. Initial efforts focused on basic tools, such as maturity gap analysis, to identify and address potential risks.

1.1.2 The 1980s

In the 1980s, ALM became a formalised and widely adopted practice driven by the challenging high-interest rate environment of the time. This situation created two significant challenges for S&L (Savings and Loan) institutions in the U.S. First, federal regulations capped the interest rates they could offer on deposits, making them less competitive than other investment options and prompting savers to withdraw their funds. Second, S&Ls predominantly issued long-term fixed-rate mortgages, which lost substantial value as interest rates increased, effectively eroding the net worth of the S&L industry. Policymakers responded by passing the Depository Institutions Deregulation and Monetary Control Act[2] of 1980 (Curry and Shibut, 2000). The

[2] United States federal financial statute passed in 1980 and signed by President Jimmy Carter on March 31. It required that banks accepting deposits from the public periodically report to the Federal Reserve System (FRS) and maintain required reserve minimums. It gave the Federal Reserve greater control over non-member banks.

S&L crisis highlighted the critical need for effective mismatch management. The crisis was exacerbated by interest rate deregulation and then Federal Reserve Chairman Paul Volcker's push to raise benchmark rates. The rates that S&Ls could charge for their mortgages could not keep pace with the rates they had to pay for the funds to pay those mortgages (Hong Kong Institute of Bankers, 2018). Many S&Ls heavily relied on short-term deposits to fund long-term (30-year) fixed-rate mortgages. When interest rates spiked, these institutions found themselves in trouble as the cost of their liabilities outpaced the returns on their assets, resulting in substantial financial losses (U.S.$150 billion). In particular, S&L institutions held total assets of $604 billion insured by FSLIC (Federal Savings and Loans Insurance Company).[3] The vast majority of these assets were held in traditional S&L mortgage-related investments. However, a mismatch between assets and liabilities, coupled with sharply rising interest rates, caused net income to decline from $781 million to losses of $4.6 billion in 1981 and $4.1 billion in 1982. Between 1980 and 1982, 118 S&Ls, with $43 billion in assets, failed, resulting in an estimated $3.5 billion cost to the FSLIC. Additionally, there were 493 voluntary mergers and 259 supervisory mergers among S&L institutions (Adam, 2007).

By the late 1980s, another financial crisis emerged, this time rooted in the real estate market. Early in the decade, commercial construction experienced a boom driven by high demand for real estate investments. Banks, impatient to capitalise on this trend, began lending aggressively in a highly competitive environment. As a result, real estate loans issued by banks more than tripled. However, the credit risks taken by these institutions were significant, with loan-to-value ratios often approaching 100% and customer lending requirements being notably negligent. When the real estate bubble burst toward the end of the decade, property values plummeted. The quality of loans rapidly declined, leading to widespread bank failures, particularly among those heavily exposed to commercial real estate lending. The crisis underscored the consequences of poor credit risk modelling within balance sheets. In response, the Basel regulatory framework was introduced, aiming to strengthen risk management practices. This period also marked the formal establishment of dedicated risk management and credit risk teams within banks, reflecting the growing importance of managing credit exposure effectively (FDIC, 1997).

Learning from these crises, managers of financial firms recognised the necessity of a new, qualified, strong, and effective regulation, independent of industry, with adequate financial

[3] The Federal Savings and Loan Insurance Corporation (FSLIC) was a former U.S. government agency that insured deposits at savings and loan institutions. It operated until the late 1980s, when its functions were assumed by the Federal Deposit Insurance Corporation (FDIC) in 1989.

resources. Furthermore, they focused on developing a process that could monitor the mismatch risk between assets and liabilities, enabling the bank to manage its balance sheet and maintain a loan-to-deposit mix consistent with its long-term growth and risk management goals. Thus, they began developing new financial techniques, such as gap analysis, duration analysis, and scenario analysis (Corlosquet-Habart et al., 2015).

1.1.3 The 1990s

The 1990s marked a new era for ALM, driven by advancements in financial modelling and computing technology. These innovations enabled the development of more sophisticated ALM techniques, allowing institutions to model various risk scenarios and implement dynamic strategies. The introduction of financial derivatives, such as interest rate swaps and options, further expanded the toolkit for managing risks. These instruments provided a means to hedge against adverse movements in interest rates, foreign exchange rates, and other market variables. A significant advancement was the rise of securitisation, which allowed firms to tackle asset and liability risks more effectively by transferring assets or liabilities off their balance sheets. This approach not only mitigated asset and liability risks but also freed up balance sheet capacity, enabling institutions to pursue new business opportunities. During this period, ALM also began to encompass broader risk categories, including market, credit, and foreign exchange risks. The Basel Accords, first introduced in 1988, integrated ALM concepts into regulatory frameworks, linking risk management practices to capital adequacy requirements. These developments established ALM as a cornerstone of financial risk management.

1.1.4 The 2000s and beyond

In the early 2000s, ALM evolved beyond a pure risk management tool to become a strategic function within financial institutions. ALM frameworks were increasingly used to align financial planning with long-term objectives, optimise profitability, and support regulatory compliance. The 2008 global financial crisis[4] underscored the critical importance of robust ALM practices. Institutions with weak ALM frameworks faced three severe issues:

- *Excessive Reliance on Short-Term Funding*: Many financial institutions, leading to the 2008 crisis, relied heavily on short-term funding to finance long-term, illiquid assets like mortgage-backed securities (MBS). This mismatch in maturities created significant liquidity risks. When funding markets dried up during the crisis, institutions could not roll over their short-term obligations, leading to severe liquidity crises;

[4] For more information about the relationship between ALM and the 2008 Financial Crisis, see Kreuser (2012).

- *Overexposure to Mortgage-Backed Securities*: Banks and financial institutions aggressively invested in mortgage-backed securities and collateralised debt obligations (CDOs), driven by the perception of low risk and high returns. However, these assets were backed by subprime mortgages that were highly sensitive to default risks;
- *Interest Rate Risk Mismanagement*: Leading up to the crisis, many institutions failed to adequately account for the risks associated with changes in interest rates. Adjustable-rate mortgages (ARMs), which became increasingly common, posed significant risks when interest rates rose. Borrowers struggled to meet higher payments, leading to widespread defaults, which further devalued mortgage-backed assets.

The crisis renewed the focus on liquidity management, stress testing, and scenario analysis. It also highlighted the need for greater transparency in ALM practices, particularly regarding off-balance-sheet exposures and complex financial instruments. Regulators introduced stricter guidelines, such as Basel III, which emphasised liquidity coverage ratios (LCR) and net stable funding ratios (NSFR), directly tying regulatory compliance to ALM practices.

In the post-crisis era, ALM has continued to evolve, leveraging advancements in technology and analytics to drive further growth. Artificial intelligence, machine learning, and big data analytics have enhanced the predictive capabilities of ALM models, enabling institutions to identify emerging risks and opportunities with greater precision.

After several years of economic recovery, the COVID-19 pandemic emerged. The pandemic profoundly impacted financial markets, liquidity dynamics, interest rate environments, and the overall risk landscape, thereby influencing how banks and financial institutions approached ALM. During the early stages of the pandemic, financial markets experienced extreme volatility and uncertainty. This led to sudden liquidity shortages as businesses and individuals withdrew funds or delayed loan repayments. Central banks globally provided significant liquidity injections and implemented measures such as reduced reserve requirements, which eased pressure on ALM teams by providing access to cheaper funding sources. In response to the economic slowdown, central banks also lowered interest rates to historic lows. This created challenges for ALM, as traditional interest income from loans and investments was significantly reduced. ALM teams had to navigate the narrow interest rate spreads while ensuring profitability and protecting the net interest margin. Moreover, the pandemic triggered a rise in credit risk as businesses, particularly in vulnerable sectors, faced financial strain. Loan defaults and non-performing assets (NPAs)[5] increased, directly affecting the balance sheet's asset side.

Regulators introduced several measures to help banks manage the crisis, including moratoriums on loan repayments, relaxed capital requirements, and temporary exemptions from certain regulatory constraints. These measures influenced ALM strategies by allowing more flexibility in managing liquidity and capital adequacy. However, they also required careful planning to ensure compliance when these relief measures were phased out.

The pandemic accelerated digital adoption, altering customer behaviour in terms of savings, borrowing, and transaction patterns. Banks witnessed shifts in deposit flows, with customers holding more liquid assets during uncertain times. ALM now addresses a broader spectrum of risks, including environmental, social, and governance (ESG) considerations,[6] reflecting the growing importance of sustainable finance. Its role has expanded to include non-financial corporations, which adopt ALM techniques to manage risks such as commodity price volatility and foreign exchange exposure.

1.2 Definition

The Society of Actuaries (SOA, 2003)[7] gives this definition of ALM:

"ALM is the ongoing process of formulating, implementing, monitoring and revising strategies related to assets and liabilities to achieve an organisation's financial objectives, given the organisation's risk tolerances and other constraints".

In other words, Asset Liability Management (ALM) is a strategic financial approach employed by financial institutions to address the risks associated with mismatches between their assets and liabilities. It is an essential component of risk management, focusing on maintaining a balance that ensures both financial stability and profitability.

[5] Non-Performing Assets (NPAs) are loans or advances issued by banks or financial institutions that no longer bring in money for the lender since the borrower has failed to make payments on the principal and interest of the loan for at least 90 days.

[6] For examples of ESG integration for ALM, see Orcesi *et al.* (2016) and Chen *et al.* (2023).

[7] It is an international organisation dedicated to supporting actuaries by offering professional development opportunities, educational programs, examinations, research, and various resources aimed at advancing the actuarial profession and fostering the career growth of its members.

1.2.1 ALM in financial institutions

In financial institutions, assets typically include loans, investments, and other forms of receivables that generate income. Liabilities, on the other hand, consist of obligations such as customer deposits, borrowed funds, or insurance claims. When the terms, interest rates, or cash flows of these assets and liabilities are not aligned, risks arise. ALM provides the tools and strategies to identify, measure, and mitigate these risks.

Zawalinska (1999) highlights three key requirements for successfully implementing Asset Liability Management (ALM). The first is a deep understanding of the ALM concept, which includes a comprehensive grasp of banking risks. ALM not only facilitates a clear understanding of the scope of various risks but also enables their quantifiable assessment and effective management. Even without a formal ALM program, understanding these principles offers valuable insight into the risk/reward trade-offs that financial institutions face. The second requirement is the establishment of an effective information system. Successful risk management relies on collecting and monitoring relevant data, which provides critical insights into the level of financial risk impacting the institution. The third step involves designing and implementing the ALM decision-making process. This process is typically carried out by the Asset Liability Committee (ALCO), which is responsible for evaluating and making strategic ALM decisions.

In the framework of ALM, both asset management and liquidity management play integral roles in maintaining a financial institution's stability and ensuring it meets its strategic objectives. Together, they help balance profitability, risk, and the ability to meet obligations, even under volatile market conditions. Asset management focuses on optimising the institution's portfolio of assets, ensuring that investments and loans generate adequate returns while maintaining an acceptable risk profile. It involves decisions about asset allocation, risk diversification, and performance monitoring to maximise financial returns without threatening stability. On the other hand, liquidity management ensures that the institution has enough readily available resources to meet its short-term obligations, such as customer withdrawals, loan disbursements, or regulatory requirements. It emphasises maintaining a balance between holding liquid assets and investing in less liquid but higher-yielding instruments. Effective liquidity management helps banks avoid insolvency and maintain smooth operations even during periods of financial stress.

While asset management drives profitability and long-term growth, liquidity management ensures operational continuity and customer trust by safeguarding the institution against liquidity shortages. The interplay between these two components is central to a successful ALM strategy, as it helps manage risks such as interest rate fluctuations, credit defaults, and funding constraints while meeting regulatory requirements.

ALM is applied in various industries, including banks, insurance, pension funds, and corporate finance, as well as at the individual household level,[8] but with different priorities and challenges. While the core principles of ALM (balancing assets and liabilities to manage risks and optimise financial performance) are consistent across industries, the specific objectives, tools, and challenges can vary significantly depending on the context.

For example, in insurance companies,[9] ALM focuses on ensuring that premium income and investment returns are sufficient to cover claims and other liabilities over a long time horizon. The maturity mismatch here is usually less dynamic compared to banks, as insurance companies have more predictable liability structures based on actuarial models.

Similarly, pension funds[10] use ALM to manage the long-term goal of meeting retirement obligations. The emphasis is on investment strategies that ensure a stable and sustainable return over the long term. In these contexts, ALM is less about managing liquidity and more about addressing longevity risk and ensuring sufficient funding for future liabilities.

Corporations outside the financial sector use ALM primarily to optimise their balance sheets and manage cash flows. For instance, companies might use ALM to ensure they can service debt, fund expansion projects, or maintain sufficient liquidity during economic fluctuations. The tools and techniques are often simpler than those used in banking, focusing on budgeting, cash flow analysis, and capital structure optimisation.

1.2.2 ALM in banks

In banks, ALM is the process by which they measure, monitor, and manage the impact on assets and liabilities resulting from changes in interest rates, exchange rates, and other factors that affect the liquidity of the banks themselves. This means that three of the main risks to a financial institution and their potential impact on the bank's balance sheet are managed through ALM. In particular, it enables the financial institution to obtain adequate remuneration, maintain the level of surplus of assets over liabilities, and take into account not only the interest rate but also the earning capacity and the desired level of debt. Generally, it deals with the banking book, which generates both interest rate and liquidity risks. The Banking Book encompasses all transactions

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[8] See Berger and Mulvey (1998) and Consigli (2007) for examples of ALM models for individual households.
[9] See Carino et al. (1994) for examples of ALM models for insurance companies.
[10] See Mulvey (1996) and Consigli and Dempster (1998) for examples of ALM models for pension funds.

recorded on an "accrual" basis, including retail banking activities. It covers loans to individuals and corporations, deposits, investments, and debt categorised as either Available for Sale (AFS) or Held to Maturity (HTM).

When discussing ALM in banks, it's important first to understand the foundational principles that underpin its effectiveness. The key concepts of ALM in banks are (Choudhry, 2007):

- *Liquidity*: In the context of ALM, liquidity does not refer to how easily an asset can be traded in the secondary market but rather to how readily it can be converted into cash. Regulatory authorities require a banking book to maintain a minimum share of its assets in highly liquid instruments. Liquidity is crucial for any institution accepting deposits to ensure it can meet customer demands for immediate-access funds. Within a banking book, the most liquid assets include overnight funds, while medium-term bonds are among the least liquid. Short-term assets like Treasury Bills (T-bills) and Certificates of Deposit (CDs) are also categorised as highly liquid;
- *Interest rate term structure*: The yield curve's shape at any given moment, along with projections about its short- and medium-term evolution, heavily influences a bank's ALM strategy. Market risk plays a crucial role, particularly in terms of interest rate sensitivity. This includes both the present-value sensitivity of specific financial instruments to fluctuations in interest rates and the impact of rate changes on floating-rate assets and liabilities;
- *Maturity profile*: Assets and liabilities may have either matched or unmatched maturities, with unmatched maturities being more typical; however, matched ones are also used, depending on the strategies in place. Matching maturities secures a fixed return through the spread between the funding cost and asset yield. The maturity structure, the lack of a secured spread, and the shape of the yield curve together influence the overall interest rate risk associated with the banking book;
- *Default risk*: The risk which arises from the possibility that borrowers may fail to make scheduled payments of interest or principal owed to the bank.

ALM can be either reactive or proactive, a distinction that is particularly useful for banks operating in environments with more or less deterministic characteristics. Reactive ALM aims to respond to changes in the asset and liability portfolio, which are driven by customer-related banking activities. It adjusts the bank’s overall position by making financial market transactions that offer a more favourable risk-return profile than unmanaged positions. On the other hand, proactive ALM actively influences the creation of customer-related assets and liabilities, and engages in financial market operations to build complementary or offsetting positions, thereby achieving the desired overall position. An example of a proactive tool is gap analysis, which is used to assess mismatches between the maturities and interest rate sensitivities of assets and liabilities. This analysis enables banks to identify vulnerabilities and implement targeted strategies to address them. Additionally, stress testing and scenario analysis simulate extreme market conditions to evaluate their impact on the balance sheet. Both types of ALM come with pros and cons. Reactive ALM imposes few restrictions on internal communication and information management, allowing the bank to operate with minimal administrative costs. However, its main drawback is the need for post-event adjustments, which can result in a less efficient balance sheet and reduced operational flexibility due to the delayed response inherent in reactive systems. Proactive ALM, in contrast, proves particularly valuable in competitive environments where the bank contends with smaller, more specialised institutions that work closely with high-value clients with more complex needs.

The primary function of ALM is to identify, limit, and manage both on- and off-balance sheet risks while adhering to internal policies and regulatory constraints. Risk management in this context involves not only minimising risks but also leveraging them to generate revenue and meet budgetary targets. It is important to note that completely eliminating all risks associated with a bank's customer business and balance sheet is nearly impossible. ALM focuses on managing several key risk categories (Lubinska, 2020):

- *Interest Rate Risk in the Banking Book (IRRBB)*: This includes the risk of reduced interest income due to unfavourable movements in interest rates and the potential decline in the market value of interest rate positions. ALM frameworks, reporting systems, and limits must account for both these aspects;
- *Liquidity Risk*: The risk of running out of funds and becoming illiquid, which is mitigated by maintaining liquidity buffers that can be quickly converted into cash in stressful situations;
- *Liquidity Cost Risk*: The risk of diminished interest income or lower market value due to increased liquidity costs or funding spreads;
- *Foreign Exchange (FX) Risk*: Potential losses from adverse movements in foreign currency exchange rates;
- *Credit Spread Risk in the Banking Book (CSRBB)*: Losses from changes in credit spreads affecting the market value of bonds and derivatives portfolios;

- *Operational Risk*: The risk of loss resulting from inadequate or failed internal processes, people, systems, or external events, including fraud, legal risks, and natural disasters;
- *Trading Risk*: The risk of financial loss arising from adverse price movements in assets held for trading purposes, including market risk, liquidity risk, and counterparty risk associated with trading activities;
- *Funding risk:* The risk that a financial institution may not be able to meet its obligations or secure funding when needed or may only do so at unfavourable terms due to market or liquidity constraints.

Management of IRRBB, CSRBB, and FX risks in ALM is typically governed within the Internal Capital Adequacy Assessment Process (ICAAP),[11] as determined by the institution's Management and Supervisory Board through the risk strategy. Meanwhile, Liquidity Risk and Funding Cost Risk are addressed under the Internal Liquidity Adequacy Assessment Process (ILAAP).[12] These risks are generally managed separately from the bank's customer business, reflecting the specialised and independent approach required for effective ALM.

As seen above, not all balance sheet risks fall within the scope of ALM or the Asset Liability Committee (ALCO). Credit risk, which typically accounts for the largest share of a bank's capital, is often managed by a separate body, such as the Total Bank Management Committee or, in some banks, a Risk Committee. This risk is closely tied to the bank's commercial strategy and the products it chooses to offer. It remains a common practice to keep credit risk management separate from financial risk management, though the specific committee responsible for overseeing credit risk may vary between banks.

One of the core objectives of ALM is risk management, particularly concerning interest rate risk and liquidity risk. Banks operate in a dynamic environment where interest rates can fluctuate significantly. Interest rate risk can manifest itself in two forms. The first form is the most obvious one, which occurs when changes in market interest rates adversely affect an institution's earnings or the economic value of its assets and liabilities. For instance, if a bank has issued long-term fixed-rate loans while relying on short-term deposits to fund them, a rise in interest rates can increase the cost of its liabilities while the income from its assets remains

[11] The Internal Capital Adequacy Assessment Process (ICAAP) is a structured approach used by a bank to identify, assess, aggregate, and monitor significant risks. This process culminates in the development of a risk profile that serves as the foundation for capital allocation.

[12] The Internal Liquidity Adequacy Assessment Process (ILAAP) refers to the procedure a firm employs to identify, measure, manage, and monitor its liquidity in compliance with established standards.

unchanged. Such a change affects the cash flows of assets and liabilities, or rather their present value, because financial instruments are valued based on market interest rates. The second form is associated with optionality, which arises with products such as early redeemable loans (Choudhry, 2007). This risk management approach involves grouping incoming and outgoing cash flows according to their maturities; once this is done, assets of a given maturity are matched with liabilities of the same maturity. Any remaining mismatch between assets and liabilities can be addressed using models that focus on maturity or duration, as well as through hedging and acquiring securities. This mismatch can appear in two forms: a mismatch in the maturities of assets and liabilities along the term structure or a mismatch in the differing interest rates applied to individual asset or liability contracts. This phenomenon is referred to as the ALM gap. The first type is identified as the liquidity gap, while the second is known as the interest-rate gap.

The other main type of risk managed by ALM is liquidity risk, which refers to both the liquidity of markets and the ease with which assets can be converted into cash. Liquidity risk arises when a financial institution is unable to meet its short-term obligations due to a lack of available cash or liquid assets. ALM also plays a critical role in ensuring financial stability. By aligning the cash flows, maturity structures, and interest rate sensitivities of assets and liabilities, institutions can minimise the likelihood of financial distress, especially during economic downturns or periods of market volatility. This stability is crucial not only for the institution's solvency but also for maintaining the confidence of depositors, investors, and other stakeholders. For example, an institution might strategically allocate resources to higher-yielding assets while carefully managing the associated risks. This balance requires the use of advanced financial models, scenario analyses, and forecasting tools to ensure accurate predictions.

Regulatory compliance plays a central role in ALM for banks. Frameworks such as Basel III impose strict requirements related to capital adequacy, liquidity coverage, and leverage ratios, which banks must adhere to. These regulations are designed to ensure financial stability and protect depositors, adding a layer of complexity to ALM in the banking sector. By monitoring the bank's risk-weighted assets and liabilities, ALM ensures that capital levels are sufficient to absorb potential losses and meet both regulatory standards and operational needs. Banks also face unique challenges, such as managing credit risk, market risk, and operational risk, which require sophisticated models and stress testing to address. Another defining feature of ALM in banks is its reliance on depositors and borrowers. Banks must align their ALM strategies with customer behaviour, which can be unpredictable, especially during economic downturns. For example, unexpected withdrawals or defaults can significantly impact a bank’s balance sheet, requiring dynamic and responsive ALM practices.

Despite its benefits, ALM also has certain drawbacks. Implementing an effective ALM framework requires significant investment in technology, skilled personnel, and analytical tools. These costs can be a burden, particularly for smaller institutions with limited resources. It’s also necessary to keep in mind that each institution has unique objectives, risk tolerances, and constraints. This makes it challenging to create an optimisation algorithm that accurately reflects these specific characteristics when assessing portfolio allocation decisions. Additionally, the complexity of ALM models can be challenging to manage and may require continuous updates to remain effective in a dynamic financial environment.

Another limitation of ALM is its reliance on assumptions and forecasts. Financial markets are inherently unpredictable, and even sophisticated models may fail to anticipate extreme market conditions or black swan events accurately. This can lead to suboptimal decisions or expose the institution to unforeseen risks.

Moreover, ALM's focus on long-term financial stability may sometimes conflict with short-term profitability goals. For instance, measures to reduce interest rate risk or maintain liquidity buffers might limit the institution's ability to take advantage of certain high-yield investment opportunities. Striking a balance between these competing objectives can be challenging for management.

In some cases, ALM practices may inadvertently lead to excessive risk aversion. Overemphasis on mitigating risks could restrict innovation and limit the institution's ability to adapt to changing market demands. This cautious approach might hinder growth and competitiveness in a highly dynamic financial landscape.

Lastly, translating risk preferences and their changes over time into mathematical terms is a complex task. Likewise, integrating all components of an ALM model (such as assets, liabilities, objectives, and institutional constraints) into a coherent framework is a significant challenge (Romanyuk, 2010).

1.2.3 Observations

In Sakovich (2012), it is highlighted that ALM initially focused solely on managing interest rate risk. Over time, it evolved to address other types of risks, incorporating strategies to align assets and liabilities to mitigate existing gaps. Factors such as national accounting standards and internal bank policies regarding the classification of assets and liabilities significantly influence the effectiveness of ALM strategies.

On a broader level, ALM enables the formulation of business policies, efficient capital allocation, and the design of financial products with well-planned pricing strategies. A critical aspect is choosing a liability structure that matches the expected maturity or duration of existing assets, thereby shielding the bank's profits from potential interest rate fluctuations. Financial innovations, such as interest rate derivatives, adjustable-rate loans, and asset securitisation, have expanded the tools available for managing interest rate risk, reducing costs for financial institutions.

This raises a question: With the advent of new financial products, does the dependency between a bank's assets and liabilities still exist, or are they now effectively independent of each other? An American study[13] offers insight, showing that for large banks, the relationship between assets and liabilities has shifted towards greater independence over the years, thanks to instruments such as interest-rate swaps and adjustable-rate loans. However, this trend does not hold for smaller banks, where dependency remains significant.

Additionally, capital-to-asset ratios have become stringent constraints, prompting banks to adopt more efficient balance sheet management. This shift often involves prioritising asset management over liabilities. For instance, banks have replaced high-yield but riskier assets with lower-yield, safer alternatives, improving profitability and reducing exposure to asset devaluation. Enhanced liquidity and flexibility in asset management have been achieved through tools like floating rate notes, whose secondary market has grown significantly in depth.

Notably, an increasing number of banks now use a combination of techniques to manage margin adjustments. They often resort to temporary investments in interbank markets or short-term government securities to effectively handle balance sheet surpluses. This multi-faceted approach underscores the sophistication and adaptability of modern ALM practices.

1.3 Exploring the ALM Department in Banks

The ALM desk or unit is a dedicated division within a financial institution responsible for performing a variety of functions. Its specific scope of responsibilities depends on the nature of the institution's operations and activities. Generally, its position in the bank organisation is inside risk management, which supervises different types of risk. Sometimes, it could be inside

[13] Consult De Young and Yom (2008) for more information.

the Treasury Department or the Budget Department. The first monitors short-term liquidity risk and reduces the bid-ask spread on interbank loans and the cost of deposits. The treasury has monopolistic access to financial markets, aiming to optimise volume and cost arbitrage. It is also responsible for managing the institution's overall liquidity position. The second controls the costs and risks of the bank (Adam, 2007).

1.3.1 Traditional ALM unit

The function of ALM within an organisation is shaped by the strategic priorities established by the bank's executive management, whether the focus is on risk management or investment. When an ALM unit operates with a profit target of zero, it functions as a cost centre, primarily tasked with minimising operational expenses. This approach aligns with a strategy centred on commercial banking as the firm's primary activity, where ALM policy is dedicated solely to mitigating interest rates and liquidity risks through hedging.

The next stage in the evolution of an ALM unit involves taking responsibility for minimising the cost of funding. In this role, the unit may still be exposed to interest rate risk, depending on its outlook for future interest rate movements. As previously mentioned, the bank's core operations often result in either a surplus or a deficit of funds. Fully hedging this surplus or deficit to eliminate interest rate exposure can have an associated opportunity cost, as it removes the potential for gains from favourable market rate movements. However, without a complete hedge, the institution remains exposed to interest rate risk. The ALM desk is tasked with monitoring and managing this risk while being credited for any cost savings achieved in funding expenses due to its management of the exposure. These savings are typically calculated as the difference between the funding costs under a full hedging strategy and the actual costs incurred under the ALM desk's chosen approach. To manage this exposure effectively, interest rate risk limits are established, and the ALM desk ensures that the bank operates within these boundaries.

The final stage of ALM's development transforms it into a profit centre, with the responsibility to optimise funding policies while adhering to predefined risk limits. These limits can be based on gap limits, Value at Risk (VaR),[14] or other metrics, such as earnings volatility. In this advanced role, the ALM desk assumes responsibility for managing all financial risks, combining risk management with strategic profit optimisation.

[14] Value at risk (VaR) is a measure of the risk of loss of investment/capital. It quantifies the maximum expected loss (with a specified probability) over a set time frame, such as a day, under normal market conditions. For a given portfolio, time horizon, and probability *p*, the *p* VaR can be defined informally as the maximum possible loss during that time after excluding all worse outcomes whose combined probability is at most *p*. This calculation is based on mark-to-market valuation and assumes no portfolio trading during the specified time horizon.

The evolution of the ALM function has led it to adopt a more dynamic and proactive role. At the same time, the earlier stages of ALM development remain part of the "traditional" approach. However, practitioners have a growing perspective that ALM should extend beyond its conventional risk management responsibilities. It is increasingly seen as a tool for enhancing the bank's net worth through strategic positioning of its portfolio and, consequently, its balance sheet. In addition to its traditional duties of managing liquidity and interest rate risks, ALM is now being tasked with overseeing the bank's regulatory capital and actively optimising the balance sheet to maximise profitability. These advancements have resulted in financial institutions implementing far more sophisticated ALM operations than those typically associated with the traditional banking book. This marks a significant shift in ALM's role, transforming it into a key driver of value creation within the organisation.

Traditionally, ALM teams in banks were integrated into either the Finance Department or the Risk Management Department, and they usually consisted of three sub-teams: a simulation team for computing risk indicators, a financial modelling team, and a product analysis team. Moreover, a bank's ALM function primarily focuses on managing risks related to the banking book. While this core responsibility remains relevant, additional functions have been integrated into the ALM unit since then. Many financial institutions continue to follow this traditional approach, as the nature of their operations may not support more advanced ALM practices. The primary responsibilities of a traditional ALM desk can be summarised as follows:

- *Interest rate management*: The ALM desk is responsible for monitoring interest rate exposure and aligning the portfolio within the prescribed limits while considering its market outlook. Smaller banks, or subsidiaries of foreign-based banks, often operate without taking on interest rate risk, meaning their portfolios do not include short gaps. In other cases, the ALM desk handles hedging interest rate risk or strategically positioning the portfolio based on its market perspective;

- *Liquidity and funding management*: The ALM unit manages the portfolio's composition and is influenced by its outlook on market interest rates and its assessment of the relative value of different assets. For instance, the unit might choose to increase its holdings of short-term government bonds beyond the usual level, reducing its allocation to high-quality certificates of deposit (CDs), or make the opposite adjustment based on its strategic evaluation;

- *Reporting on hedging of risks*: The ALM desk plays a key role in providing senior management with regular updates on the bank's risk exposure. This reporting may be delivered through weekly hardcopy reports or other media to ensure transparency and informed decision-making;

- *Setting up risk limits*: The ALM unit is responsible for setting, implementing, and enforcing risk limits. However, an independent "middle office" risk function often oversees compliance with these limits to maintain objectivity and adherence;
- *Capital requirements reporting*: This involves preparing reports on capital utilisation and position limits as a percentage of the allowed capital. These reports are also submitted to regulatory authorities to ensure compliance with capital adequacy requirements.

1.3.2 Developments in the ALM unit

At the top level, the ALM department is overseen by the Asset Liability Committee (ALCO). The ALM unit is typically divided into specialised teams, each focusing on specific functions:

- *Liquidity management team*: It ensures that the bank has sufficient funds to meet short-term obligations by monitoring cash flows, managing liquidity buffers, and ensuring compliance with regulatory liquidity requirements like the Liquidity Coverage Ratio (LCR);
- *Interest rate risk management team*: It assesses and mitigates risks associated with fluctuations in interest rates. They use tools such as gap analysis and scenario modelling to align assets and liabilities and reduce exposure to interest rate changes;
- *Funding and capital management team*: It focuses on optimising the bank's funding strategies and maintaining an appropriate capital structure. This involves ensuring an optimal mix of funding sources and compliance with capital adequacy ratios required by regulatory frameworks like Basel III;
- *Modelling and analytics team*: It develops financial models that measure and forecast risks, contributing to stress testing and scenario analysis to prepare for adverse financial conditions;
- *Reporting and compliance team*: This team ensures that the department adheres to internal policies and regulatory guidelines and prepares detailed reports for internal stakeholders and regulatory authorities.

The ALM department works closely with other key units, such as the treasury, risk management, finance, and business units, to ensure cohesive strategies. For instance, it collaborates with the treasury to manage funding and investments and with the risk management team to address regulatory compliance and monitor risk exposures.

An increasing number of financial institutions are strengthening their risk management practices by expanding the responsibilities of the ALM function. These enhancements include elevating the roles of the Treasury head and the ALCO, adopting additional risk exposure measures like option-adjusted spread and Value at Risk (VaR), and integrating traditional interest rate risk management with credit risk and operational risk. The growing use of credit derivatives has enabled this more holistic approach to risk management. The expanded responsibilities of the ALM desk may encompass:

- Utilising the VaR tool to evaluate risk exposure;
- Combining market risk and credit risk management;
- Applying new risk-adjusted return measures;
- Optimising portfolio performance;
- Actively managing the balance sheet, including guiding asset securitisation (removing assets from the balance sheet), hedging credit exposure through credit derivatives, and enhancing returns on the liquidity book by engaging in activities such as stock lending and repos.

1.3.3 Asset Liability Committee (ALCO)

The Asset and Liability Management Committee (ALCO) is a key structure within a bank designed to manage its assets and liabilities effectively, balancing potential profits against associated risks. Depending on the bank's scale of operations, ALCOs can operate at local, regional, or global levels. The committee typically includes representatives from both the asset and liability sides of the business, particularly decision-makers whose actions influence the bank's balance sheet.

ALCO's scope covers all aspects of ALM, encompassing front-office money market activities, back-office operations, and middle-office reporting and risk management. The committee is composed of senior bank executives, such as the Chief Executive Officer (CEO) or Managing Director, Treasurer, Chief Financial Officer (CFO), Chief Operating Officer (COO), Chief Credit Officer, and heads of consumer, risk management, and corporate banking. Its exact composition may vary, but it often includes the heads of treasury, trading, and risk management, with representatives from the credit committee and loan syndication teams also participating (Choudhry, 2020).

It plays a key role in setting targets for net interest income, devising strategies to achieve those targets, and managing the bank's balance sheet within a robust risk management framework while adhering to regulatory requirements. ALCO ensures effective fund management to meet profitability objectives while maintaining control over interest rate and liquidity risks. Its specific responsibilities can vary depending on the size and strategic priorities of the bank. Additional tasks may include developing strategies to address cash flow needs based on scenario analysis, forecasting interest rate movements, and evaluating risks related to credit, liquidity, and interest rates.

A standard ALCO meeting will address the following key action items:

- *Management reporting*: This process involves reviewing various management reports, either approving them or identifying items that require action. Key considerations include lending margins, interest income, variances from the previous projections, customer activities, and future business opportunities. Current policies related to lending and portfolio management will also be assessed and either maintained or adjusted as needed;
- *Business planning*: Current asset and liability portfolios will be reviewed, and plans for future business strategy will be developed. This process involves evaluating the performance of existing operations, with a particular focus on return on capital. The existing asset portfolio will be analysed to balance risk and reward, and decisions will be made on whether to continue, adjust, or discontinue specific lines of business. Any proposed new initiatives will be discussed, and if approved in principle, they will proceed to the next phase. At this stage, new business proposals will be evaluated based on their anticipated returns, revenue potential, and associated risk exposure;
- *Hedging policy*: This policy considers the acceptance of risk exposure, adherence to existing risk limits, and the use of hedging instruments, including derivatives. Many bank ALM desks meet their hedging needs using straightforward instruments like interest rate swaps and exchange-traded short-term futures contracts. The use of more complex instruments, such as options or even simpler tools like Forward Rate Agreements (FRAs), is less prevalent than might be expected. The hedging policy takes into account factors such as revenue from the cash book, current market volatility, and the overall cost of hedging. In some cases, certain exposures may remain unhedged if the cost of hedging, including both direct expenses and the opportunity cost of reduced income from the cash book, is deemed too high. Hedging policies are developed in

alignment with the bank’s broader funding and liquidity strategies. The final policy must reflect the bank’s stance on key factors, including:

1. Expectations regarding the future direction and levels of interest rates;
2. Balancing the need to manage and control risk exposure to maximise revenue and income;
3. The institution's level of risk aversion and the extent of risk it is willing to accept.

It is also responsible for reviewing the bank’s overall funding strategy. During each meeting, minutes are recorded and circulated to attendees and relevant staff, ensuring transparency and follow-up on decisions made. Key responsibilities of ALCO members include reviewing:

- Minutes from the previous meeting;
- Reports on the ratio of interest rate-sensitive assets to liabilities, gap analysis, risk metrics, and the funding position;
- The bank’s outlook on future interest rate levels and how the balance sheet should be positioned to reflect this outlook, including anticipated short- and medium-term funding costs;
- Stress testing results, such as “what if?” scenarios, to evaluate the impact of market changes on the banking book and determine whether adjustments are needed in response to shifting market conditions or risk tolerance;
- Current interest rates on loans and deposits, ensuring alignment with the bank’s lending and funding strategies;
- The maturity profile of the liquidity portfolio, including instruments like T-bills, CDs, and short-term government bonds, as well as the current and projected liquidity position over the short and medium term.

1.3.3.1 Policies

While ALCO meets regularly, typically monthly, not every responsibility is discussed at each meeting. The chair sets the agenda in consultation with committee members, ensuring that discussions remain focused on current priorities. ALCO’s policies are designed to be dynamic and flexible, allowing for adjustments as operating conditions evolve. Committee members must agree upon any policy changes, and exceptions to these policies typically require approval from both the CEO and ALCO.

As previously mentioned, one of ALCO's primary responsibilities is ensuring that the bank maintains an adequate level of liquidity at all times. For instance, a medium-sized banking institution typically targets a loans-to-deposits ratio of approximately 75-85% and a loans-to-core-deposits ratio of around 85-95%. These ratios are reported to ALCO and reviewed on a monthly basis. If the reported figures deviate significantly from these target ranges, such as by 5% or more, the committee will review the situation and request adjustments to align with ALCO's liquidity policy.

Additionally, ALCO establishes an interest rate risk policy to define acceptable levels of interest rate exposure. This policy provides guidance for managing the impact of interest rate changes on the bank's earnings, with the goal of minimising earnings volatility caused by rate fluctuations. At each meeting, ALCO members review risk and position reports to ensure compliance with the risk policy. Typically, the six-month and twelve-month $\frac{A_{ir}}{L_{ir}}$ cumulative ratio[15] is expected to remain within the 90-110% range. Any significant deviations outside this range are likely to prompt corrective measures. The committee also evaluates the results of scenario analyses on the bank's balance sheet. If these tests reveal a potential earnings impact exceeding a threshold, such as 10%, ALCO may instruct changes to the shape or maturity profile of the book. The committee monitors the bank's current risk exposure and duration gap as part of the overall risk management process. Using rate sensitivity analysis and simulation modelling, ALCO assesses whether the existing risk levels are acceptable and initiates adjustments if necessary.

Despite the widespread use of VaR as the primary tool for measuring market risk, funding portfolios, such as repo books, still rely heavily on gap reports to assess interest rate risk exposure. These reports allow ALCO to evaluate risk sensitivity across the maturity structure. Cumulative gap positions, along with the ratio of asset revaluations to liability revaluations, are calculated and compared to earnings from the current asset and liability structure. Key timeframes for calculating interest rate risk exposure typically include 90-day, six-month, and one-year gap positions. The ratio of the gap to earning assets is generally maintained within a range of ±15% to ±20%.

Another critical method used by ALCO to monitor interest rate changes is simulation modelling. This approach assesses the potential impact of changes in interest rates or shifts in the shape of the banking book on the institution's earnings. Simulation modelling provides

[15] This formula is used to analyze the Interest Rate Risk Cumulative Ratio, which measures the relationship between interest rate-sensitive assets (A_{ir}) and interest rate-sensitive liabilities (L_{ir}). The ratio provides insight into the institution's exposure to changes in interest rates.

senior management with valuable insights into the risks associated with specific strategies. The process involves three main steps:

1. *Constructing a Base Case*: Develop a starting balance sheet and income statement based on the current shape of the banking book and projections for expected growth trends.
2. *Scenario Analysis*: Evaluate the impact of various scenarios, such as:
    - No change in interest rates;
    - Upward parallel shifts of 100 and 250 basis points in the yield curve;
    - Downward parallel shifts of 100 and 250 basis points;
    - A steepening or flattening of the yield curve by 25 basis points between three-month and three-year maturities;
    - A combination of parallel and pivotal shifts at selected points;
    - Changes in the volatility of three-month T-bill yields;
    - A 20 basis point change in swap spreads.
3. *Comparing Results*: Compare earnings differences under these scenarios to the projected earnings in the current interest rate environment.

ALCO typically establishes guidelines for interpreting simulation results. For instance, a rule might state that a 100 basis point change in interest rates should not affect Net Interest Income (NII) by more than 10%. If a simulation reveals a more significant impact, ALCO will reassess whether the current risk strategy remains appropriate or if adjustments are required to mitigate exposure.

Table 1 shows the different approaches of ALCO based on the type of bank.

Table 1. ALCO approach based on the type of bank

	CONSUMER BANKING	COMMERCIAL BANKING	INTERNATIONAL COMMERCIAL BANKING	INVESTMENT BANKS
ALM PROBLEM	IRRM; long-term fixed-rate Assets supported by savings accounts; deposit run-off risk;	Financial structure; IRRM; basis risk.	Complexity arising from the international scope and currency diversity of operations; the need to coordinate national	Financial structure; assets are considered as inventory; reliance on sold funds.

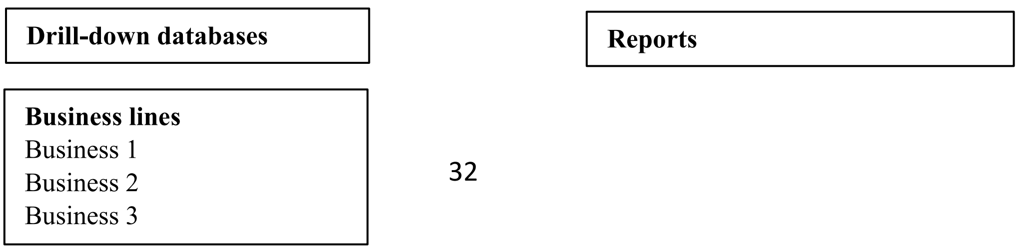
	mismatch risk.		ALM units; the inability to theoretically define an optimal integrated financial structure at the group level.	
STRUCTURE	Small committees with regular meetings that include the CEO.	Small committees including the CEO; delegation of funding and investment management to the Treasury or fund manager.	Coordination of local ALM units; frequent meetings at various levels; active involvement of the CEO.	ALM integrated across multiple businesses and involving the entire top management; ongoing decision-making processes.
POLICY	Reactive adjustments.	Reactive ALM; Preventive position-taking through investment portfolios.	Proactive ALM at the national level; Reactive ALM at the group level.	Proactive ALM; "Trading" behavior.
TOOLS	Interest rate swaps; futures; bond futures; asset sales; bond options; options on bond futures.	Interest rate swaps; secured or unsecured access to loans, debt sales, purchase of investment securities.	Transfer pricing system; financial techniques and products (securitisation of debts, quality swaps).	ALM integrated into the broader risk management framework.

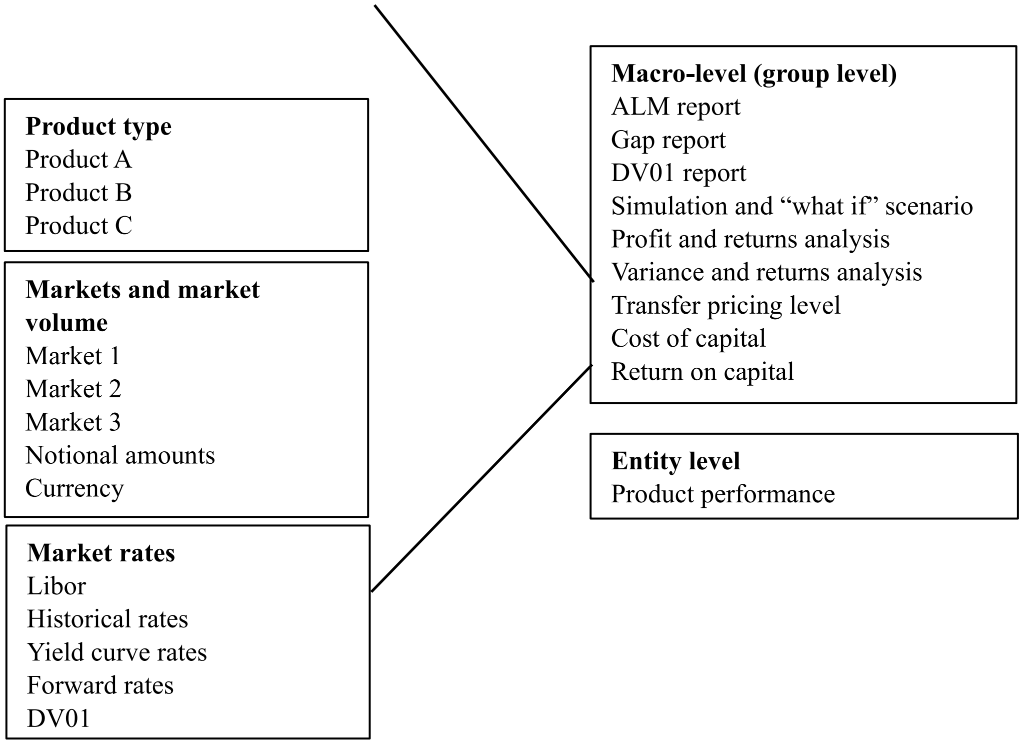
Source: author's elaboration

1.3.3.2 Reports

In traditional commercial banks, the ALM desk regularly provides the ALCO with reports on the institution's risk exposure. The ALCO reviews and discusses these reports during scheduled meetings. These reports focus on key areas such as changes in interest income, the specific areas affected by income fluctuations, and updated short-term income projections. The ALM report connects these elements across the entire organisation and within individual business units. It examines both macro-level drivers of interest income variations, such as shifts in the yield curve, and desk-specific factors, such as new business developments and customer behaviour.

Figure 2. ALCO reporting input and output



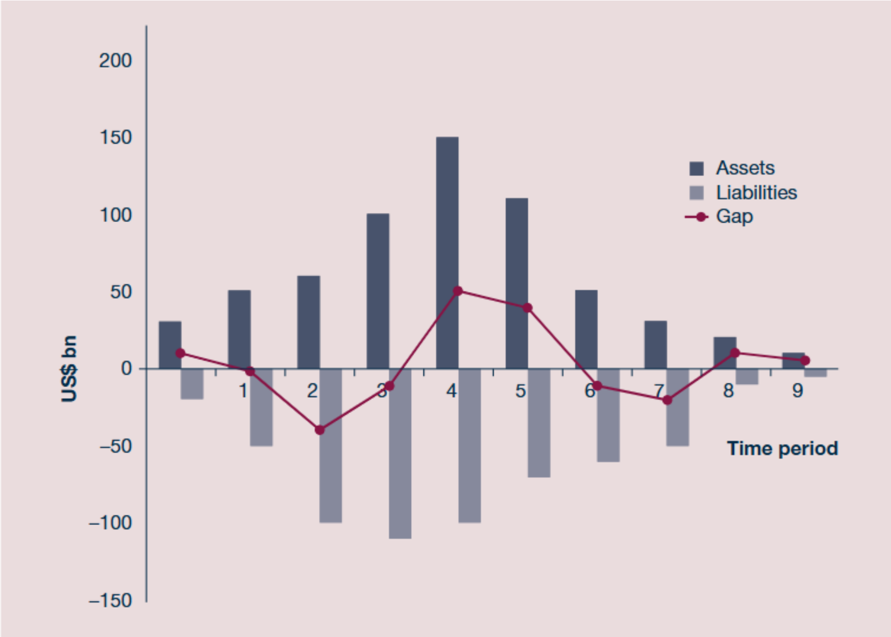


Source: author's elaboration

Above, Figure 2 provides a visual representation of the overall reporting framework. Indeed, the ALCO relies on management reports prepared by the ALM or Treasury department, with the Treasury middle office often handling the compilation of these reports. The primary report is the overall ALM report, which details the composition of the bank's ALM book. Additional reports focus on specific business lines, analysing the return on capital generated by each. These reports must break down aggregate revenue and risk levels by business line and further by product type across different lines of business. Other key reports include those assessing gaps and gap risks, as well as VaR or DV01 (interest rate risk) reports and credit risk exposure analyses. The reporting system must provide a clear breakdown of revenues, returns, and risks by country, sector, business line, and product type. Furthermore, scenario planning is incorporated, projecting expected performance under various macroeconomic and microeconomic conditions.

Figure 3 illustrates a typical dynamic gap positioned in an ideal ALM "Smile," reflecting projected interest rate gaps based on the current profile. This report highlights the bank's future funding requirements, enabling ALCO to provide guidance aligned with its outlook on future interest rate movements. Additionally, it identifies areas where revenue may be sensitive to falling interest rates by showing the volume of assets in those positions. If ALCO anticipates an adverse impact on interest income, it can issue instructions for hedging. The x-axis represents time buckets ranging from overnight to two years or beyond, with banks customising these buckets to meet their specific requirements.[16]

Figure 3. ALM and expected liquidity and interest rate gap, snapshot profile

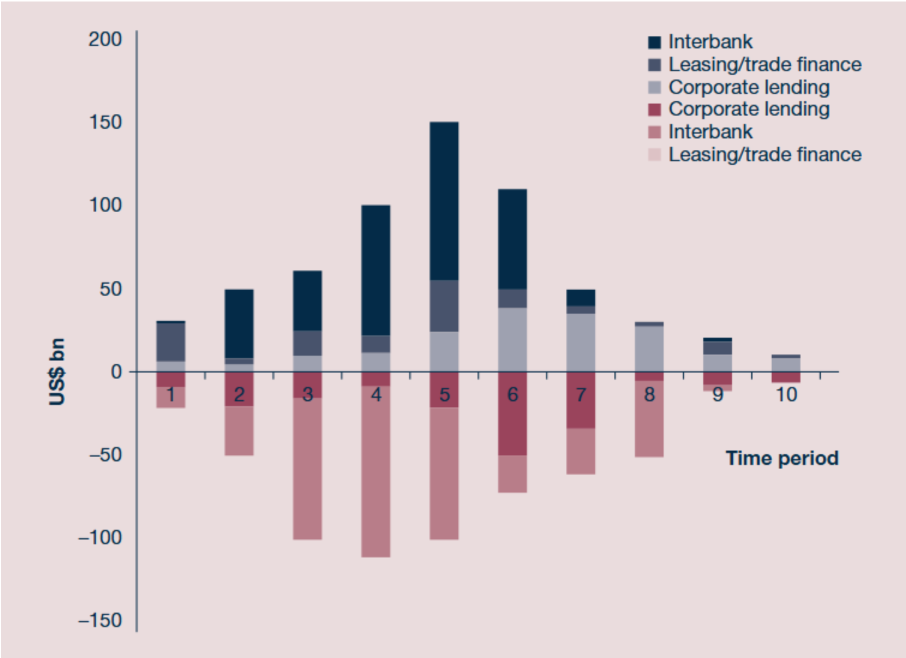


Source: Hong Kong Institute of Bankers (2018)

Figure 4 presents the same report but with a detailed breakdown by product or market, using a hypothetical sample of different business lines. This format allows ALCO to identify which specific assets and liabilities are contributing to the gaps. This insight is critical for determining whether individual products or markets align with the bank's overall policy. If necessary, adjustments to the policy can be made based on the findings in the report. Additionally, ALCO can assess the proportion of total assets attributed to each business line and identify which line has the largest forward funding requirement.

[16] For instance, a bank might treat the "overnight" time bucket as a standalone category or include it within a broader "overnight to one-week" period. Similarly, some banks may separate each month from one to twelve into individual buckets, while others may group certain months into combined time frames. There is no single correct approach to this.

Figure 4. ALM breakdown by product (or market) segment

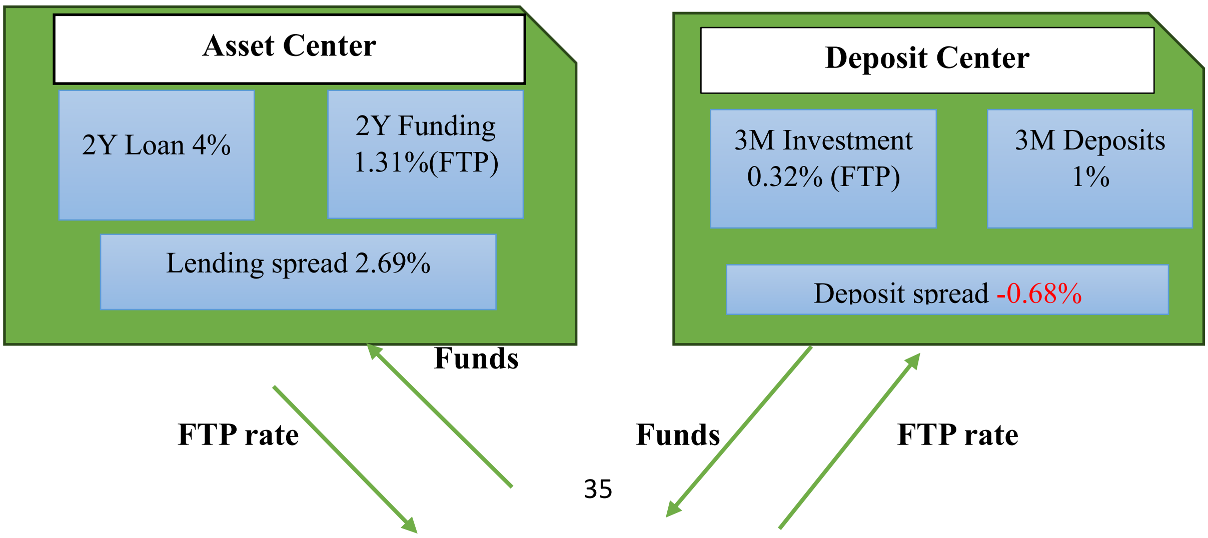


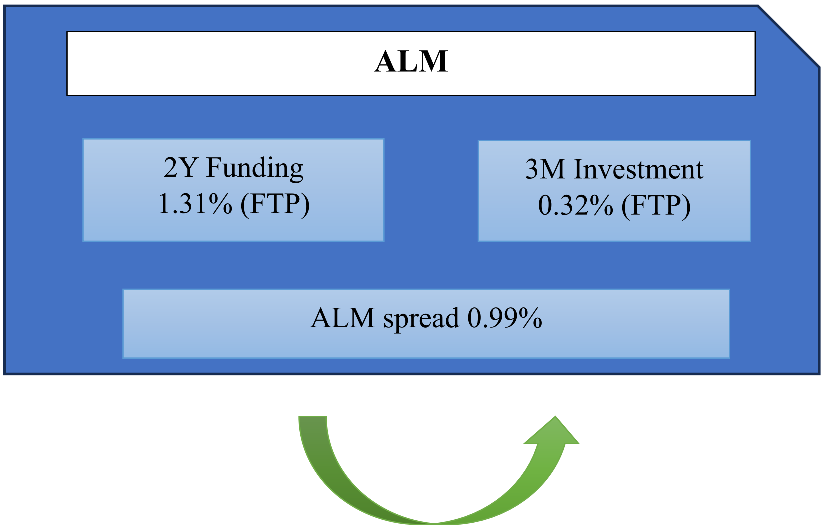
Source: Hong Kong Institute of Bankers (2018)

1.3.4 Fund Transfer Pricing Process

The role of the ALM unit is often described as being like a "bank within a bank." This is because ALM applies the Funds Transfer Pricing (FTP) rate to both the asset centre and the liability centre. The asset centre, which manages products for clients borrowing from the bank (such as credit cards, mortgages, or commercial loans), charges the FTP rate. Conversely, the liability centre, responsible for products used by clients investing or depositing funds in the bank, is credited with the FTP rate. This process transfers financial risks, such as interest rate risk and funding risk, from the business units to the ALM function, which assumes responsibility for managing these risks. This transfer of risk is what gives ALM its "bank within the bank" identity, and this concept forms the foundation of the FTP process, as illustrated in Figure 5 (using plausible values).

Figure 5. Maturity Matched Funds Transfer Pricing and ALM role





MATURITY TRANSFORMATION IRRBB EXPOSURE

Source: Lubinska (2020)

The Funds Transfer Pricing (FTP) process is a financial management framework used by banks and other financial institutions to allocate the costs and benefits of funding across different business units. It plays a crucial role in ensuring fair resource allocation, promoting accountability, and aligning business unit activities with the institution's overall strategic and financial objectives. Moreover, FTP encompasses a set of policies and methodologies designed to divide a transaction's outcome into the customer contribution and the risk contribution. It also shifts ALM risks, such as interest rate and liquidity risks, from individual business units to the ALM function for centralised management. Furthermore, FTP serves as a vital tool for managing the balance sheet effectively and aligning with the bank's strategic objectives. A well-structured FTP framework provides the necessary guidance and control to achieve the bank's targeted balance sheet goals.

As noted previously, FTP assigns an internal transfer price to both the funding (liabilities) and the deployment (assets) of resources within the bank, representing the cost of acquiring funds for liabilities and utilising those funds for assets. For example, if a bank's ALM function identifies increased funding costs due to market volatility, the FTP process adjusts the internal transfer price to reflect this change. Thus, business units responsible for liabilities, such as deposits, are credited with a funding rate that reflects the value of the funds they generate. Conversely, business units responsible for assets, such as loans or investments, are charged an internal rate that reflects the cost of the funds they use. This system creates a transparent and standardised method for measuring the profitability of individual units. Without a transfer pricing system, net fund users would benefit from interest income without bearing the full cost of the associated interest expenses, while net fund providers would incur interest expenses without receiving full credit for the related interest income.

FTP supports risk management by integrating insights from the Asset Liability Management (ALM) function. ALM identifies risks such as duration mismatches or interest rate exposures, and FTP ensures these risks are accounted for in the pricing of loans, deposits, and other financial products. This alignment between ALM and FTP helps the bank maintain profitability while staying within its risk appetite. The process also enhances decision-making by providing business units with clear cost and revenue benchmarks. By understanding the costs associated with funding and the returns on investments, units can make informed decisions about pricing, product offerings, and resource allocation. Additionally, FTP facilitates regulatory compliance by ensuring that funding costs and risk-related expenses are transparently reflected in the bank's financial reporting.

Banks primarily have three basic transfer pricing methods available, each with potential variations. Other industries, such as manufacturing, employ their own methods and adaptations due to distinct revenue and cost structures. These methods are (Kawano, 2005):

- *Single Pool*: The single pool method is based on the principle that there is a single "pool" responsible for both buying and selling funds. As a result, fund providers and users are credited or charged using a single unified rate;
- *Multiple Pool*: The multiple pool method is based on the assumption of at least two separate pools: one for fund users and another for fund providers. Consequently, two or more rates are applied. Additional pools can also be created to account for the repricing characteristics of different funding sources and uses. It is advised in scenarios with numerous fund providers and users, as well as a highly variable funding portfolio. This approach enables a more objective assessment of performance;
- *Matched Maturity Marginal Funds Transfer Pricing (MMMFTP)*: This approach is based on the current market cost of marginal funds, ensuring that the repricing characteristics align with those of the assets being financed. In this approach, different rates for deposits and loans are used, and a yield curve approach based on maturity is employed. There is no net funds position since each profit centre functions as both a provider and user of funds. The goal is to ensure a stable net interest margin for each source or use of funds. A central money or funds desk acts as the intermediary, buying and selling funds while managing interest rate risk.

The first two methods described can be applied either on a net or gross basis. On a net basis, each profit centre is charged or credited based on its overall position as a net user or net provider of funds. In contrast, under the gross basis, assets and liabilities are assessed separately. Fund users purchase from the "gross" asset pool, while fund providers sell to the "gross" liability pool. Despite the differing approaches, the total net funds charge or credit remains the same under both methods. The gross method, however, offers more detailed information and is slightly more complex as a result.

For both the single-pool and multiple-pool methods, the transfer rate can be determined using either an average rate or a marginal rate. The average rate is calculated based on the income or expense associated with the funds pool. For example, it could be determined by dividing the total interest expense on deposits by the average total deposits, with adjustments made for float and reserve requirements. Otherwise, marginal rates are derived from open market rates, such as Treasury bill (T-bill) rates. These rates can be determined at a specific point in time or calculated as an average over a given period.

1.3.5 Securitisation

ALM units in banks often take on a more active role in managing the balance sheet, with securitisation being a prime example. Securitisation allows banks to unlock additional value from assets held on the balance sheet and, in many cases, to remove those assets entirely, thereby freeing up lending capacity. This process involves selling balance sheet assets to third-party investors. At its core, securitisation is relatively straightforward: the sold assets generate future cash flows that provide returns to the investors who purchase them. To mitigate risk for these investors, uncertainties related to asset cash flows are managed or restructured, utilising a variety of methods to enhance predictability and reduce exposure (Loutskina, 2011).

The fundamental concept of securitisation involves selling assets to investors, typically through a special purpose vehicle (SPV) or another intermediary structure. Investors receive a fixed or floating rate return on the assets they purchase, with cash flows from the original assets funding this return. While it is uncommon for investors to buy the assets directly, it does happen on rare occasions. More often, a class of securities is created to represent the assets, which the investors then purchase. Commonly securitised assets include mortgages, car loans, and credit card loans. However, virtually any asset with cash flows that can be reliably predicted or modelled is a candidate for securitisation. The intermediary vehicle is designed to issue securities with a risk-return profile tailored to attract the targeted group of investors (Jiangli, 2007).

Securitisation results in the creation of asset-backed bonds, which are debt instruments derived from a pool of loan assets that generate interest, typically on a floating rate basis. The asset-backed market is extensive and diverse, encompassing a variety of instruments. Modern techniques employed by investment banks allow the creation of bond structures from virtually any type of cash flow. In this process, loans held as assets on a bank's or financial institution's balance sheet are bundled together and used to back the issuance of bonds. The interest payments generated from the original loans are used to service the cash flows for the new bond issue. Traditionally, mortgage-backed bonds are categorised separately as mortgage-backed securities (MBS), while all other securitised issues are classified as asset-backed bonds (ABS).

To achieve diversification, various asset types are typically pooled together, generating a mix of interest payments, principal repayments, and prepayments. However, the exact nature of these cash flows is uncertain due to factors like payment and prepayment variability, loan defaults, and payment delays. Despite this uncertainty, pooling a large number of loans helps smooth out fluctuations in cash flow, making it stable enough to support the issuance of notes. The cash flows from the pooled assets are redirected to investors through a specialised structure, and a credit rating for the issuance is usually obtained from one or more private credit rating agencies. Most asset-backed securities (ABS) carry high credit ratings, such as double-A or triple-A, primarily due to credit enhancement measures, like credit insurance, that provide additional guarantees for the bonds. The securitisation process separates the quality of the original cash flows from the quality of the cash flows received by investors. Often, the original borrowers remain unaware of the securitisation and notice no changes in the handling of their loans. Additionally, the credit rating assigned to the securitised issue is independent of the selling bank's credit rating and is frequently different.

Securitising assets provides a dual advantage for the issuing bank. First, selling assets to investors reduces the bank's capital requirements since these assets are removed from the balance sheet. This results in cost savings on the capital that would otherwise be required to support those assets. Second, if the credit rating of the issued securities is higher than that of the originating bank, it can lead to reduced funding costs. For example, a double-A-rated bank issuing triple-A-rated securities benefits from borrowing at a lower rate than it would in the open market. This advantage has driven significant growth in specialised institutions, such as credit card banks in the United States, including Capital One, First USA, and MBNA Bank, which have leveraged triple-A-rated funding and lower capital charges. Without securitisation, such rapid growth would have been unlikely.

Although securitisation incurs costs, such as transaction fees, payment structure maintenance, and legal expenses, these are typically outweighed by the benefits. The primary advantage is the reduction in funding costs, which are influenced by several factors:

- *Lower cost of funds*: Enhanced credit ratings of the issued bonds result in cheaper borrowing costs. The extent of this benefit depends on current market spreads and the originating bank's credit rating, which fluctuates in response to market conditions.
- *Capital charge savings*: By reducing the size of the balance sheet, the bank lowers the minimum earnings needed to achieve adequate shareholder returns, thereby instantly improving return on capital.

The associated costs of securitisation include:

- *Issuing structure and payment mechanism setup*: Costs depend on the complexity and risk of the original assets. Higher-risk assets require more costly measures to secure cash flows for investors;
- *Legal, operational, and servicing costs*: These include the expenses involved in structuring and managing the securitisation.

Despite these costs, the reduction in funding costs typically far exceeds the expenses, making securitisation a highly attractive strategy. To evaluate the feasibility and impact of securitisation on return on capital, the originating bank conducts a detailed cost-benefit analysis before proceeding. This assessment is often undertaken by the ALM unit, which plays a central role in the process.

1.3.6 Bond Futures Contracts

A commonly used risk management tool on ALM desks is the government bond futures contract. This standardised contract, traded on exchanges, locks in today's price for the delivery of a specified quantity and quality of a bond at a future date within the contract's expiration month. Unlike short-term interest rate futures, which involve only cash settlement, bond futures require the actual physical delivery of a bond at settlement. A bond futures contract represents the underlying physical bond, which must be delivered upon the contract's expiration. This makes bond futures similar to commodity futures, where physical delivery of the underlying commodity is also required. A futures contract is essentially an agreement between two parties that defines the terms of an exchange set to occur at a future date. When traded on an exchange, these contracts are standardised, distinguishing them from over-the-counter (OTC) agreements, and are therefore referred to as exchange-traded futures. Most futures contracts worldwide operate on three-month maturity intervals, with standard expiration dates in March, June, September, and December. At these designated times, contracts expire, and a final settlement price is established. Liquidity in these contracts tends to decrease as the maturity date extends further into the future. Typically, the most liquid trading occurs in the "front month" contract (the contract closest to expiration, such as the June 2006 future in April 2006), with some liquidity also present in the next one or two contracts. Beyond this, trading activity and liquidity diminish significantly (Jarrow and Oldfield, 1981).

When a party enters into a futures contract, it can either hold the position until maturity or close it out before the maturity date. If the position is closed early, the party records either a profit or a loss. If held to maturity, the party with a long position will receive delivery of the underlying asset (e.g., a bond) at the settlement price, while the party with a short position will deliver the asset. This process is known as physical settlement, though it is sometimes confusingly referred to as cash settlement. There is no counterparty risk in trading exchange-traded futures because the clearing house acts as an intermediary. The clearing house facilitates settlement by serving as the buyer for all contracts sold and the seller for all contracts purchased. To participate, traders are required to deposit a margin (a cash amount determined by the clearing house and the exchange). Margins consist of two components (Eales and Choudhry 2003):

- *Maintenance Margin*: The minimum required cash balance to be held with the clearing house, as set by the exchange;
- *Variation Margin*: An additional deposit is required to cover trading losses if the size of open positions[17] increases.

Bond futures are widely used for hedging longer-term risk exposures, such as government bond portfolios, and for speculative purposes. In theory, when hedging a cash bond position with bond futures, if cash bond prices and futures prices move in tandem, losses in one position are offset by gains in the other. When prices move in perfect synchrony, the hedge is considered perfect. In practice, however, even the price of the "cheapest to deliver" (CTD) bond, which is typically assumed to underlie the bond's future, will not always move perfectly in line with the future price over time. The difference between the cash bond price and the futures price is known as the basis, and the risk of unexpected changes in the basis is referred to as basis risk.

[17] An open position is a position in a contract that is held overnight and not closed out.

Futures provide a liquid and straightforward method for hedging bond positions. The goal of hedging is to offset potential losses on a cash position with gains from the futures hedge. However, the hedge may not be exact for bonds other than the CTD bond due to basis risk, as the bond being hedged often differs from the CTD bond. The general principle is as follows:

- If a trader has a long position (or a net long position if managing both long and short positions) in the cash market, an equivalent number of futures contracts will be sold to establish the hedge;
- If the trader has a short position, futures contracts will be purchased instead.

Hedging needs arise for various reasons:

- A market-maker may hedge positions created through client transactions, particularly when the timing for unwinding these bond positions is uncertain. The hedge protects against declines in bond value while they are held;
- A fund manager, on the other hand, may need to secure a specific cash amount at a future date to meet fund obligations. The manager might sell futures contracts as a hedge to mitigate the risk of rising interest rates and protect the portfolio's value until the bond sale date.

In both cases, hedging strategies are designed to minimise the impact of adverse market movements on the value of positions or portfolios.

When establishing a hedge position, it is crucial to determine the correct number of futures contracts to trade. This calculation is based on the hedge ratio, which depends on the relative volatilities of the bond and the futures contract. The hedge ratio serves as the basis for determining the appropriate number of contracts to execute and is calculated using the following formula:

$$Hedge\ ratio = \frac{Volatility\ of\ bond\ to\ be\ hedged}{Volatility\ of\ hedging\ instrument}\ [1.1]$$

To calculate the hedge ratio, it is essential to use the volatility values of each instrument. From this calculation, it becomes clear that if the bond is more volatile than the hedging instrument, a larger quantity of the hedging instrument will be needed.

Several methods can be used to calculate hedge ratios, with the most common being:

1. The conversion factor method (also called the price factor method), which is suitable for deliverable bonds;
2. The modified-duration method (also known as the BPV method).

When hedging a bond included in the futures delivery basket, the conversion factor is often employed to calculate the hedge ratio. This approach is particularly advantageous because it is transparent and remains consistent, regardless of fluctuations in the prices of the cash bond or the futures contract. The number of futures contracts required to hedge a deliverable bond using the conversion factor method can be determined through the following formula:

$$Number\ of\ contracts = \frac{M_{bond} \times CF}{M_{fut}} \quad [1.2]$$

In this formula, M represents the nominal value of the bond or futures contract, and CF is the CTD conversion factor. The conversion factor method is applicable only for bonds within the delivery basket. It is crucial to apply this method to a single bond and avoid using the ratio of conversion factors for two different bonds when determining a hedge ratio, as this approach is incorrect.

Unlike the conversion factor method, the modified-duration hedge ratio can be applied to all bonds, whether they are deliverable or non-deliverable. To calculate this hedge ratio, the modified duration of the bond is multiplied by its dirty price to obtain the basis point value (BPV). The BPV quantifies the impact of yield changes on the bond's price, enabling traders to calculate a hedge ratio that accounts for the price sensitivity of the chosen bond relative to the CTD bond in response to interest rate fluctuations. However, the BPV-based hedge ratio requires regular updates since it fluctuates with changes in the bond's price and/or the futures contract price. Consequently, periodic adjustments to the number of futures contracts used in the hedge may be necessary. The number of futures contracts needed to hedge a bond using the BPV method is determined by the following formula:

$$Number\ of\ contracts = \frac{M_{bond}}{M_{fut}} \times \frac{BPV_{bond}}{BPV_{fut}} \quad [1.3]$$

The BPV of a futures contract is defined relative to the BPV of its CTD bond, as expressed by [1.4]:

$$BPV_{fut} = \frac{BPV_{CTDbond}}{CF_{CTDbond}} \quad [1.4]$$

To evaluate the effectiveness of a hedge position, it is essential to compare the performance of the futures position with that of the cash bond position to determine how closely the hedge instrument replicated the performance of the cash instrument. The effectiveness of the hedge can be calculated using a straightforward formula, expressed as the percentage value of the hedge's performance:

$$Hedge\ effectiveness = -\left[\frac{F_{p/l}}{Bond_{p/l}}\right] \text{ [1.5]}$$

CHAPTER II

LITERATURE REVIEW

Asset Liability Management (ALM) emerged in the 1970s, influenced by rising interest rate volatility and market deregulation. Dedication was the earliest form of ALM. Macaulay (1938) was the first to introduce the notion of duration, defined as the present-value-weighted average time remaining until cash flows are received from a portfolio or security. He developed a measure to account for the time dimension of assets and liabilities, known as Macaulay duration, which quantifies the sensitivity of fixed cash flow assets or liabilities to interest rate fluctuations. Hicks (1939) addressed changes in the value of assets inferred from changing interest rates. His observations concluded that asset values depend on the maturity and time pattern of relevant cash flows. Hicks (1939) standardised the observed cash flows as an annuity and calculated its elasticity terming it as an average period. Samuelson (1945) employed duration in order to address the concern of bank profitability against rising interest rates in the post-World War II scenario. He gave another version of duration under the name of the "weighted average time period." It became popular during the historically high-interest-rate environment of the late 1970s and early 1980s. Leibowitz (1986a, 1986b) was the first to use the term "dedication" to describe cash flow matching because it required matching a sequence of cash inflows (assets) to a sequence of cash outflows (liabilities). This involved ensuring that each inflow of funds was "dedicated" to meeting one particular obligation.

In the 1980s, dedication became immunisation, which was an asset management approach that paid attention to matching the interest rate sensitivity of the liabilities in present-value dollars. The aim was to lower surplus volatility (the gap between the dollar amounts of assets and liabilities) by ensuring that asset duration mirrored liability duration. Academics played a key role in developing ALM strategies that neutralised the interest rate sensitivity of both assets and liabilities. With interest rates on a long-term rise, the financial industry became increasingly interested in these strategies. Dedication and later immunisation strategies were adopted by defined benefit pension fund managers eager to lock in high returns. Wall Street firms, most prominently Salomon Brothers with Leibowitz as its intellectual leader, developed sophisticated software models to help traders implement these strategies. Quantitative scholars wrote many papers promoting and critiquing immunisation strategies during this time.[18]

[18] Among them, there are Keintz and Stickney (1980), Fong and Vasicek (1984), and Maloney and Yawitz (1986).

However, when rates started to fall in 1982, reinvestment risk (or prepayment risk) became a significant challenge for immunisation and dedication strategies, particularly for mortgage-backed securities portfolios. Call risk broke the predictability of cash flows and maturity schedules, compromising the reliability of these models. As pointed out by Thompson (1981), the risks of this kind can undermine immunisation strategies. Leibowitz and Weinberger (1982) proposed a new concept called "contingent immunisation", which provided a more flexible alternative for dealing with cash flow insecurities.

After the equity correction of 2000-2003, due to the stock market downturn of 2002, institutions had no alternative but to reconsider basic ALM, owing to falling funded ratios, significant actuarial losses and rising contribution costs. This revival of ALM represented the transition to a new approach known as liability-driven investing (LDI).

The Basel Committee on Banking Supervision (BCBS) (2001) has had a significant influence on global asset-liability management. Internationally, the BCBS issued a broad set of supervisory standards, guidelines, and best practices in the area of banking oversight in 2001, with the objective of promoting consistency in regulatory approaches. What came next was the Basel II framework, released in 2004, which provided a global standard for the amount of capital a bank must hold to protect itself against various financial and operational risks. Basel II further focused on strengthening risk and capital management practices by requiring banks to maintain a level of capital commensurate with their risk exposure arising from lending and investment activities. In simple terms, the higher the level of risk, the greater the capital reserves that must be maintained to protect a bank's solvency and financial stability. This framework was established to fortify the resilience of the global financial system by reducing the risk of contagion from the failure of a major bank or several financial institutions.

This chapter is organised as follows. Section 2.1 explores the ALM model theory in the banking industry over the years. Section 2.2 illustrates the main ALM strategies and techniques. Finally, section 2.3 focuses on bank regulation. In particular, it outlines the Basel Accords and how they have influenced banks since their introduction. It concludes with an analysis of the principal risk management techniques imposed by the Basel Committee on Banking Supervision (BCBS).

2.1 Bank ALM Models

Generally speaking, asset and liability management (ALM) models can be deterministic or stochastic, and both types have become common and useful normative tools for the banking industry. In deterministic models, the dynamics of financial variables (such as interest rates or equity volatility) are assumed to be predetermined over a mapping of time. This process yields one projected outcome, the central scenario. Such a scenario measures cash inflows and outflows generated by the firm's assets and liabilities and discovers assets that do not correspond with cash inflows and outflows. More scenarios would provide a fuller analysis; however, these deterministic models help quickly identify both minor and major strengths and weaknesses in other hedging strategies, as well as how to address potential mismatches. These models implement linear programming, account for certain realisations of random events, and are computationally efficient for various problem sets.

Conversely, stochastic models attempt to capture uncertainty but generally involve significant approximations to make them tractable for implementation and parameter estimation. Unfortunately, such simplifications may lead to unrealistic assumptions. Stochastic methods can be more complex in terms of computation, including chance-constrained programming, dynamic programming, sequential decision-making theories, and linear programming under uncertainty.

2.1.1 Deterministic models

Looking to the past, the deterministic linear programming model developed by Chambers and Charnes (1961) was a pioneer in asset and liability management. Chambers and Charnes formulated, analysed, and interpreted a mathematical programming model that more realistically represented the properties of bank operations than earlier efforts. In their model, the task was to determine the optimal portfolio of stocks for a bank over several periods, considering the regulations that govern the acceptable levels of risk associated with the portfolio's returns. Dozens of applications of their model can be found, for example, in Cohen and Hammer (1967), Robertson (1972), Lifson and Blackman (1973), and Fielitz and Loeffler (1979). Regardless of the differences in disaggregation, uncertainty, and dynamism, all these models had one aim: to maximise a linear profit-oriented objective function subject to linear constraints.

Building on this foundation, Eatman and Sealey (1979) developed a multi-objective linear programming model for controlling the balance sheets of commercial banks. They took aim at the trade-off between profit and solvency, where profit was defined by the bank's profit function. Since liquidity and risk are key components of a bank's solvency, Eatman and Sealey added the capital adequacy (CA) ratio and the risk-asset to capital (RA) ratio as indicators of these factors. By considering asset and liability composition, the CA ratio offered a comprehensive measure of liquidity and risk. A high CA ratio suggested less liquidity and a risky position, so a lower CA ratio would help banks to increase liquidity and lower risk. The RA ratio was also used to assess risk: the higher the RA ratio, the more risk exposure. This ratio was critical in risk reduction, and minimising it became a goal. Policy and managerial considerations were among the constraints in their model.

Giokas and Vassiloglou (1991) extended these developments by proposing a multi-objective programming approach to bank assets and liabilities management. In their opinion, bank management sought not only to maximise revenues but also to minimise risks, allocate capital efficiently, and pursue other objectives, such as maintaining market share and increasing deposits and loans. Because conventional linear programming can only manage one goal in the objective function, it is unable to tackle this type of problem. The most popular method for multiple-criteria decision-making is goal programming, which enables the decision-maker to incorporate a wide range of constraints and objectives easily.

2.1.2 Stochastic models

Many stochastic methods were developed in conjunction with deterministic ones. Most of these are static mean-variance approaches based on Markowitz's (1959) theory of portfolio selection. This approach defines risk as variance in a single-period planning horizon, relies on normally distributed returns, and employs risk-averse utility functions in decision-making. In this framework, the value of an asset is determined not only by its expected return and variance but also by the covariance of its return with the return of all other current and potential investments. For example, Pyle's (1971) static model applied the stock version of Markowitz's theory to allow a bank to choose how much of certain assets and liabilities to hold at the end of a given period. His model focused entirely on portfolio risk, excluding every other type of uncertainty the bank might face, such as trading activity, asset-liability matching, transaction costs and similar factors. An improvement on the original approach was applied by Brodt (1978), who adjusted Markowitz's principles to develop a dynamic balance sheet management model that aimed to maximise profit for a given risk level over a multiperiod planning horizon. His two-period linear model included uncertainty and sought to construct an efficient frontier between the expected profit and the deviation function. Brodt applied mean absolute deviation or semi-absolute deviation instead of variance, allowing the adjustment of the upper and lower bounds of the deviation functions to provide greater flexibility and precision to risk-return optimisation.

Charnes and Thore (1966), followed by Charnes and Littlechild (1968), introduced using chance-constrained programming models to treat uncertainty in the banking operation. These models dealt with future deposits and loan repayments as joint, normally distributed, random variables and replaced the traditional capital adequacy formula with a chance constraint that satisfied withdrawal claims. This approach provided a computationally feasible framework for realistic scenarios. Expanding this idea, Pogue and Bussard (1972) developed a 12-period chance-constrained model that emphasised the uncertainty of future cash requirements. Nevertheless, a major drawback of this approach was that it could not allow for differential penalties on different magnitudes of constraint violation or for distinct types of constraints.

Wolf (1969) proposed a sequential decision-theoretic approach, applying sequential decision analysis with implicit enumeration to derive optimum solutions. Although useful in single-period models, this approach was unsuitable for multi-period horizon problems. Wolf contended that the solution from a one-period model would be equivalent to that of an n-period one, as if the fundamental issue of the alignment of asset and liability maturities could be ignored. Bradley and Crane (1972) developed a stochastic decision tree model with a large number of desirable characteristics for an operational bank portfolio management system. Their model was based on economic scenarios and was designed to capture every possible outcome. These scenarios were organised as a tree diagram, with each branch standing for specific economic conditions and their associated cash flows and interest rates. They formulated the problem as a linear program aimed to maximise the expected terminal wealth of the firm subject to constraints on cash flow, inventory balancing, capital losses, and asset class composition. In order to tackle the computational difficulties, Bradley and Crane redeveloped the asset and liability issue, creating a general programming decomposition algorithm that significantly minimises the computational complexity.

Dynamic programming is another stochastic modelling technique which was introduced by Samuelson (1969), Merton (1969, 1990), and others. The goal of this approach, is to build a state space at every time interval for the variables driving the system. Stochastic control does not identify specific scenarios in the state space but instead complicates it. Finite-element or dynamic programming algorithms can be used to overcome these issues. Merton (1969) analysed two main variables that account for major differences in optimal investment and expenditure policies among universities. The present value of liability payments is linked to the underlying economic variables, which the analysis showed means that prudence and performance evaluations must reflect the distinctive mix of activities and capitalised values of non-endowment cash flow sources for individual institutions. This modelling approach was applied to asset management problems by Eppen and Fama (1971). Using a well-accepted control policy, their model framed the optimisation process under uncertainty as a stochastic control model. To ensure that asset proportions match predefined goals, the portfolio is rebalanced at the conclusion of each period. The model is readily applicable and implementable, as it utilises a discrete approximation of the continuous sample space. Such dynamic models are essential as they capture part of the uncertainty of the decision-making process.

Another stochastic modelling approach is stochastic linear programming with simple recourse (SLPSR), also known as linear programming under uncertainty (LPUU). This technique defines each realisation of random variables concerning given constraints and has a finite number of variables and time periods. Cohen and Thore (1970) considered their single-period model as a means to perform sensitivity analysis, not so much as a normative decision-making framework. In contrast, Crane (1971) extended the approach to a two-period model. Nonetheless, the complexity of computations involved and the perception concerning the restrictions of the model limited its application to problems with a small number of time periods and variables. In particular, Booth (1972) implemented this formulation by simplifying possible realisations and variables, enabling its use over two time periods. Later, Kallberg et al. (1982) adjusted this method for a firm's short-term financial planning in the form of a stochastic linear programming problem with simple recourse in which the forecasted cash requirements were treated as discrete random variables. They first seek to reduce costs on multiple (net) sources of funds subject to a four-quarter horizon on expected penalty costs from constraint violations. Their study showed that the mean model produced a significantly inferior solution compared to the stochastic linear programming formulation, although penalty costs and penalty distributions were symmetric.

Kusy and Ziemba (1986) extended a multi-period stochastic linear programming model with simple recourse to help manage assets and liabilities in banking. Their formulation balanced computational feasibility with practical application, maximising the net present value of bank profits net of expected penalty costs in the event of infeasibility. The model, which was applied for Vancouver City Savings Credit Union throughout a five-year planning period, incorporated institutional, legal, financial, and policy considerations as well as the uncertainties that go along with them. The results showed that asset and liability management (ALM) outperformed theoretically and operationally in relation to equivalent deterministic linear programming models with similar implementation and computational requirements. Furthermore, the qualitative and quantitative characteristics of the solutions were sensitive to the model's stochastic components, such as asymmetries in cash flow distributions. The Kusy and Ziemba model included several features: 1) multi periodicity, which includes the synchronisation of cash flows over time by aligning asset maturity with anticipated cash outflows, transaction costs related to selling assets before maturity, and fluctuating yield margins over time; 2) simultaneous evaluation of assets and liabilities in order to align their liquidity and adhere to accounting standards; 3) transaction costs, which include brokerage fees and additional expenditures related to purchasing and disposing of securities; 4) uncertainty of cash flows, taking into account the unpredictability of depositors' withdrawal requests and deposits, which guarantees that the bank's asset portfolio allows it to satisfy these claims; 5) the integration of variable interest rates in the decision-making process to prevent lending and borrowing decisions that could ultimately be deleterious to the bank's financial health; and 6) legal and policy constraints appropriate to the bank's operating environment. The Kusy and Ziemba approach was sophisticated, yet it had drawbacks. It was not completely dynamic and lacked end effects because it used a rolling process to handle issues over two periods at a time. The scenarios were viewed as independent over time and divided into high, low, and average returns.

The Russell–Yasuda Kasai model (Carino et al., 1994) is another example of a multistage stochastic programming application which maximises the firm's long-term wealth by generating significant income returns. This model expands upon this previous work to create a large-scale dynamic model that accounts for potentially dependent scenarios, end effects, and all the appropriate institutional and policy constraints of Yasuda Kasai's business enterprise. The work of Carino et al. employs a multistage stochastic linear program that maximises expected long-run profits minus expected costs for constraint violations over the infinite horizon. It includes Yasuda Kasai's portfolio of assets and liabilities over a five-year horizon and an infinite horizon, steady-state end-effects period. The constraints reflect the institutional, cash flow, legal, and tax limitations on the asset and liabilities mix over time.

Using one or more of the decision rules, an ALM model can be designed to optimise the setting of decision rules and perform basic scenario analysis. Despite their relative smallness, these optimisation problems frequently produce nonconvex models, making it challenging to determine the global optimal solution. Falcon Asset Liability Management (Mulvey and Crowder, 1997) and Towers Perrin's Opt: Link System (Mulvey, 1996) are examples of optimising decision rules. Scenario analysis is usually defined as a single deterministic realisation of all uncertainties throughout the planning horizon. The process mainly creates scenarios reflecting the universe of possible outcomes (Glynn and Iglehart, 1989; Dantzig and

Infanger, 1993). The primary concept is to create a representative set of both optimistic and pessimistic scenarios within a risk-analysis framework. One of the largest actuarial firms in the world, Towers Perrin, utilises CAP: Link, a capital market scenario creation technology, to conduct this type of exercise. This was done in order to help its clients understand the advantages and risks associated with capital market investments. The system generates a representative sample of individual simulations (usually 500 to 1000), beginning with the interest rate component. Towers Perrin uses a version of the two-factor interest rate model by Brennan and Schwartz (1982). The other submodels respond to the interest rates and other economic fundamentals. Towers Perrin has implemented the system in more than fourteen countries in Europe, Asia and North America.

Several implementations of simulation models have been reported for different types of financial institutions (Derwa, 1972; Robinson, 1973; Grubmann, 1987). For example, Derwa employed a computer model and is now working at Société Généralé de Banque to develop better management decision-making in banks. Since the model was constructed as a decision tree, it was feasible to proceed step-by-step and look at the factors converging on the bank's primary goals. Derwa concluded that the issues introduced by the application of model management are far more complex to overcome than the technical ones associated with mathematics or data processing.

Mulvey and Vladimirou (1989) applied dynamic generalised network programs for financial planning problems under uncertainty. They created a model within the framework of a multi-scenario generalised network that represents uncertainty by collecting discrete scenarios of uncertain quantities and capturing the key elements of different discrete-time financial decision problems. However, these models are small and cannot handle problems of a practical size. Some researchers attempted to reduce the number of scenarios for uncertainty representation and keep the stochastic programs obtained computationally tractable through sampling (Mulvey and Crowder, 1979) or cluster analysis methods (Dantzig and Glynn, 1990).

Korhonen (2001) introduced a multistage stochastic programming technique for the strategic financial management of a financial conglomerate, including several companies. He developed a comprehensive strategy that addressed several potential future scenarios over a multiperiod planning horizon. The strategy consists of several competing objectives set at the group, corporate, or specific business area levels. Furthermore, the decision-maker's preferences were permitted to change over time in response to shifting operational circumstances and the trade-off relationships between the objectives.

Kouwenberg (2001) developed a methodology for generating scenarios for asset liability management. He proposed a multistage stochastic programming model for a Dutch pension fund. The coefficients of the stochastic program were generated using randomly sampled event trees, which matched the mean and covariance of the distribution of returns. He conducted rolling-horizon simulations to explore the model performance and the scenario generation procedures. He analysed the average switching behaviour of the best investment policies; the analysis's findings demonstrated that selecting the proper scenario generation technique might enhance the multistage stochastic program's performance.

2.2 ALM strategies and techniques

ALM includes several strategies and techniques aimed at aligning a financial institution's assets and liabilities while reducing risks related to interest rate changes, liquidity shortages, and market volatility. A significant number of strategies have evolved, ranging from simple to those utilising advanced theories from finance or actuarial science. Therefore, overseeing and evaluating all these strategies has become increasingly complex. Early techniques such as cash flow matching and immunisation concentrated on creating predictable results by aligning the maturities of assets and liabilities. Advanced techniques such as duration matching, gap analysis, scenario analysis, and derivatives for hedging have expanded the range of options.

Successively, strategies and techniques will be classified into three distinct groups: 1) static, 2) value-driven, and 3) return-driven. Generally, techniques are considered essentially static, while strategies require a defined set of decision-making principles for behaviour and are explicitly dynamic. Multi-scenario analysis and risk-return analysis will be treated separately. This is because multi-scenario analysis, despite being static, is generally intended for multiperiod decision-making. In contrast, risk-return analysis is a comprehensive framework for evaluating techniques and strategies across all categories.

2.2.1 Static techniques

The static techniques outlined here, arranged in order of increasing sophistication, are cash flow payment calendars, gap analysis, asset and liability segmentation, and cash flow matching. Most of these approaches are commonly applied in the banking and insurance industries, perhaps due to their relative simplicity and ease of use. They emphasise a perfect alignment between assets and liabilities, particularly in the case of cash flow matching. Moreover, these methodologies are static and offer only a one-dimensional view of assets and liabilities, hence lacking the capacity for a consistent trade-off between risk and return. Any of them expressly quantifies neither risk nor reward. Static techniques are composed by:

- *Cashflow payment calendar:* Presents a complete overview of all cash inflows and outflows by maturity. It is an instrument for identifying significant discrepancies between cash flows resulting from assets and liabilities;
- *Gap analysis*: Gap analysis is derived from the literature concerning bank asset-liability management. Clifford (1981) defines the Gap as the difference in balance sheet values between fixed-rate and variable-rate assets and liabilities. A non-zero gap indicates exposure to interest rates. For example, when variable-rate assets exceed liabilities, a decrease in rates will lead to a reduction in net operating income. Furthermore, gap analysis may be enhanced to consider maturity differences between assets and liabilities;[19]
- *Segmentation*: Segmentation divides liabilities based on variations arising from product characteristics. Moreover, each segment acquires a distinct asset portfolio customised to align with particular characteristics of the liabilities;
- *Cashflow matching*: It seeks to reduce discrepancies between asset and liability cashflows, typically via linear programming techniques. A portfolio is selected from an asset universe that ensures all liability payments are made within a minimal acceptable timeframe and at a minimal cost. It is noteworthy that, unlike the other three techniques, which are descriptive, this technique is primarily prescriptive. Cash flow matching may result in several practical challenges. A perfect match may not always be obtainable in the market, particularly when liability cash flows have extended maturities and matching assets are unavailable. Consequently, the programming problem that must be addressed using the cash flow matching technique may be deemed infeasible. Secondly, a stringent matching criterion may prove overly restrictive for portfolio management, as it excludes strategies that incorporate higher risk in pursuit of greater returns. This is particularly relevant when liabilities are priced at a premium, and an exact matching approach fails to fully recover the costs associated with the liabilities from the asset portfolio. Thirdly, these strategies require comprehensive and precise knowledge of the timing of all cash flows, which is often impractical. In addition, the previously mentioned challenge may be amplified by the potential fluctuations in cash flows. For instance, when cash flows are correlated with interest rates or other stochastic

[19] For more information about segmentation see Attwood and Ohman (1984).

variables, such as insurance claims, achieving cash flow matching overall potential future scenarios may be impractical.

2.2.2 Multi-scenario analysis

Multi-scenario analysis seeks to establish a connection between the previously discussed static techniques and dynamic strategies. The multi-scenario technique is still static in nature, but it is also possible to formulate scenario-contingent actions. Liability and asset portfolio cashflows are projected using a multi-scenario analysis. These projections are made under different assumptions regarding the future development of several key variables, such as interest rates, inflation, etc. The analysis shows under which scenarios cashflows are not matched and the consequences for the overall organisation. Additionally, it still focuses on flows rather than values. Multiscenario analysis enables the modelling of complex relationships and allows for a multi-dimensional risk concept. However, the multiple scenarios and different dimensions of risk also constitute the fundamental issues related to this technique. The user is likely to be biased towards particular scenarios that are considered more likely, whereas other scenarios may lead to the most serious distress. This may still be true when so-called randomly generated scenarios are created. Furthermore, even though multi-scenario analysis may lead to problem detection more generally than a single scenario or static analysis, multi-scenario analysis alone does not provide an easy tool for management unless objectives, restrictions and their relative importance are clearly specified (Winklevoss, 1982).

2.2.3 Value-driven strategies

Building on the concept of the Macaulay duration, Redington (1952) formulated a strategy to preserve the net value, or surplus, of a portfolio composed of assets and liabilities with fixed cash flows, so-called immunisation. These strategies seek to replicate a risk-free asset dynamically. The four primary types of immunisation strategies are: standard immunisation, model-conditioned immunisation, and key rate immunisation.

2.2.3.1 Standard immunisation

The purpose of standard immunisation is to match the interest rate sensitivities of assets and liabilities. This is mathematically equivalent to equating the first-order partial derivatives of their valuation functions concerning the current interest rate. The second-order partial derivatives of the assets have to be at least as big as that of the liabilities. For fixed-coupon assets, the first-order partial derivative divided by the initial value is known as the modified Macaulay duration. In contrast, the second-order derivative is commonly known as convexity. Duration represents the sensitivity of an asset or liability’s value to interest rate changes at a specific point, while convexity measures how this duration changes as interest rates vary. When asset and liability durations are matched, the initial changes in their respective values will be of the same magnitude and direction. However, this will be true for infinitesimally small shifts in a flat-term structure of interest rates and only for a brief period. As a result, immunisation necessitates continuous rebalancing of portfolios, making it an inherently dynamic strategy. Constructing and maintaining an asset portfolio with greater convexity than the liability portfolio ensures that the asset value changes in a way that consistently outperforms the liability value. Consequently, the net value (assets minus liabilities) remains stable and does not decline.

The concept of convexity and its implications highlight a fundamental weakness of standard immunisation, which is the assumption of a flat term structure. If an asset portfolio can be immunised with greater convexity than its corresponding liability portfolio, then under this assumption, any change in interest rates would appear to generate value from nothing. This contradicts the fundamental no-arbitrage principle in financial theory. However, this apparent arbitrage opportunity primarily reflects the risk-return trade-off in real-world interest rate environments. This becomes evident when examining how differences in convexity arise. Convexity increases as the dispersion of cash flows widens. Up to this point, the analysis has considered only a single interest rate. However, in practice, the interest rates applied to assets and liabilities differ based on their respective maturities and depend on the term structure of interest rates. Assuming a single relevant interest rate, as standard immunisation does, means that the results are valid only when the term structure experiences parallel shifts. In reality, non-parallel shifts are equally significant, and their impact on the value of asset and liability portfolios increases with convexity. Moreover, term structure risk also grows as convexity increases.

Aside from the issues with non-parallel shifts of the term structure, modified Macaulay duration explicitly assumes fixed cash flows. Consequently, they are typically inapplicable to scenarios in which cash flows are contingent upon interest rates, such as assets and liabilities with prepayment options or interest rate-sensitive coupon payments. Furthermore, similarly to all dynamic strategies, the efficacy of the immunisation approach is contingent upon the liquidity of the associated assets.

2.2.3.2 Model-conditioned immunisation

To facilitate more advanced structural alterations, several variations to the traditional immunisation strategy have been developed. These modifications are contingent upon assumptions of the stochastic process that controls the development of the term structure. The resulting immunisation strategies vary only in the duration and convexity measures employed and are:

- *Single factor immunisation*: The most straightforward model for conditioned immunisation applies the theory of the long-term structure of interest rates, as developed by Cox, Ingersoll, and Ross (1985). This model considers only the short-term interest rate as the sole stochastic factor influencing bond prices. Based on their assumptions regarding the term structure, the sensitivity of bond prices to shifts in the term structure, driven by changes in the short-term interest rate, can be expressed through a model-specific duration. Different formulations of the term structure process will yield varying duration measures. However, once the appropriate duration measure has been established, the resulting immunisation strategy aligns closely with the principles of standard immunisation;
- *Multi-factor immunisation*: The term structure model developed by Cox, Ingersoll, and Ross can be extended from a single-factor to a multi-factor approach. A multi-factor model utilises a limited number of independent variables to influence and shape the term structure of bond price returns. In models based on the Cox, Ingersoll, and Ross framework, the key factors are generally associated with theoretical parameters, such as the historical mean of the short-term interest rate or interest rate volatility. Conversely, alternative models, such as the Heath, Jarrow, and Morton (1991) bond pricing model, incorporate variables derived from observed forward rates, relying on statistical identification rather than theoretical assumptions. Once these determinant factors are identified, it is possible to formulate immunisation strategies that protect the portfolio against fluctuations in these factors.

Model-conditioned strategies primarily get their most significant advantage from their accuracy and the inclusion of derivative instruments within the same term structure framework. However, one drawback is the non-stationarity of factors, which poses risks to the model's validity over time and requires constant surveillance to identify such instability. Although theoretically superior to standard immunisation, the practical advantages of model-conditioned techniques are still subject to dispute. A significant advancement in term structure modelling is the incorporation of effective duration. This measure captures the price sensitivity of assets or liabilities with embedded options. It extends modified Macaulay duration into a price elasticity measure that can be applied across the entire bond universe. However, while effective duration is broadly applicable, its estimation depends on the assumptions underpinning the chosen term structure model.

2.2.3.3 Key rate immunisation

Key rate immunisation, introduced by Ho (1990) and Reitano (1990, 1991), is closely related to standard immunisation, but it explicitly acknowledges the potential for non-parallel shifts in the term structure. The key rate immunisation approach addresses this by segmenting cash flows. It operates under the assumption that the shape of the term structure is primarily influenced by a limited set of pivotal or key interest rates, with other values being derived through interpolation. Similar to standard immunisation, further assumptions regarding the behaviour of key interest rates can be used to estimate effective (key rate) durations. Key rate immunisation can be seen as a compromise between standard immunisation and full cash flow matching. It offers greater accuracy than the former while being more flexible and less restrictive than the latter. Its primary advantage over model-conditioned strategies is that it is independent of any specific model. Nonetheless, compared to standard immunisation, it requires a higher level of complexity.

2.2.4 Return-driven dynamic strategies

Return-driven strategies are mostly based on returns or spreads, in complete contrast with respect to immunisation strategies. This frequently leads to neglecting the essential value to be monitored, which is fundamental to immunisation strategies. As a result, they may fail to capture and represent all associated risks. There are two categories of return-driven strategies:

- *Spread management*: Spread management focuses on maintaining a yield spread between asset and liability portfolios. This approach is related to the concept of segmentation and a buy-and-hold investment strategy. Generally, the yields of both asset and liability portfolios are related to treasury bond yields obtained from the term structure. It also analyses the factors affecting spread fluctuations, including disparities in duration and credit risk, thereby using techniques such as option-adjusted spread (OAS) analysis and spread duration.[20] Spread management tends to focus on nominal assets and liability values. However, within the context of Asset-Liability Management (ALM), effective spread management should be based on market values and integrated into a broader risk-return framework to ensure a comprehensive and strategic approach (Herskowitz, 1989);
- *Required rate of return analysis:* The required rate of return analysis, as developed by Miller, Rajan, and Shimpi (1990), evaluates the future cash flows of liabilities and determines the rate of return needed on the current cash balance of the liabilities to meet

[20] Fore more details on spread-duration, see Leibowitz and Krasker (1989).

these future obligations. Such evaluated returns are then used to decide a suitable asset portfolio, potentially dependent on various scenarios in relation to a particular risk criterion. The main advantages of this method are its inherent simplicity and its ability to identify trading opportunities. Its simplicity and ability to identify trading opportunities are the main advantages of this approach. However, the disadvantages are related to its focus on returns, which may lead to the implicit acceptance of unidentified risks. For instance, higher returns are generally caused by increased credit risk or mismatch risk, which this system does not clearly identify as such in the strategy.

2.2.5 Risk-return analysis

The risk-return analysis, based on Markowitz's work (1952) and the subsequent development of the Capital Asset Pricing Model (CAPM) and Arbitrage Pricing Theory (APT), is a key tool for investment decisions. It offers the most comprehensive theoretical framework for evaluating such financial decisions. The core principle is that when two portfolios of assets and liabilities have different expected returns, this variation is either due to differences in risk (where a higher return corresponds to greater risk) or because one of the portfolios is inefficient. When presented with a range of portfolios, a rational investor will only consider efficient portfolios and opt for the one that offers the most favourable risk-return trade-off based on their individual risk preferences. Several scholars have applied portfolio selection principles to asset and liability matching, with Wise (1984a, b) and Wilkie (1984) considering ultimate surplus as a key determinant, and later Leibowitz and Langeteig (1991) also considering it.

Risk-return analysis is a valuable framework, but it depends on carefully choosing inputs like risk and return. In particular, these inputs are improperly defined or rely solely on non-stationary historical data. That’s the reason why risk-return analysis can increase errors in a substantial way.

2.3 The Basel Rules

Banks and financial institutions in general are subject to various regulations, the most critical of which pertains to the capital level a bank must maintain, ensuring a buffer to support its operational activities. An institution is generally subject to the regulatory requirements of its domestic regulator. Still, it may also be obligated to comply with cross-border regulations, such as the European Union's Capital Adequacy Directive.[21] A capital requirement framework proposed by a committee of central banks under the auspices of the BIS in 1988 has been adopted unanimously by banks globally. These are referred to as the BIS regulatory

[21] In the United States, banking supervision is conducted by the Federal Reserve.

requirements or the Basel capital ratios, named after the Swiss town where the BIS is located. According to Basel requirements, all cash and off-balance sheet instruments in a bank's portfolio are allocated a risk weighting based on their assessed credit risk, which dictates the minimum capital that must be held against them. The Basel rules on regulatory capital were established in the 1980s due to widespread concerns regarding several large banks engaged in cross-border operations with insufficient capital (King and Tarbert, 2011).

The regulatory bodies of the G-10 nations formed the Basel Committee on Banking Supervision. The 1988 Basel Committee on Banking Supervision study proposed regulations that were subsequently implemented globally as the "Basel rules".[22] The Basel Accord provided a framework for calculating risk and assigning asset weights based on the borrower's type and location. The Basel Accord set a minimum capital requirement of 8% of risk-weighted assets for banks. This standard took effect in 1992. Banking authorities designed the current capital adequacy criteria to increase the stability of the global banking system and harmonise international regulations. The 1988 Basel Accord was a pivotal development in banking regulation, establishing a clear formal standard for bank capitalisation.

It was later endorsed by national regulators in more than 100 nations. The Basel rules have no regulatory authority as such; instead, they are adopted by individual national regulatory regimes as a minimum standard requirement. This indicates minor discrepancies in the global fundamental Basel requirements, with the European Union's Capital Adequacy Directives as the prime example.

2.3.1 Basel I

The BIS rules establish a minimum capital-to-assets ratio of 8% of asset value. Assets are characterised by risk, and the weighted risk assets are multiplied by the 8% rate. Every asset is assigned a risk-weighting: 0% for risk-free assets, such as certain government bonds; 20% for interbank lending; and up to 100% for the highest-risk assets, including certain corporate loans. For example, a loan in the interbank market would be assigned a 20% weighting, whereas a loan of identical size to a corporation is assigned the highest weighting of 100%. The BIS requirements are set regarding the type of capital allocated against assets. International regulation delineates the following categories of capital for a bank (Choudhry, 2007):

- *Tier 1*: This is perpetual capital, which can absorb losses through the non-payment of a dividend. This is shareholders' equity and also non-cumulative preference shares;

[22] Bank for International Settlements, Basel Committee on Banking Regulations and Supervisory Practice, *International Convergence of Capital Measurement and Capital Standards*, July 1988.

- *Upper Tier 2*: This is also perpetual capital, subordinated in repayment to other creditors; this may include, for example, undated bonds such as building society PIBS and other irredeemable subordinated debt;
- *Lower Tier 2*: This is capital that is subordinated in repayment to other creditors, such as long-dated subordinated bonds.

The level of capital requirement is given by the following formulas introduced by Basel I:

$$\frac{Tier\ 1\ capital}{Risk\ weighted\ assets} > 4\% \quad [2.1]$$

$$\frac{Tier\ 1 + Tier\ 2\ capital}{Risk\ weighted\ assets} > 8\% \quad [2.2]$$

The ratios in [2.1] and [2.2] establish minimal thresholds. A bank's risk-adjusted exposure comprises both the cash risk-adjusted exposure and the total risk-adjusted off-balance sheet exposure. The capital charge calculation (risk-adjusted exposure) for cash products in the banking book is given by:

$$Principal\ value\ \times Risk\ weighting\ \times Capital\ charge\ [8\%] \quad [2.3]$$

Calculated for each instrument.

The total of the exposures is calculated. Firms may employ netting or portfolio modelling to diminish the overall principal value. The capital requirements for off-balance sheet instruments are reduced because, for these instruments, the principal is rarely at risk. Interest-rate derivatives, such as FRAs with maturities under one year, incur no capital requirements, but a long-term currency swap requires capital ranging from 0.08% to 0.2% of the nominal principal. The BIS differentiates between banking book transactions conducted by retail and commercial banks (mainly deposits and loans) and trading book transactions executed by investment banks and securities houses. Capital treatment occasionally varies between banking and trading portfolios. A repo transaction, for instance, faces a charge on the trading book. The formula for determining the capital allocation is:

$$CA = max.\Big(\big((C_{mv} - S_{mv}) \times 8\% \times RW\big), 0\Big) \quad [2.4]$$

Where

C_{mv} is the value of cash proceeds

S_{mv} is the market value of securities

RW is the counterparty risk-weighting (as a percentage).

Basel I's weaknesses were the lack of accounting for the credit risk ratings of diverse corporate borrowers and its lack of alignment between risk-based and economic risk. On 3 June 1999, the BIS issued proposals to update the rules relating to the capital requirements, which were completed as Basel II in June 2004 (Lubinska, 2020).

2.3.2 Basel II

The recently introduced regulatory guidelines aim to bolster the safety and stability of the financial system, adopting a more comprehensive approach to risk management and enhancing competitive parity. These proposals were intended to apply universally to banks, not just those operating across national borders. While the 1988 Basel Accord relied on extensive counterparty credit requirements, and despite a 1996 amendment to cover trading book risks, it faced criticism for its inflexibility. In contrast, the new Basel II framework consists of three pillars and is designed to align more closely with the specific risk profiles of credit exposures. These are:

- *Pillar 1*: A new capital requirement for credit risk, along with a charge for the new category of operational risk.[23] The capital requirements are defined under two approaches: the Standardised approach and the Internal Ratings-based (IRB) approach.[24] In the standardised approach, a bank's assets are categorised based on their formal credit ratings, whereas in the IRB approach, they are categorised according to the bank's own internal risk assessment;
- *Pillar 2*: The requirement for supervisors to take action if a bank's risk profile is high compared to the level of capital held; this is based on three principles. First, banks must have a process for calculating their capital requirements in line with their unique risk profile. Second, the risk-weighted capital requirement under Pillar is considered a minimum, and banks are expected to hold additional capital as a buffer against potential losses. Finally, supervisors are tasked with continuously monitoring the capital levels of banks under their oversight and intervening promptly to ensure these levels do not fall below what is deemed adequate to support the bank's operations;
- *Pillar 3*: The requirement for greater disclosure from banks than before to enhance market discipline. There are also additional disclosure rules that vary from the core rules. These supplementary rules provide banks with more flexibility in their reporting, especially where particular requirements are deemed irrelevant to their specific operational activities or insignificant. The required disclosures cover aspects such as capital levels, capital adequacy, and risk exposure.

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[23] The level of capital requirement ([2.1], [2.2]) is modified with the introduction of operational risk in the risk-adjusted exposure.

[24] The IRB approach is composed of two other approaches: the Foundation Internal Ratings-based (FIRB) approach and the Advanced Internal Ratings-based (AIRB) approach.

The global financial crisis exposed limitations in the Basel II framework, despite its focus on advanced risk models. The crisis highlighted problems with the definition of Tier 1 capital, which banks used to fulfil Basel II requirements while minimising their capital costs. There were also concerns about how banks structured their liabilities, as trading book and securitisation assets had lower capital requirements than banking book assets under the Basel II framework. The crisis also revealed flaws in the risk management models used by many international banks. Most significantly, it showed a gradual decline in capital levels over two decades, leaving many banks unprepared for substantial losses. In fact, insufficient capital buffers were particularly problematic for several systemically important financial institutions (King and Tarbert, 2011).

2.3.3 Basel III

The Basel III framework, the most recent development in the Basel Accords, was established by the Basel Committee on Banking Supervision (BCBS) to address capital adequacy, market liquidity risk, and stress testing, with a focus on financial stability. These global regulatory reforms, which were agreed upon by the G-20 in November 2010 and subsequently issued by the BCBS in December 2010, aim to strengthen the capital adequacy requirements in terms of both the quality and quantity of capital that banks must hold to absorb potential losses. As a result, Basel III is an attempt to mitigate the underlying causes of the most recent financial crisis. The new framework introduces enhanced regulations, including a more stringent definition of capital and the implementation of a global liquidity standard (BCBS, 2010).

These regulatory measures were aimed at improving transparency around liquidity requirements and strengthening market discipline. These disclosure requirements, which banks will be required to conform to from the first reporting period after 1 January 2015, are consistent with the Basel III framework, and the national authorities have adopted them in accordance with their legal structures. These guidelines serve two unique but complementary objectives. The first is to bolster a bank's resilience to short-term liquidity risk by ensuring it maintains adequate, high-quality liquid assets to withstand a significant stress scenario lasting 30 days. To this end, the Committee published the "Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools." The second objective is to mitigate funding risk over a longer horizon by requiring banks to fund their activities with sufficiently stable funding sources, thereby reducing the risk of future funding stress. To achieve this, the Committee published "Basel III: The Net Stable Funding Ratio." These standards are a critical component of the Basel III reform package, and together, they will strengthen banks' resilience to liquidity shocks, promote a more stable funding profile, and enhance overall liquidity risk management (Lekatis, 2014).

Figure 6 shows the minimum LCR requirements set over the years.

Figure 6. Minimum Liquidity Coverage Ratio requirements

	1 January 2015	1 January 2016	1 January 2017	1 January 2018	1 January 2019
Minimum LCR	60%	70%	80%	90%	100%

Source: Basel Committee on Banking Supervision (2013)

The high-quality liquid assets (HQLA) comprise cash or readily convertible assets that can be liquidated in private markets with minimal or no loss of value. At a minimum, the unencumbered stock of HQLA should allow the bank to withstand the stress scenario until day 30. By this time, the management and supervisors can be expected to implement suitable corrective measures or the bank can resolve the situation in an orderly manner.

The Liquidity Coverage Ratio is given by [2.5] (BCBS, 2013):

$$LCR = \frac{Stock\ of\ HQLA}{Total\ net\ outflow\ over\ the\ next\ 30\ calendar\ days} \geq 100\% \quad [2.5]$$

The asset stock comprises two categories of assets. These are the assets that the bank holds on the first day of the stress period, regardless of their remaining maturity. 'Level 1' assets can be included without restriction, whereas 'Level 2' assets are limited to 40% of the total asset stock (Ahmed, 2015).

The total net cash outflow metric represents the expected net cash flows in a defined stress scenario over a 30-day period. It is calculated by subtracting the projected cash inflows from the projected cash outflows. The cash outflows are determined by applying runoff or drawdown rates to the outstanding balances of various liability categories and off-balance sheet commitments. Similarly, the cash inflows are calculated by applying inflow rates to the outstanding balances of contractual receivables, subject to a cap of 75% of the total expected cash outflows (BCBS, 2013).

The Net Stable Funding Ratio (NSFR) is another regulatory measure implemented by the Basel Committee to foster a more resilient banking system. It requires banks to maintain a stable funding profile in relation to the composition of their balance sheet. As a result, it restricts excessive reliance on short-term wholesale funding and encourages funding stability. The issues stemming from the excessive maturity transformation undertaken by financial institutions came to the fore during the 2007 financial crisis, when numerous banks faced difficulties due to inadequate liquidity management frameworks. The NSFR is defined as the ratio of available stable funding to required stable funding, which should be maintained at a minimum of 100% on an ongoing basis. The NSFR is calculated through the following formula (BCBS, 2014):

$$\frac{Available\ amount\ of\ stable\ funding}{Required\ amount\ of\ stable\ funding} \geq 100\% \quad [2.6]$$

When analysing the maturity of an equity or liability instrument, it is presumed that investors will always exercise call options as early as possible. In contrast, the amount of stable funding that is required is calculated based on the liquidity risk profile of an institution's on-balance sheet assets and off-balance sheet exposures. When determining the maturity of an equity or liability instrument, investors are assumed to exercise call options at the earliest possible date. Conversely, the required stable funding is measured based on the liquidity risk profile of the institution's assets and off-balance sheet exposures. The required stable funding is calculated by applying the required stable funding (RSF) factor to the carrying value of assets, in accordance with the categories prescribed by the BCBS. The RSF factors assigned to different asset types are intended to estimate the number of assets that would need to be funded, either because they will mature or because they cannot be liquidated through sale or utilised as collateral in a secured borrowing transaction within a year without incurring substantial costs (BCBS, 2014).

Tier 3 capital is no longer considered in the regulatory framework. Additionally, the systemic risk buffer and the buffer for systemically important institutions are determined on a case-by-case basis, depending on the bank, country, and economic conditions. The internal capital requirement set by the regulator under Pillar 2 must be met through the Supervisory Review and Evaluation Process (SREP), resulting in a total capital requirement that can accumulate to 20% or more. To ensure the quality of regulatory capital, there are stringent rules regarding the eligibility of capital instruments that can be included. Specifically, Tier 1 capital is designed to absorb any ongoing operating losses of the bank, and Tier 2 capital is intended to serve as a liability base for wind-down scenarios.

Finally, Basel III has increased the capital requirements for securities financing activities, repurchase agreements, and counterparty credit risk arising from derivatives. The new framework has developed strategies to mitigate systemic risk and the cyclical effects of Basel II. It implements a countercyclical capital buffer that varies from 0% to 2.5%, depending on the state of the economy.

2.3.4 Stress testing

A bank stress test is a simulation premised on an examination of the financial statement of that institution. Large international banks commenced using internal stress tests in the early 1990s. In 1996, the Basel Capital Accord was amended to require banks and investment firms to conduct stress tests to assess their ability to respond to market events. However, before 2007, stress tests were customarily performed solely by the banks themselves for internal self-evaluation.

The global financial crisis highlighted substantial deficiencies in the methodologies employed by banks to assess and mitigate risk throughout the financial system. With regard to stress testing conducted by banks, the scenarios implemented prior to the crisis were found to be substantially more benign than the crisis itself, and the loss estimates generated by these exercises fell well short of banks' actual loss experience. In addition to revealing the shortcomings of stress-testing practices within banks, the financial crisis also prompted a fundamental shift in the use of stress testing within the regulatory domain. Regulatory stress tests transitioned from being small-scale, discrete exercises within the broader risk assessment framework to large-scale, comprehensive risk assessment programs in their own right, directly informing policy responses (BCBS, 2009).

The Supervisory Capital Assessment Program (SCAP) by the U.S. Federal Reserve in 2009 was an early example of the new wave of stress tests. The SCAP aimed to assess whether the largest U.S. banks had capital buffers sufficient to cover losses and enable them to continue operating under a scenario of severe stress. This scenario was intentionally more adverse than the expected economic conditions at the time. The success of the SCAP work encouraged widespread implementation of regular stress testing protocols by central banking authorities and regulatory bodies. The first EU-wide stress test was conducted in late 2009 under the direction of the Committee of European Banking Supervisors. This was followed by another exercise directed by the CEBS[25] in 2010 and a series of exercises under the European Banking Authority from 2011 onwards (Schuermann, 2010).

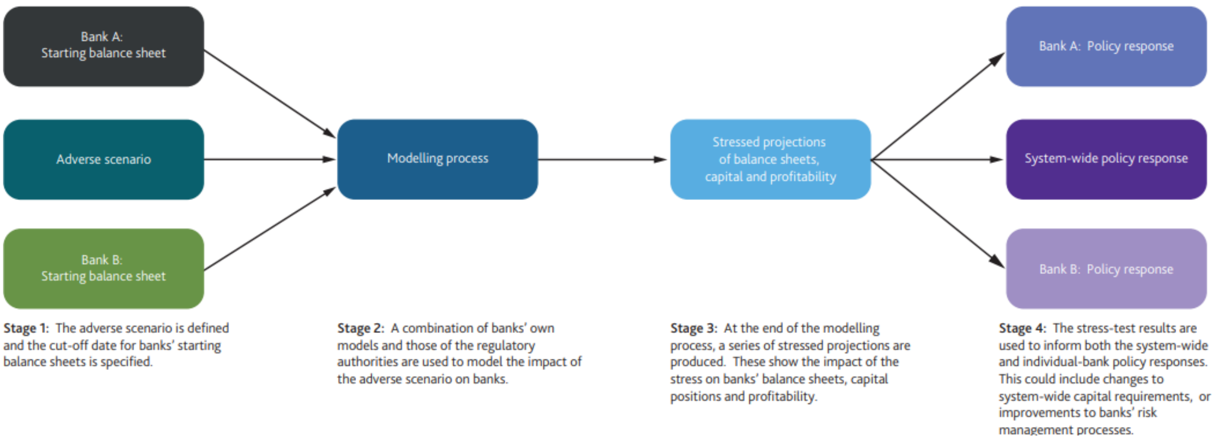
The potential stresses analysed aim to evaluate the banks' resilience to the risks they face. These often consist of severe macroeconomic and financial market scenarios, including an intense recession accompanied by financial market instability. These are not the central forecasts for

[25] The Committee of European Banking Supervisors (CEBS) was an autonomous advisory entity on banking supervision within the European Union (EU), active from its inception in 2004 until its dissolution on 1 January 2011, when the European Banking Authority (EBA) assumed all its functions and obligations in accordance with Regulation (EC) No. 1093/2010 of the European Parliament and Council dated 24 November 2010.

the economy and markets; rather, they represent unlikely but severe outcomes chosen by stress testers because of their potentially damaging impact on banks. If such hypothetical events were to occur, they would likely lead to banks incurring losses and a reduction in the capital available to absorb further losses. Stress-test practitioners often supplement these adverse scenarios with a baseline scenario where the macroeconomic and financial environment evolves in accordance with their principal assumptions. Baseline projections can provide useful information about banks' anticipated strategies for the years ahead, as well as serve as a benchmark against which to analyse results under hypothetical stress. Projections of banks' capital positions conditional on the stress scenario tend to be the primary findings of a stress test. These results can be utilised for various purposes, with some authorities employing them to highlight financial stability risks, others incorporating them into their approach to setting individual bank capital requirements, and some using them to inform macroprudential policy as well.

Figure 7 offers a schematic representation of one form of concurrent stress test centred on individual banks. Other stress test approaches may encompass diverse or supplementary elements, such as feedback mechanisms arising from the anticipated responses of other financial market actors to the unfavourable scenario.

Figure 7. An illustration of a stress test



Source: Dent et al. (2016)

The design of a stress test scenario typically consists of two main parts: selecting the types of risks to assess and determining the intensity of potential shocks. One approach is to simulate a deep and widespread recession that affects the broader economy and financial markets. This also allows regulators to calibrate their responses more effectively to reflect the interconnections of risks across banks and their impact on the different portfolios on the balance sheets of banks. To build such scenarios, authorities typically use economic models to keep stress projections consistent. These adverse scenarios usually include forecasts for key macroeconomic indicators (such as unemployment rates, economic growth, and asset prices) that align with expected trends during severe recessions. As a result, both asset prices and output decline dramatically, while unemployment is observed to increase (Dent et al., 2016).

Unfavourable macroeconomic conditions can affect the capital positions of banks through different mechanisms. For example, high unemployment might lower households' capacity to repay mortgages and unsecured loans. A decline in property prices could reduce the value of collateral-securing mortgages, causing greater losses when borrowers default. In addition, if banks encounter rising funding costs, adverse economic conditions may yield further repercussions, including diminished profitability from their lending and deposit-taking operations. Stress tests may also include adverse traded risk scenarios when changes in financial market conditions reduce the profitability of banks' trading operations. Additionally, stress tests may cover elements that are less directly tied to the economy, such as higher redress payments for past misconduct.

Banks generally run scenario-based stress tests (baseline and adverse scenarios) to ascertain how such events will affect their finances in terms of their balance sheets, profitability, and capital levels. There are several ways to arrive at these projections, for example, through models developed either by the banks themselves or by regulatory authorities or, in most cases, a combination of both. Projections could also be produced on the basis of macroeconomic top-down models or microeconomic bottom-up models. A top-down model seeks first to understand the stress's system-wide implications before dwelling on individual bank impacts, and a bottom-up micro-model seeks to assess the stress's effects first at the individual bank level, subsequently looking into system-wide consequences.

Bottom-up modelling can be undertaken either by the stress-testing authority or by the participating banks themselves. The key advantages of having banks produce their own bottom-up stressed projections are that they may possess more granular data and better-customised models than regulatory bodies, for whom developing bespoke models for each participating bank would be resource-intensive. In cases where the banks are responsible for providing the projections, the authorities typically adopt a quality assurance role, scrutinising the banks' diverse approaches to ensure the results are as comparable across institutions as possible. Authorities may also generate their own bottom-up projections. This approach offers the benefit of greater control over the underlying assumptions, thereby enhancing the comparability of the results across institutions (Grundke., 2011).

Meanwhile, the key advantage of utilising top-down macro-models is their enhanced capability to capture system-wide implications of a stress scenario, although this may result in greater uncertainty regarding projections for individual banks. Top-down modelling is conventionally undertaken by authorities responsible for stress testing. Banks have limited ability to factor in system-wide impacts as they lack access to comprehensive data on other firms within the system (Kapinos and Mitnik, 2016).

Various approaches to stress testing enable the attainment of distinct objectives. For instance, a methodology that prioritises detailed modelling of the stress impact at a portfolio level within diverse institutions is likely more suitable for authorities aiming to set capital for individual banks. Conversely, stress testers seeking enhanced comprehension of systemic risks may be less interested in the insights derived from resource-intensive granular models, favouring instead macro-models that better project the systemic ramifications of a stress event. Some authorities adopt a mixed approach, whereby banks are responsible for generating their own forecasts, which are subsequently adjusted by the authorities based on a combination of top-down and bottom-up analysis. These adjustments may serve to improve the consistency of projections across banks or, in principle, to account for system-wide impacts of the stress that an individual bank's models may not fully capture.

Within the broader regulatory capital framework, stress tests focused on banks' capital positions (also referred to as solvency-oriented assessments) are merely an analytical instrument utilised to evaluate banks' compliance with the stipulated requirements. Consequently, stress testing is simply a supplementary element to a resilient capital framework and not its substitute. Moreover, the reliability of stress test results is related to the data, methodology and assumptions adopted in their preparation. Although significant progress has been made in the development of these methodologies over recent years, the way stress test results continue to evince significant uncertainty is worrying. It is for this reason that stress-test results are just one of the inputs.

CHAPTER III

INTEREST RATE AND LIQUIDITY RISK MANAGEMENT

Asset and Liability Management (ALM) scope can be categorised into two distinct areas: the first pertains to universal concepts, while the second focuses on bank-specific aspects influenced by situational factors. Within the first category, key areas include interest rate risk management, liquidity, and capital. Financial theories are of little help in designing a bank's balance sheet; for this reason, banks have to implement different methods to maintain the desired capital level. Due to capital shortages, this strategy is no longer practicable or efficient in the present financial landscape. As a result, new capital adequacy management strategies have emerged, particularly focusing on business areas without capital requirements. A notable example is US banks, which are not subject to capital requirements for products equivalent to loans, but are classified as off-balance sheet items.

Liquidity management encompasses the overall liquidity position of a bank and, more specifically, the management of short-term funding. Liquidity requirements within a single bank might differ considerably; for example, domestic banking businesses, because of regulatory protections and market concentration, may be shielded from market disturbances that could otherwise affect short-term liquidity. A market-oriented liquidity management approach could involve analysing and influencing cash flow patterns to minimise costs and facilitate handling new regulatory requirements. At the core of cash flow structures is a schedule of asset and liability maturities. The next step involves identifying incoming and outgoing flows from assets and liabilities without a fixed maturity date but with stable movement patterns. Less easy to determine, yet highly important, is the need for contingency measures to mitigate potential risks against the possibility of unforeseen events.

The second key universal concept in ALM, Interest Rate Risk Management (IRRM), treats the bank as a portfolio of interest-bearing instruments, primarily bonds. The net return of such a portfolio is inherently sensitive to market interest rate fluctuations, with varying impacts depending on the maturity structure of the underlying securities. IRRM seeks to balance current and potential future profits or losses, consistent with the bank’s overall risk tolerance. In order to do so, banks need to accurately forecast future cash flows from their portfolio, separating fixed repricing schedules from interest rate-sensitive instruments. Consequently, interest rate forecasting and time horizon planning become fundamental components of risk management.

Capital serves two primary functions: firstly, funding the bank's infrastructure, including fixed assets; and secondly, protecting deposits against unexpected losses. This highlights risk as the core issue in capital adequacy management, underscoring the importance of identifying, measuring, and effectively managing risk to ensure financial stability.

The second category, which relates to bank-specific aspects influenced by particular situational factors, comprises elements that can significantly affect the decision-making process in Asset and Liability Management (ALM). Various approaches can be employed to incorporate these factors into the ALM planning process.

Among these factors are:

1. *Relevant financial markets*;
2. *Applicable regulatory framework*;
3. *Taxation and accounting considerations in ALM decisions*;
4. *Competitive structure of the bank's market*;
5. *The bank's business model and activity mix*.

These aspects play a crucial role in risk management, not only in relation to interest rate and liquidity risks but also to all other risks inherent in banking operations.

This chapter is organised as follows. Section 3.1 explores the concept of Interest Rate Management, illustrating the main methods to manage this risk and, after that, several measures of Interest Rate Risk. Lastly, section 3.2 follows the same structure as the previous one but shifts its focus to Liquidity Risk.

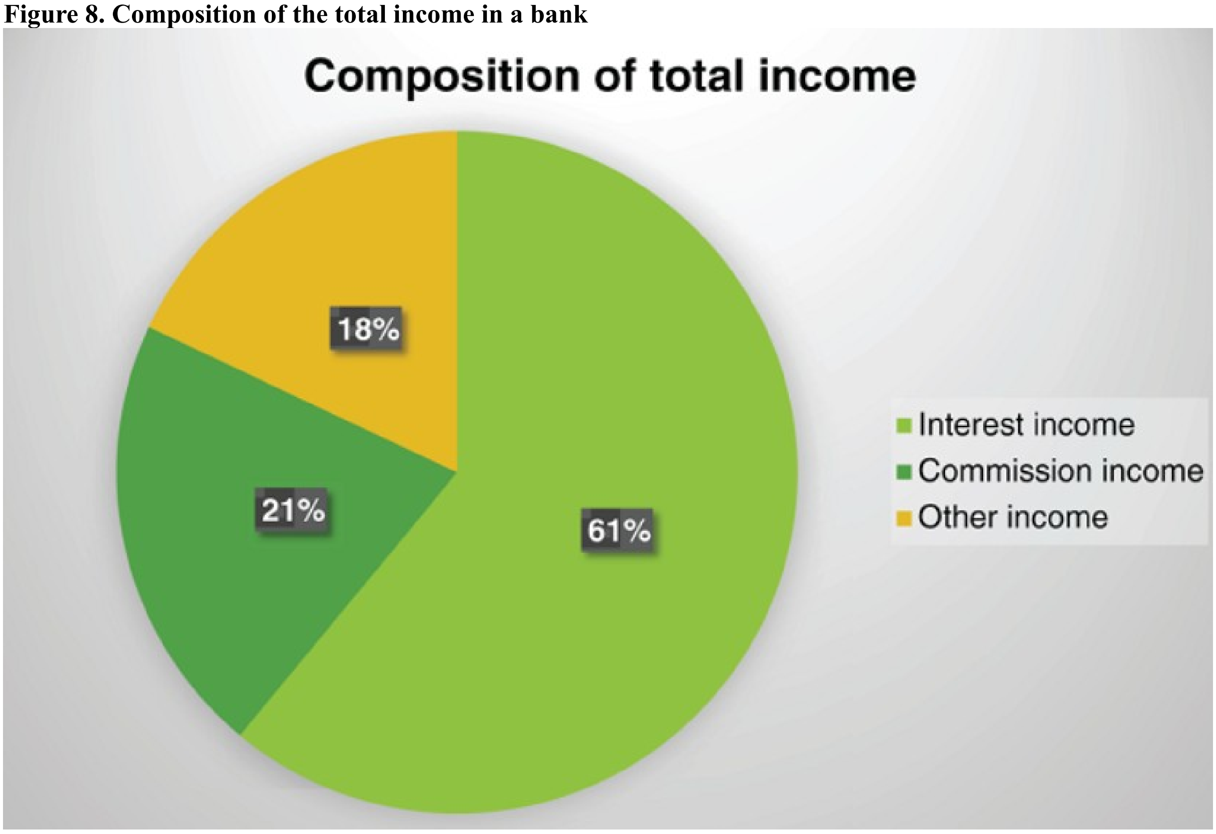
3.1 Interest Rate Risk Management (IRRM)

Interest Rate Risk (IRR) has become a hot topic in recent years, and there is a clear trend towards standardising the IRR approaches for measurement, modelling and monitoring in the banking industry. From a regulatory perspective, the journey started in April 2016 when the Basel Committee on Banking Supervision (BCBS) published the final Standards (BCBS Standards) on IRR that replaced the 2004 Principles. The new standards set out the Committee's expectations on the management of IRR in terms of identification, measurement, monitoring, control and supervision and reflect changes in supervisory practices due to the exceptionally low interest rates, whilst providing methods and models to be used by banks in a wider and enhanced risk management framework. BCBS Standards had an essential impact on the global adoption of standardised metrics. They emphasised a clear difference between market risk (inherent in the trading book) and IRR (inherent in the banking book) (Lubinska, 2021).

Interest rate risk refers to the exposure of a bank's financial standing to unfavourable fluctuations in interest rates. Accepting this risk is a routine aspect of banking and can be a crucial source of profitability and shareholder value. Nevertheless, excessive interest rate risk can significantly threaten a bank's earnings and capital base. Variations in interest rates impact a bank's earnings by altering its net interest income and the level of other interest-sensitive income and operating expenses. Furthermore, changes in interest rates affect the underlying value of the bank's assets, liabilities, and off-balance-sheet instruments, as the present value of future cash flows is altered when interest rates change. Consequently, an effective risk management process that mitigates interest rate risk within prudent levels is essential for the safety and soundness of banks (BCBS, 2016).

Changes to interest rates threaten a bank's earnings by impacting its Net Interest Income (NII), which is the bank's main source of earnings. It is estimated that NII contributes, on average, about 60% to a bank's total income (Figure 8).

Figure 8. Composition of the total income in a bank



Source: Lubinska (2021)

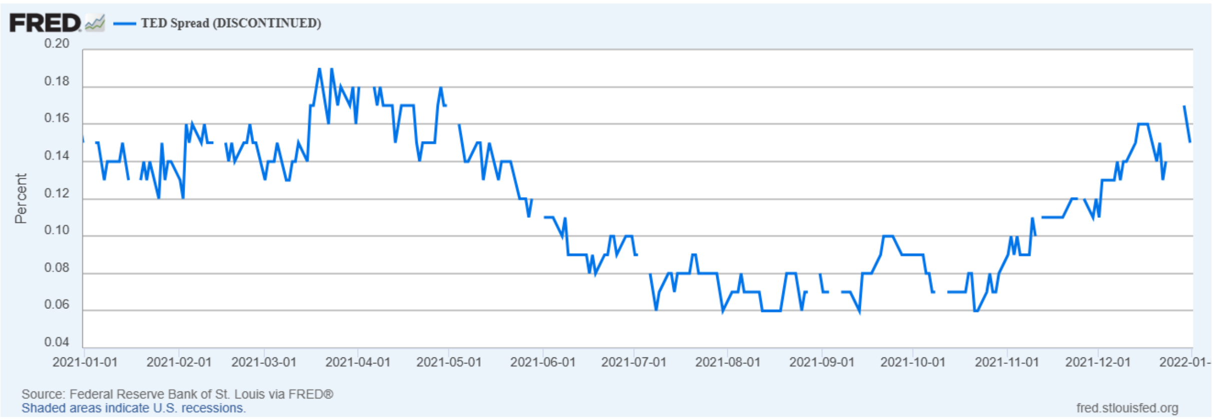
Changes to interest rates also threaten the underlying value of the bank's assets, liabilities, and off-balance sheet instruments, given the adverse impact that may arise on the present value of items, particularly their future cash flows. This is known as the impact on the economic value of the banking book, which is understood as the sum of the net present value of assets, the net present value of liabilities and the net present value of off-balance sheet items.

There are four primary sources of interest rate risk inherent in an ALM book (BCBS, 2016):

- *Mismatch, gap or repricing risk*: As financial intermediaries, banks encounter interest rate risk in various ways. The primary and most commonly discussed form of interest rate risk stems from timing disparities in the maturity and repricing of bank assets, liabilities, and off-balance-sheet positions. Such repricing mismatches are inherent to banking operations, but they can make a bank's income and underlying economic value susceptible to unpredictable changes in interest rates. For instance, a bank that has financed a long-term fixed-rate loan with a short-term deposit may confront a decline in both the future revenue from the position and its underlying worth if interest rates rise. These declines arise due to the loan's fixed cash flows over its lifetime, while the interest paid on the funding is variable and escalates following the maturity of the short-term deposit;
- *Yield curve risk*: Repricing mismatches can also make a bank vulnerable to changes in the yield curve's gradient and configuration. Yield curve risk manifests when unforeseen yield curve shifts negatively impact a bank's revenue or underlying economic worth. For instance, the intrinsic economic worth of a long holding in 10-year government bonds secured by a short position in 5-year government notes could diminish dramatically if the yield curve becomes steeper, even if the position is hedged against uniform yield curve movements. The ALM manager will change the structure of the book to take into account their views on the yield curve;
- *Basis risk*: Another important source of interest rate risk, known as basis risk, originates from imperfect correlation in the adjustment of the rates obtained and paid on several instruments with comparable repricing characteristics. When interest rates fluctuate, these divergences can lead to unanticipated changes in the cash flows and profit margins between assets, liabilities and off-balance sheet instruments with similar maturities or repricing frequencies. For example, a strategy of funding a one-year loan that reprices monthly based on the three-month US Treasury bill rate, with a one-year deposit that reprices monthly based on three-month LIBOR, exposes the institution to the risk that the spread between the two index rates may change unexpectedly (Figure 9);

- *Option risk*: The options embedded in numerous bank assets, liabilities, and off-balance sheet portfolios constitute an additional and increasingly crucial source of interest rate risk. Formally, an option grants the holder the right, but not the obligation, to purchase, sell, or alter the cash flow of an instrument or financial contract. Options can be standalone instruments, such as exchange-traded options and over-the-counter contracts (OTC) or embedded within otherwise standard instruments. While banks utilise exchange-traded and OTC options in both trading and non-trading accounts, instruments with embedded options are typically more significant in non-trading activities. Examples of instruments with embedded options include various types of bonds and notes with call or put provisions, loans that give borrowers the right to prepay balances, and various types of non-maturity deposit instruments that grant depositors the right to withdraw funds at any time, often without penalties. If not adequately managed, the asymmetric payoff characteristics of instruments with optionality features can pose a significant risk, particularly to those who sell them, as the options held, both explicit and embedded, are generally exercised to the advantage of the holder and the disadvantage of the seller. Moreover, the proliferation of options can entail significant leverage, which can amplify the impact (both negative and positive) of option positions on the firm's financial condition.

Figure 9. TED spread from 01-01-2021 to 01-01-2022



Source: Federal Reserve Bank of St. Louis via FRED

3.1.1 Interest Rate Risk Management Models

To manage this risk, management avails itself of computer-based tools that identify guidelines for the subsequent analysis phase. In this sense, not only does the available data become central, but also the chosen computer-based model into which the data is entered to perform the technical analyses and, finally, the reports that constitute the guidelines for risk management analysis, with the consequent choice of actions to be undertaken. The data used in the analysis are collected in the financial statements, which include all types of assets and liabilities characterised by risk. Therefore, the accounting rules and the national or international standard-setter employed are of considerable importance.

By its very nature, accounting in general and the balance sheet in particular do not provide direct information about interest rate risk. Still, collecting precise data is the first step in devising defensive strategies against risk exposure. Computer-based models are critical for managing interest rate risk because they provide a framework for measuring current exposure and its impact on management decisions. To deepen the management's knowledge about the sensitivity of the balance sheet to the interest rate, it is necessary to draw up a report on the static gap, where the gap means the difference between interest-sensitive assets and interest-sensitive liabilities over a defined time interval, such as 30 days. Interest rate-sensitive assets include maturing, repricing, and amortised assets within the designated time frame. Additionally, some assets may be subject to early repayment, although not all banks factor these into the gap calculation. Interest rate-sensitive liabilities include maturing, repricing, and liabilities that allow early redemption. Thus, the gap is essentially a structured dataset grouping assets and liabilities based on contractual maturity, repricing frequency, and amortisation schedules.

Forecasting plays a critical role in risk management. Equally important are the assumptions underlying the forecasts, which are typically based on five key factors:

1. *Roll strategies for maturing funds*;
2. *Target forecasts or growth projections for balance sheet asset and liability categories*;
3. *Expected maturity distribution for newly added funds*;
4. *The interest rate environment*;
5. *Pricing relationships*.

Once these assumptions are established, financial institutions can apply simulation models to analyse the economic and managerial implications of their assumptions on corporate performance.

Simulation models play a crucial role as they produce the possible scenarios that the bank must face in terms of risks, precisely due to the assumptions made preliminarily about the possibility of these risks occurring. Additionally, these models allow financial institutions to stress-test their exposure to interest rate fluctuations. Unlike the static gap model, the dynamic gap model, which is integrated into simulation models, enables banks to combine existing exposures at the start of the simulation with additional exposures expected to arise throughout the period under analysis.

Over time, interest rate risk management has evolved through the development of various analytical techniques. Some models have been introduced as enhancements to previous methodologies, while others present fundamentally different approaches to risk evaluation. The most well-known techniques include:

- *The repricing gap model*;
- *The duration gap model*;
- *Cash-flow mapping models*;
- *Internal transfer pricing methodologies*.

A detailed analysis of these methodologies will be provided in the following sections.

3.1.1.1 The Repricing Gap Model

The repricing gap model is income-based, in the sense that the interest margin is the variable on which the possible variation in interest rates is considered. To this end, the concept of the gap is introduced as a synthetic measure of exposure to interest rate risk that links the variations in market interest rates to the variations in the interest margin. This relationship is expressed through the following formula:

$$G_t = SA_t - SL_t = \sum_{j=1}^{n} sa_{t,j} - \sum_{i=1}^{m} sl_{t,i} \quad [3.1]$$

Where G_t is the Gap for the period under review, while SA_t and SL_t are respectively sensitive assets and liabilities or rather those which expire or which are subject to review interest rate during the period t. $sa_{t,j}$ represents instead the j-nth sensitive asset and $sl_{t,i}$ represents the i-nth sensitive liabilities.

The overall net interest income, related to the activity of credit intermediation, is as the difference between the interests of financial assets, II, and the interests of financial liabilities, IE:

$$NII = II - IE = r_A \cdot FA - r_L \cdot FL = r_A(SA + NSA) - r_L(SL + NSL) \quad [3.2]$$

from which:

$$\Delta NII = \Delta r_A SA - \Delta r_L SL \quad [3.3]$$

The variation ΔNII is based on the simple consideration that the Δr_m produce effects on interest rates or yields of the bank r_A and r_L, and consequently the Δr_m produce effects even on the SA_t and SL_t.

If we assume that the changes in active and passive interest rates are equal, we will have:

$$\Delta r_A = \Delta r_L = \Delta r \quad [3.4]$$

from which:

$$\Delta NII = \Delta r(SA - SL) = \Delta i\left(\sum_{j=1}^{n} sa_{t,j} - \sum_{i=1}^{m} sl_{t,i}\right) = \Delta r \times G_t \quad [3.5]$$

From the last formula, it becomes evident that as the variation in interest rates increases, the net interest income also rises, provided that the gap is positive (meaning that the value of assets exceeds that of liabilities). This leads to a greater increase in interest income at the expense of interest expense, resulting in a rise in the net interest margin. Conversely, in the presence of a negative gap, interest expense grows more than interest income, producing a negative net interest margin. If the gap is positive and interest rates are rising, the overall effect on the change in the net interest income will also be positive. However, the net interest income will decrease if interest rate movements are downward and interest-sensitive assets exceed interest-sensitive liabilities (Table 2). Therefore, in an environment where interest rates are expected to rise, banks should aim to reduce the absolute value of any potential negative gap or increase the size of a likely positive gap. Conversely, when a decline in market interest rates is anticipated, banks should implement strategies opposite to those outlined above (Lubinska, 2021).

Table 2. How do variations of the net interest income vary with respect to gap and interest rate changes

	$\boldsymbol{Gap > 0}$ **(Positive net reinvestment)**	$\boldsymbol{Gap < 0}$ **(Positive net refinancing)**
$\boldsymbol{\Delta r > 0}$	$\Delta NII > 0$	$\Delta NII < 0$
$\boldsymbol{\Delta r < 0}$	$\Delta NII < 0$	$\Delta NII > 0$

Source: Author's elaboration

Up to this point, it has been assumed that sensitive assets and liabilities have identical maturities or that their repricing occurs within the following twelve months. However, in reality, this is not always the case. There are two primary methods for addressing this issue: the maturity-adjusted gap and the marginal and cumulative gaps.

The maturity-adjusted gap is based on the idea that changes in interest rates affecting rate-sensitive assets and liabilities have an impact only during the period between the instrument's maturity or repricing date and the end of the gapping period. In particular, in the case of any sensitive assets j-nth, that yields an interest rate $r_{a,j}$ at maturity p_j, it will produce a loan rate related to the next year (Bisceglia and Cico, 2017):

$$ii_j = sa_j \cdot r_{A,j} \cdot p + sa_j\left(r_{A,j} + \Delta r_{A,j}\right)\left(1 - p_j\right) \quad [3.6]$$

The preceding formula illustrates how the interest rate of a rate-sensitive asset can be divided into two components: one certain component, represented by $sa_j \times r_{A,j} \times p_j$, and one uncertain component, represented by $sa_j\left(r_{A,j} + \Delta r_{A,j}\right)\left(1 - p_j\right)$. The uncertain component reflects the potential fluctuations in interest rates due to future market conditions.

From this, it follows logically that changes in interest income are influenced solely by the uncertain component, leading to the conclusion that (Bisceglia and Cico, 2017):

$$\Delta ii_j = sa_j \Delta r_{A,j}\left(1 - p_j\right) \quad [3.7]$$

and considering all the n assets of the bank,it turns out that

$$\Delta II = \sum_{j=1}^{n} sa_j \, \Delta r_{A,j}\left(1 - p_j\right) \quad [3.8]$$

likewise for the liabilities we will have

$$\Delta ii_i = sl_i \Delta r_{L,i}(1 - p_i) \quad [3.9]$$

and for all the m banks‘ liabilities we‘ll have

$$\Delta II = \sum_{i=1}^{m} sl_i \Delta r_{L,i}(1 - p_i) \quad [3.10]$$

Assuming a uniform variation of the active and passive interest rates, or rather

$$\Delta r_{A,j} = \Delta r_{L,i} = \Delta r, \forall (j,i) \in \{1,2, \dots, n(m)\} \quad [3.11]$$

we can then estimate the variation of the interest margin of the bank as

$$\Delta NII = \Delta II - \Delta IE = \left(\sum_{j=1}^{n} sa_j\left(1 - p_j\right) - \sum_{i=1}^{m} sl_i(1 - p_i) \right) \Delta r = G^{MA} \Delta r \quad [3.12]$$

In this case, G^{MA} represents the maturity-adjusted gap, which refers to the gap adjusted for maturity. It is calculated as the difference between rate-sensitive assets and liabilities, with each component weighted according to the time interval between its maturity date or interest rate reset and the end of the gapping period.

The second approach refers to marginal gaps and cumulative gaps:

- Marginal (or periodic) gaps represent the difference between assets and liabilities subject to interest rate renegotiation within a specific future period. These are denoted as $G'_{t1}, G'_{t2}, G'_{t3}$, and so on;
- Cumulative gaps, on the other hand, measure the difference between assets and liabilities with interest rate adjustments occurring by a given future date. These are represented as G_{t1}, G_{t2}, G_{t3}, and so forth.

The distinction between these two types of gaps is essential because an absolute gap does not exist; rather, the gap depends on the definition of the gapping period chosen for monitoring the impact of interest rate fluctuations on the bank's exposure. The number of gaps will correspond to the period the bank considers relevant for assessing interest rate risk. If the reference period is extended to the final maturity of all assets and liabilities, the calculated value will effectively represent the bank's equity. According to the definitions provided above, cumulative gaps are simply the algebraic sum of the marginal gaps over time. For example, if we consider only two periods, t_1 and t_2, we can state that:

$$G_{t1} = G'_{t1} + G'_{t2} \quad [3.13]$$

$$G'_{t2} = G_{t1} - G'_{t1} \quad [3.14]$$

To accurately assess a bank's actual exposure to interest rate fluctuations, it is useful to introduce an average maturity t_j^*, which serves as a reference point within marginal gaps. This measure represents the midpoint between the starting date $(I - t_j)$ and the final date of the given period t_j. It is calculated as follows:

$$t_j^* = \frac{t_j + t_{j-1}}{2} \quad [3.15]$$

This approach allows us to use t_j^* as an approximate repricing date for both assets and liabilities included within the marginal gap G_{tj}^*. By doing so, it enables the calculation of changes in the net interest margin without necessarily relying on the exact repricing date:

$$\Delta NII \cong \Delta r \sum_{j|t_{j\leq 1}} G_{tj}^{*} \cdot \left(1 - t_j^{*}\right) = \Delta r \cdot G_1^{W} \quad [3.16]$$

where, G_1^W represents the one-year weighted cumulative gap, while ΔNII refers to the duration of the net interest margin which is an indicator of the sensitivity of the interest margin to changes in market interest rates. Since the calculation employs t_j^* , the precision of this indicator is slightly lower than that provided by the maturity-adjusted gap. However, in terms of its conceptual meaning, it remains highly similar: if interest rates decline, the bank will be exposed to an amount equivalent to ΔNII.

The practical utility of marginal gaps extends beyond static interest rate risk assessment. They also enable the calculation of changes in the net interest margin when multiple interest rate fluctuations occur within a year. To achieve this, it is necessary to consider the different time horizons over which variations produce effects. But this leads us to an important deduction: thanks to the marginal gaps, we can calculate the effect on the interest margin of a possible time path of interest rates. Even if the bank were subject to a single rate variation, the financial institution would not be equally immunised from interest rate risk. A change in the net interest margin may still occur even when the cumulative gap is zero, as long as marginal gaps differ from zero. This happens for two main reasons:

1. The presence of effects on the net interest margin generated by a single market interest rate fluctuation (i.e., a non-zero weighted cumulative gap);
2. The frequent occurrence of interest rate variations, potentially with opposite signs to the marginal gaps (i.e., non-zero marginal gaps).

3.1.1.2 The Duration Gap Model

As previously mentioned, when discussing the limitations of the repricing gap model, one of its key weaknesses is that it fails to account for the impact of interest rate fluctuations on the market value of assets and liabilities. We previously highlighted the necessity of shifting the target variable used for risk assessment. By shifting the focus to stock variables, particularly the market value of the bank's assets, a more accurate model is obtained for the management and containment of interest rate risk. First, we define what is meant by the duration of a financial instrument, namely the arithmetic mean of the maturities of the cash flows associated with it, where each maturity is weighted by the ratio between the present value of the cash flow associated with that specific maturity and the price of the financial instrument itself. By making explicit both the residual life of the instrument and the amount of the intermediated flows, the duration allows us to use it as a risk indicator. From a mathematical perspective, this concept is formalised as Macaulay duration, which is defined by the following expression (Bierwag and Kaufman, 1985):

$$D = \sum_{t=1}^{T} t \cdot \frac{\frac{CF_t}{(1+r)^t}}{P} \quad [3.17]$$

where, t represents the time to maturity (in years) of an individual cash flow, while CF_t refers to the cash flow received at time t. The symbol r denotes the yield to maturity (YTM) required by the market at the final maturity date T, and P represents the price or market value of the financial instrument. Finally, T signifies the overall maturity of the asset. Since we have previously mentioned the potential use of duration as a risk indicator, it is necessary to demonstrate this assertion. To do so, we begin with the definition of the price of a financial instrument:

$$P = \sum_{t=1}^{T} \frac{CF_t}{(1+r)^t} \quad [3.18]$$

deriving with respect to the yield rate, we have:

$$\frac{dP}{dr} = \frac{-1 \cdot CF_1}{(1+r)^2} + \frac{-2 \cdot CF_2}{(1+r)^3} + \cdots + \frac{-T \cdot CF_T}{(1+r)^{T+1}} \quad [3.19]$$

From [3.19] it follows that:

$$\frac{dP}{dr} = -\frac{1}{(1+r)} \left[\frac{CF_1}{(1+r)} + \frac{CF_2}{(1+r)^2} + \cdots + \frac{CF_T}{(1+r)^T} \right] \quad [3.20]$$

Dividing both sides by P gives us:

$$\frac{dP}{dr}\frac{1}{P} = -\frac{1}{(1+r)} \sum_{t=1}^{T} t \cdot \frac{\frac{CF_t}{(1+r)^t}}{P} = -\frac{D}{(1+r)} \quad [3.21]$$

and consequently:

$$\frac{dP}{P} = -\frac{D}{(1+r)} \cdot dr \quad [3.22]$$

in which, $\frac{D}{(1+r)}$ represents the modified duration. This measure is particularly useful for quantifying the percentage change in the price of a financial instrument in response to an infinitesimal change in market yields. In reality, if we consider finite variations in yield rates rather than infinitesimal ones, we have that modified duration can be seen as an indicator of the sensitivity of the financial instrument to changes in market rates. Specifically, we can express this as:

$$\frac{\Delta P}{P} \cong -\frac{D}{(1+r)} \cdot \Delta r \quad [3.23]$$

Duration is characterised by three fundamental properties:

1. It is expressed in time units, often in years;
2. For a fixed-rate financial instrument, the duration increases as the instrument's residual maturity lengthens and as the cash flow from the coupon decreases, assuming all other factors remain constant;
3. The duration of a portfolio is the weighted average of the durations of the individual securities within it, with each security weighted by its market value.

Having introduced the concept of duration, we can now address the duration gap model's core: the duration gap estimation. Due to its being an indicator of the asset's sensitivity, the novelty introduced by the duration gap allows us to estimate the effect that would be had on the market value of the balance sheet items as a result of a change in interest rates. This concept can be formulated mathematically by considering DM as the modified duration of the financial positions. Keeping in mind that both duration and modified duration represent the weighted averages of active and passive financial positions, the duration for assets can be expressed as:

$$\frac{\Delta MV_A}{MV_A} = -\frac{D_A}{(1+r_A)} \cdot \Delta r_A = -MD_A \cdot \Delta r_A \quad [3.24]$$

while for liabilities we will have:

$$\frac{\Delta MV_L}{MV_L} = -\frac{D_L}{(1+r_L)} \cdot \Delta r_L = -MD_L \cdot \Delta r_L \quad [3.25]$$

from which:

$$\Delta MV_A \cong -MV_A \cdot MD_A \cdot \Delta r_A \quad [3.26]$$

$$\Delta MV_L \cong -MV_L \cdot MD_L \cdot \Delta r_L \quad [3.27]$$

where D_A and D_L represent the average weighted durations of the bank’s assets and liabilities, MD_A and MD_L, the respective modified durations and r_A and r_L, the average asset and liability yield rates.

By combining [3.26] and [3.27], we can estimate the change in the market value of the bank's equity:

$$\Delta MV_B = \Delta MV_A - \Delta MV_L \cong (-MV_A \cdot MD_A \cdot \Delta r_A) - (-MV_L \cdot MD_L \cdot \Delta r_L) \quad [3.28]$$

Assuming that changes in asset and liability yield rates are the same ($\Delta r_A = \Delta r_L = \Delta r$), [3.28] becomes:

$$\Delta MV_B \cong -(MV_A \cdot MD_A - MV_L \cdot MD_L) \cdot \Delta r \quad [3.29]$$

Dividing both sides of equation [3.29] by the asset market value, we get:

$$\frac{\Delta MV_B}{MV_A} \cong -\left(MD_A - \frac{MV_L}{MV_A} \cdot MD_L\right) \cdot \Delta r \quad [3.30]$$

Introducing an indicator of the bank's financial leverage, L, equal to:

$$L = \frac{MV_L}{MV_A} \quad [3.31]$$

its possible to rewrite ΔVM_B as:

$$\Delta MV_B \cong -(MD_A - L \cdot MD_L) \cdot MV_A \cdot \Delta r = -DG \cdot MV_A \cdot \Delta r \quad [3.32]$$

where DG is the duration gap, defined as:

$$DG = MD_A - L \cdot MD_L \quad [3.33]$$

From the last rewriting of the variation in the value of the balance sheet items, we can note that it depends on three factors: the size of the intermediated activity carried out by the bank, the size of the variation in interest rates, and finally, the duration gap. At the same time, it is possible to identify the conditions required to immunise the market value of equity against potential interest rate changes. These conditions are primarily twofold:

1. If the initial net value is zero, that is:

   $$MV_B = MV_A - MV_L = 0 \quad [3.34]$$

   immunisation will be achieved if the sensitivity of assets and liabilities is identical:

   $$MD_A = MD_L \quad [3.35]$$

   in this scenario, the duration gap will also be negative;

2. If, on the other hand, the initial value of equity is positive:

   $$MV_A > MV_L \rightarrow MV_B > 0 \quad [3.36]$$

Immunisation will be achieved through a zero gap, meaning:

$$MD_A = L \cdot MD_L \quad [3.37]$$

This implies that the duration of assets must be lower than that of liabilities, resulting in a positive duration gap.

Even in cases where the duration gap is zero, the bank remains protected against fluctuations in market interest rates, meaning these changes theoretically do not impact the market value of equity. However, even if the duration gap is not zero, the formula used to calculate the change in the market value of equity allows for a quantification of this variation in response to interest rate changes. Table 3 summarises the general relationship between the sign of a bank's duration gap and the impact of changing rates on the market value of equity.

Table 3. Duration gap summary

Duration Gap	Change in interest rate	Assets	Liabilities	Equity
Positive	Increase	Decrease >	Decrease →	Decrease
Positive	Decrease	Increase >	Increase →	Increase
Negative	Increase	Decrease <	Decrease →	Increase
Negative	Decrease	Increase <	Increase →	Decrease
Zero	Increase	Decrease =	Decrease →	None
Zero	Decrease	Increase =	Increase →	None

Source: Author's elaboration

3.1.1.3 Cash-flow mapping models

There are models based on the more realistic assumption that interest rate variations resulting from changes in market rates are not uniform for assets and liabilities but rather differ between them. These models consider the zero-coupon yield curve (term structure) and apply cash-flow mapping techniques to align individual cash flows from a bank's assets and liabilities with a limited number of key points, or nodes, on the term structure. Each node represents a specific maturity date to which multiple cash flows (potentially with slightly different maturities) are mapped. As previously discussed, neither the repricing gap nor the duration gap is a validly applicable method in the operational reality of a bank, as they are based on the equality of interest rate variations both in the case of decreases and increases, whether they refer to assets or liabilities. This constitutes a significant problem, which cash-flow mapping models seek to solve. The first critical challenge in applying this methodology is the need for a yield curve that allows each cash flow, whether asset or liability, to be assigned a specific interest rate. This issue is tackled by constructing a term structure of interest rates based on the yields of financial instruments that do not pay interim coupons between issuance and maturity, called zero-coupon bonds. To develop this structure, market prices of bonds are used, and techniques such as bootstrapping or alternative approaches are applied to derive the interest rates that form the yield curve. The second challenge in using cash-flow mapping methods lies in identifying a limited number of maturity dates to which all asset and liability cash flows can be assigned. Various cash-flow mapping techniques have been developed to address this, with the most common being discrete interval methods and clumping techniques. They involve the determination of q nodes or vertices of the yield curve, which are fewer in number than the actual dates p of the cash flow maturities that have actually occurred. This requires careful consideration of three key factors (King, 2010):

- Short-term interest rate changes tend to be larger and more frequent than long-term rate changes;
- Interest rate volatility generally decreases as maturity increases and eventually stabilises due to mean reversion in yields;
- Bank cash flows are typically more concentrated in the short-term maturities.

All these factors lead us to consider how assigning a greater number of nodes in the short term is necessary and how the choice of these same nodes must also take into account the concrete realisation of hedging policies.

Cash-flow mapping techniques can be classified into two distinct categories: discrete interval models and clumping methods. Within the first category, three main approaches can be identified:

1. *The duration intervals method*
2. *The Basel Committee Method*
3. *The modified residual life method*

3.1.1.4 Internal Transfer Rates (ITR)

Nowadays, banks operate through a central headquarters along with multiple branches spread across the national and, often, international territory. Each branch, through its deposit-taking and lending activities, is exposed to various types of risk such as credit risk, interest rate risk, and others. To ensure effective management of interest rate risk within the banking book, banks implement an internal transfer rate system (commonly referred to as ITR). This system consists of a set of fictitious internal transactions within the bank, aimed at accumulating in a single central unit the decisions on the position the bank wants to undertake regarding variations in market rates. The ITR system is structured around four key objectives:

1. Transferring interest rate risk from the peripheral units (branches) that generate it to the central treasury unit, which is responsible for evaluating and managing this risk, including through hedging strategies;
2. Assessing the actual profitability of risk management activities, as risk is centralised in the treasury;
3. Enabling peripheral units to focus on client-related activities, without the need to handle their own funding operations or manage the investment of collected funds;
4. Accurately evaluating the contribution of each branch to the bank's overall profitability.

From an operational perspective, the ITR system involves the implementation of notional borrowing and lending transactions between the treasury and the branches. This ensures that the interest rate risk, in particular, is transferred solely to the treasury unit, allowing it to carry out the best possible management of the rate risk. There are two distinct approaches to the ITR system, depending on whether a single or multiple interest rate framework is used: the single-rate ITR and the multiple-rate ITR.

A single-rate internal transfer pricing (ITR) system involves using a fixed interest rate for all transactions between the treasury and branches, regardless of their maturity. Conversely, the multi-rate ITR system considers the maturity profile of the notional transactions initiated by the treasury. While the single-rate ITR approach is simpler to implement, it presents several drawbacks. Firstly, it is chosen on an arbitrary basis and is therefore different from the market rate recorded at the time of the analysis. Secondly, since only a single rate is used, transactions are settled on a net flow basis, resulting in a situation where most of the interest rate risk remains with the branches rather than being transferred to the treasury. This is because only the risk embedded in the net positions is centralised (Berg and Koziol, 2017).

Through their branches, banks have relationships with customers that involve fixed-rate and variable-rate transactions. In the case of fixed-rate transactions, the ITR rate is determined at the outset of the transaction and remains unchanged until maturity. However, for variable-rate transactions, where rates are indexed to market benchmarks such as Euribor or Libor, it is easier for the treasury to hedge the risk associated with the notional transaction with the branch. This is done by executing an opposite transaction in the market, effectively neutralising the risk.

However, some variable-rate transactions with clients do not follow market benchmarks and instead use administered rates for indexing. These may include Repo rates or other reference rates published by banking associations. The use of such rates presents two main challenges:

1. *Lack of hedging instruments*: No financial instruments are available in the market that allow banks to hedge against fluctuations in these administered rates fully;
2. *Basis risk*: If the bank chooses to use market instruments to mitigate interest rate risk, it may be exposed to basis risk, as the movements in the administered rate may not align perfectly with those of the hedging instrument.

It is common practice for banks to offer clients transactions with embedded options, such as: fixed-to-floating rate conversion options, variable-rate transactions with a cap, variable-rate transactions with a floor, variable-rate transactions with both a cap and a floor (interest rate collar), and lastly transactions with early repayment options.

3.1.2 Measures of Interest Rate Risk

This section examines the key measures of Interest Rate Risk in banks. It presents an overview of these measures and a brief explanation of each measure's risk subcategories.

Two primary methodologies are used to measure Interest Rate Risk (IRR) exposure. The first approach employs static models, providing a snapshot of the risk position at a particular point in time. The interest rate curve is deterministically defined, and the balance sheet remains static. This common practice is often utilised by smaller and less complex financial institutions. The static perspective is likewise applied in regulatory reporting, such as the standardised approach recommended by BCBS Standards.

Conversely, the dynamic approach, also known as simulation, enables the simulation of the IRR position under stochastically defined interest rate curve scenarios and changes in the balance sheet structure over time. This necessitates a system infrastructure capable of simulating future net interest income (NII) for various purposes under an integrated and flexible approach. Regulators have also mandated such NII simulations on multiple occasions, including EBA stress tests, ECB IRR stress tests, and Short-Term Exercises. The advanced ALM system provides a simulation module that allows for alterations to the balance sheet structure of a financial institution and simulates the movements of the term structure of interest rates.

3.1.2.1 Change in the Economic Value of Equity (ΔEVE)

The economic value of equity (EVE) represents the theoretical change in the net present value of the balance sheet, excluding equity, which consists of risk-sensitive assets minus risk-sensitive liabilities. Therefore, this measure demonstrates the equity value change resulting from an interest rate shock. Under this approach, the equity value under alternative stress scenarios is compared to the value under a base scenario. This base interest rate scenario is the present value of assets minus liabilities in the current interest rate environment. All cash flows from on-balance sheet and off-balance sheet interest rate-sensitive items in the banking book may be included in the calculation. The market value of equity is computed as the present value of asset cash flows minus the present value of liability cash flows, without incorporating assumptions about the interest rate sensitivity of equity. The balance sheet is then revalued under alternative interest rate scenarios, and the difference between the equity value under the base scenario and the alternative scenario is determined. The accuracy of the valuation of the balance sheet positions is extremely dependent upon the cash flows calculated and the discount rates used. The discount rates employed should align with the duration and risk of the cash flows. According to the BCBS Standards, the cash flows in certain time buckets are discounted using the rates at the midpoint of the time bucket, either the risk-free rate or adjusted rates if the cash flows include commercial margins. Banks have the option to deduct the commercial margin and other spread components from the notional repricing cash flows through the FTP methodology. Consequently, the discounting factor must be consistent with the approach chosen for the EVE cash flow calculation (Lubinska, 2021).

The static approach (unconditional cash flows) assumes that the timing and magnitude of cash flows remain unchanged across different scenarios, regardless of customer behaviour. In reality, there is a direct correlation between interest rate scenarios and the extent of deposit prepayment and growth. For instance, if the rates decrease, the prepayment rate tends to increase as clients shop for cheaper borrowing opportunities. Conversely, on the liability side, savers often search for new investment opportunities, potentially increasing the volatility of this product. These client behaviour-adjusted cash flows, known as conditional cash flows, represent the best practice for EVE calculation. Additionally, the ΔEVE approach provides a photograph of the risks based on the current portfolio or balance sheet composition. However, it is possible to 'simulate' the potential impact of future business activities, such as forecast growth or product cannibalisation, on this position. The impact of such a simulated position is assessed over a longer time interval, for example, annually. It reflects the situation at that specific point in time, considering the composition of the new banking book. This approach is still static, but it incorporates assumptions about growth. In contrast, the dynamic approach simulates the banking book position based on various external and internal factors, generating a simulated curve at a particular point in time.

Table 4 illustrates the changes in EVE under a number of interest rate scenarios. In particular, the change in EVE is driven by both the change in discount factor under the base and shock scenarios and the change in the value of automatic options as a function of the underlying interest rate scenarios.

Table 4. Change in the EVE under a number of interest rate scenarios

Interest rate scenario	EVE	Change relative to base scenario	Change related to base scenario/ Tier 1
+200 bps	14.669	−3.425	−1.3%
+100 bps	17.005	−1.089	−0.4%
0	18.094	-	-
−100 bps	17.864	−230	−0.08%

Source: Lubinska (2021)

The economic value of equity (EVE) under scenario i and currency c is calculated as follows (Abdymomunov et al. ,2023):

$$EVE_{i,c} = \sum_{k=1}^{K} CF_{i,c}(k) \cdot DF_{i,c}(t_k) \quad [3.38]$$

where $CF_{i,c}(k)$ represents all notional repricing cash flows within a given time bucket $k \in \{1,2,\dots,K\}$; $DF_{i,c}(t_k)$ indicates the discount factor which reflects the interest rate shock scenario i in currency c and where t_k is the midpoint of time bucket k. It represents the risk-free rate.

The discount factor is computed as:

$$DF_{i,c}(t_k) = exp\left(-r_{i,c}(t_k) \cdot t_k\right) \quad [3.39]$$

The EVE in currency c under the base scenario is calculated with the following formula:

$$EVE_{0,c} = \sum_{k=1}^{K} CF_{0,c}(k) \cdot DF_{0,c}(t_k) \quad [3.40]$$

Finally, the full change in EVE in currency c associated with scenario i is obtained by subtracting $EVE_{0,c}$ from the EVE under shocked interest rate term structure $EVE_{i,c}$ and by adding the total measure for automatic interest rate option risk $KAO_{i,c}$ as follows:

$$\Delta EVE_{i,c} = \sum_{k=1}^{K} CF_{i,c}(k) \cdot DF_{i,c}(t_k) - \sum_{k=1}^{K} CF_{0,c}(k) \cdot DF_{0,c}(t_k) + KAO_{i,c} \quad [3.41]$$

If $\Delta EVE_{i,c} > 0$, then the economic value of the banking book is going to increase; whereas if $\Delta EVE_{i,c} < 0$ the bank faces the reduction in its economic value. $KAO_{i,c}$ is an add-on for the calculation of the change in value of the automatic interest rate options, whether explicit or embedded.

3.1.2.2 Earnings at Risk (EaR) or Net Interest Income (NII) at risk

NII measures the potential loss of net interest income, which results from upward or downward movements in interest rates over a specific time frame, typically 12 months. It belongs to a category of dynamic models that assess risk exposure by considering projected changes in maturities, repricing relationships, and the size of the banking book. A key characteristic of this method is that the cash flows fluctuate based on the underlying stress scenario, known as "conditional cash flows". Examples of such flows include changes driven by early prepayment and the behavioural patterns of Current Account and Savings Account (CASA) deposits. When interest rates fall, asset-side cash flows increase due to early redemption of fixed-rate assets, while CASA volatility on the liability side decreases. This reduction in balance volatility and the growing CASA balances are observed in a low-rate environment, as customers prefer to "park" their funds in banks' accounts while awaiting more attractive investment opportunities. These "surge" deposits provide banks with a cheap and stable funding source. However, when interest rates start to rise, these funds are likely to migrate towards alternative products (Li, 2007).

Under the dynamic approach, a financial institution's Net Interest Income (NII) is assessed under a baseline interest rate scenario. This scenario is established based on the current interest rate environment and specific assumptions regarding customer deposit behaviour and balance sheet volumes. The outcome of this base scenario is then compared to an alternative (stressed) scenario to evaluate the potential impact of interest rate fluctuations. Table 5 illustrates an example of a Net Interest Income (NII) at risk calculation, which considers a range of parallel interest rate shocks.

In some instances, banks conduct NII simulations under predefined interest rate scenarios and determine sensitivity by calculating it as the difference between the highest and lowest projected results. The primary focus of this analysis is to interpret fluctuations in the reported sensitivity figure on a periodic basis. If there are no structural changes in the balance sheet composition, sensitivity variations are primarily influenced by repricing gap movements and the effect of the time factor.

Table 5. Calculation of NII

Interest rate scenario (in bps)	NII (in 000 GBP)	Change relative to base scenario (in 000 GBP)	% change
+300	5.670	-205	-3.49
+200	5.739	-136	-2.31
+100	5.807	-68	-1.16
0	5.875	-	-
-100	5.942	67	1.14
-200	6.008	133	2.26
-300	6.075	200	3.40

Source: Lubinska (2021)

3.1.2.3 Value at Risk (VaR)

Value at Risk is an estimate of the loss from a fixed set of data over a fixed time horizon that would be equal or exceeded with a given probability. For example, if the reported daily VaR is \$100,000 with a 95% confidence interval, this indicates that there is only a 5% probability that the loss on the following day will exceed \$100,000. VaR is a measure of a bank's risk exposure. Consequently, from the mathematical standpoint, it can be defined as:

$$P(V_T - V_0 \leq VaR) = 1 - \alpha \quad [3.42]$$

where α is the confidence level; V_t and V_0 arevalues Mark to Market (MTM) of the portfolio at time T and 0 respectively; finally, T is the time horizon under consideration.

VaR is a simulation-based method used to quantify changes in the market value of a portfolio resulting from fluctuations in market prices. It models a series of potential fluctuations in the yield curve and employs this to generate a distribution of potential profit and loss scenarios. Furthermore, VaR measures the potential decline in the market value of a portfolio by employing estimated volatility and correlation. The "correlation" in question refers to the relationship between the market prices of different instruments within a bank's portfolio. VaR is calculated within a specified confidence interval, typically 95% or 99%, and aims to gauge the possible losses from a position or portfolio under a normal distribution assumption. To implement VaR, a firm must collect all its position data into a centralised database (Duffie and Pan, 1997).

To calculate the VaR for a two-stock portfolio, for example, we will use the following formula:

$$VaR_{port} = \sqrt{w_1^2\sigma_1^2 + w_2^2\sigma_2^2 + 2w_1w_2\sigma_1\sigma_2\rho_{1,2}} \quad [3.43]$$

where, w_1 and w_2 are the weighting, respectively, of the first and second asset; σ_1 and σ_2 are the standard deviation or volatility of the first and second asset; finally, $\rho_{1,2}$ represents the correlation coefficient between the two assets.

Subsequently, the overall risk is determined by aggregating the risks from individual instruments across the entire portfolio. The potential move in each instrument (that is, each risk factor) has to be inferred from historical daily price movements over a given observation period. This period is at least one year for regulatory purposes, ensuring that the data underpinning VaR estimates encompasses all relevant daily market movements over the preceding year. The primary assumption underpinning VaR, which may also be considered a key weakness, is that the distribution of future price and rate changes will mirror past variations. Consequently, the potential portfolio loss calculations for VaR are based on distributions derived from historical price data in the observation period.

There are three main methodologies for calculating VaR:

1. *Variance-covariance method*
2. *Historical simulation method*
3. *Monte Carlo simulation method*

3.2 Liquidity Risk Management

Liquidity refers to a bank's capacity to finance asset growth and fulfil its obligations as they become due, without sustaining excessive losses. The fundamental role of banks in the maturity transformation of short-term deposits into long-term loans makes banks inherently vulnerable to liquidity risk, both of an institution-specific nature and that which affects markets as a whole. Almost every financial transaction or commitment has implications for a bank's liquidity.

Therefore, effective liquidity risk management helps ensure a bank's ability to meet cash flow obligations, which are inherently uncertain due to external events and the actions of other market participants. Liquidity risk management is of paramount importance because a liquidity shortfall at a single institution can have system-wide repercussions. Over the past decade, developments in financial markets have significantly increased the complexity of liquidity risk and the challenges associated with its management (BCBS, 2008).

Banks should differentiate between short-term and structural liquidity risk, which aligns with liquidity risk and funding risk definitions, respectively:

- Short-term liquidity risk describes the risk that a financial institution lacks sufficient financial resources in the near term to fulfil its obligations as they fall due, or can only obtain these resources at an excessive cost;
- Structural liquidity risk denotes the risk of actual or potential loss as the bank cannot pursue its desired business strategy or growth objectives due to a suboptimal balance sheet structure, including an over-reliance on particular funding sources.

To manage liquidity risk, it is essential to address and recognise two distinct components that constitute it: funding risk and market liquidity risk. The funding risk refers to the risk that the bank is unable to efficiently fulfil anticipated and unanticipated cash outflows without compromising its ordinary operations and financial equilibrium. On the other hand, market liquidity risk is characterised as the risk that the bank, in order to monetise a significant position in financial assets, ends up substantially influencing the price, due to the insufficient depth of the financial market in which these assets are traded, or its temporary malfunction. A difference between the two risks could be that the funding risk is dependent on the repricing period of assets and liabilities, while the market liquidity risk is dependent on the actual maturity of the items, as that is the moment when the primary cash flow will take place (Kumar and Yadav, 2013).

Liquidity risk can manifest on both sides of the bank's balance sheet, arising either from insufficient liquidity generated through selling or repurchasing assets or from inadequate liquidity available through various funding sources to meet obligations as they fall due. In reality, the triggering causes of liquidity risk can be ascribed to factors specific to the individual bank and to systemic factors. Specific factors for the individual bank refer to circumstances in which the bank's customers are prompted to recover their credits at the bank as quickly as possible, due to a deterioration of trust in the relationship between the customer and the bank or between the bank's operators and the bank itself. Systemic factors, on the other hand, refer to generalised crises of confidence in which the population of a nation resorts to bank branches to close their current accounts, or their existing relationships with the bank, and withdraw the entire amount accumulated therein. Other examples of systemic factors are, for instance, market crises with consequent periods of inactivity and inability to promptly liquidate listed financial assets. It is evident that to manage and measure the two aspects of liquidity risk, different techniques are required, which we will analyse further.

There are numerous examples of triggering events found in the market, such as the crystallisation of market, credit or operational losses within the bank, damage to the bank's reputation, or a market-wide liquidity stress. Liquidity mismatches between assets and liabilities, and significant short positions of the bank in relation to counterparties and customers, represent the most common sources of bank vulnerability. An example of a triggering event is large losses in trading portfolios that, once known in the market, can cause unsecured funding from other banks to cease being available. Another example is a market value decline of a derivative trading position, which initiates additional collateral posting to the counterparty or triggers the position's liquidation under adverse conditions. Similarly, the disclosure of large losses from credit portfolios (for example, large loan loss provision) or due to operational risks (for example, wrong settlement processes) can initiate a downgrade of the bank's external rating, which will likely precipitate a liquidity crisis for the bank. These risks are often interrelated, and their disclosure can significantly impact the bank's reputation and, consequently, its liquidity situation.

3.2.1 Funding Risk Management Models

It is clear from the previous definition of funding risk that if the maturities of the assets and liabilities on the balance sheet were precisely aligned, this risk could be eliminated entirely. Over time, the approach most commonly used has been the active management of the liquid assets held and of liquidity in general. All the methods employed have in common a focus, more or less marked, on maturity-mismatch positions in order to "ride the wave of the yield curve" and increase their profits before interest rate adjustments become necessary. Funding risk has several unique characteristics compared to other financial risks. Firstly, while it manifests as temporary fluctuations in available cash flows, it does not necessarily translate into direct financial losses. Secondly, funding risk management is often carried out by multiple legal entities within the same banking group. The second characteristic refers to the impossibility for a banking holding company to freely transfer funds from one legal entity to another in the event of a liquidity crisis, since this could have the opposite effect, that is, to weaken the legal entities in question and cause a weakening of the entire group structure. To mitigate funding risk, banks typically employ three key methodologies (Drehmann and Nikolaou, 2013).

3.2.1.1 Stock-based approach

The stock-based approach to liquidity management is based on the measurement of readily monetisable financial assets that the bank can use to mitigate a potential liquidity crisis. Monetisable assets (MA) refer to all those assets that can be rapidly converted into cash or equivalents, such as loans and some of the bank's portfolio securities. Among loans, a specific portion of on-demand credit facilities is considered, provided they can be liquidated without compromising the bank's relationship with clients or undermining the financial stability of its debtors. In this approach, the emphasis is placed not on contractual maturities but on the actual liquidity of these assets.

The portion of securities in the bank's portfolio classified as monetisable includes only those that are unencumbered, meaning they are free from any commitments or collateral agreements, and they are adjusted for a "haircut." The haircut serves two key functions: first, it accounts for a potential devaluation the bank may have to accept when selling these securities in the secondary market; the second function is to constitute the spread between the value of the securities and the value, certainly lower, of the short-term loan that the bank could obtain if it used them as collateral. Unencumbered securities may include short-term and long-term bonds, as well as equities, which can be pledged as collateral for loans. However, assets with higher volatility are subject to greater haircuts, reducing the overall value of monetisable securities.

Beyond monetisable assets, the stock-based approach also considers volatile liabilities, committed facilities, and stable credit lines, as these elements contribute to a key risk metric within this framework (Matz and Neu, 2007):

- *Volatile Liabilities (VL)*: These include on-demand or very short-term funding sources with uncertain renewal. This category encompasses funds sourced from professional counterparties, such as overnight borrowings or short-term repurchase agreements (repos), as well as the portion of on-demand client deposits deemed unstable. However, as it is improbable that all depositors will withdraw funds simultaneously, a portion of these deposits is considered "core deposits," meaning they are stable and excluded from the volatile liabilities category. Here too, the focus is on counterparties' actual behaviour rather than contractual maturities;

- *Committed Facilities (C)*: These represent off-balance sheet commitments where the bank has an irrevocable obligation to provide funding. Their repayment entails an outflow of funds that accumulates with that related to the likely repayment of volatile liabilities;
- *Stable Credit Lines (L):* These are irrevocable commitments made by third parties to the bank, enabling it to access additional funds without needing to pledge securities or other assets as collateral in times of liquidity stress.

3.2.1.2 Cash flow approach

The cash flow approach refines the classification of assets and liabilities undertaken in the stock-based approach by incorporating the maturity ladder, which consists of a structured set of time brackets. The maturity ladder is composed of eleven time buckets, including overnight, one week, two weeks, one month, two months, three months, one year, three years, five years, ten years, and beyond ten years. On-demand items receive specific treatment, focusing on their actual rather than contractual maturity. The cash flows from different balance sheet items are allocated across the time bands based on the bank's expectations, which are informed by past experiences and assume normal or moderately stressed market conditions. However, crisis scenarios should be separately quantified and reported.

A crucial aspect of this approach is the calculation of net cash flows and cumulative net cash flows:

- Net cash flow represents the balance for each individual time bucket and serves as the liquidity gap indicator;

- Cumulative net cash flow is derived by aggregating the cash flows of a given time bucket with those of preceding periods, forming the cumulative liquidity gap.

When assets exceed the resources derived from operations, a funding gap arises that necessitates sourcing from the wholesale market. Conversely, if liabilities exceed assets, the surplus resources must be invested in the market. The disparity between assets and liabilities at all future points in time is called the liquidity gap. Such gaps generate liquidity risk. A positive liquidity gap indicates a funding shortfall, implying that the bank has long-term obligations not presently financed by its existing operations. A negative liquidity gap instead indicates that the institution is unable to cope with foreseeable outgoing cash flows through the use of incoming cash flows. As mentioned earlier, long-term positions may generate short-term cash flows, making it essential to consider intermediate cash inflows and outflows. To hedge the gap exposure, banks and, in particular, ALM managers, generally apply FRAs and interest rate swaps (Choudhry, 2007).

In essence, the difference between this method and the previous one lies in the absence of stocks, replaced by the related inflows and outflows, including the interest payments. This approach shows its unreliability to accurately account for unencumbered assets, as they do reflect the contractual maturity of the securities, but are also used as collateral to obtain very short-term financing, a crucial aspect that this approach fails to consider.

3.2.1.3 Hybrid approach

The hybrid approach effectively accounts for the dual nature of unencumbered assets. If these assets are deemed eligible, they can be utilised by the bank to secure funds, even for very short-term needs. Consequently, these specific securities should be included in the shortest time bucket, while the associated haircut and interest component should remain assigned to their original maturity bucket. As a result of this adjustment, the maturity ladder will reflect an increased liquidity gap, as both cash inflows and outflows related to unencumbered assets are now incorporated into the calculation. When allocating cash flows to different time buckets, the bank makes assumptions regarding the uncertainty of these flows, whether related to their amount, timing, or both.

A scenario-based analysis is highly effective, as it enables banks to develop contingency funding plans (CFPs) in advance, ensuring they are prepared to respond effectively should the simulated liquidity crises materialise. The primary objective of a CFP is not only to react to a crisis but also to mitigate its systemic impact (Lai and Tuosto, 2016).

To assign a cash flow to one bucket rather than another, the bank makes assumptions regarding the uncertainty of cash flows in terms of their amount, timing or both. Given these uncertainties, it is preferable for banks to calculate their liquidity gap not only in normal scenarios but also, especially in stress scenarios, to measure their resilience in liquidity crisis situations. For cash flows with indeterminate maturities and uncertain timing, banks typically adopt one of two methodologies:

1. *Modelling uncertainty*
2. *Stress testing*

1. Modelling uncertainty

This approach offers two possible solutions for forecasting cash flows:

- *Replication portfolio models*: These models assume that a financial product with a fixed maturity can be replicated using a portfolio of simple financial instruments. The portfolio is designed to behave in a way that closely mirrors the original product under different market interest rate movements. The instruments typically used are plain vanilla securities traded in liquid markets, ensuring that the replicated portfolio generates similar cash flows and returns to the original product;
- *Option-based models*: These models explicitly define the value of embedded options within financial products with uncertain maturities. The option's value fluctuates depending on market interest rate movements, allowing for a more precise assessment of liquidity risk exposure.

2. Stress testing

As anticipated in Chapter II, the stress testing approach consists of a simulation exercise through which the effects of a particularly negative scenario are estimated, and in our case, we are obviously talking about the effects that liquidity risk can have on the institution's financial stability. Stress tests can be conducted using three distinct methods, which may also be applied in combination:

- *Historical approach*: This method analyses past events that affected the bank or other financial institutions, focusing on individual risk factors that previously led to liquidity stress;
- *Statistical approach*: This method is based on historical information to obtain the most truthful estimate of shocks linked to a strong liquidity tension, all thanks to the use of hypotheses on the distribution of risk factors;
- *Judgement-based approach*: This approach relies on expert judgement, incorporating insights from senior management, risk management teams, regulatory authorities, and external consultants.

The combination of these approaches allows banks to apply the most suitable methodology for each specific liquidity risk factor they encounter.

3.2.2 Liquidity Risk Ratios

This section outlines several critical liquidity risk management ratios and their implications for banks. Banks may monitor these ratios by putting in place an internally defined limit approved by the Board. They should determine their own limits based on their unique liquidity risk management capabilities, experience, and profile. These stock ratios are intended to monitor liquidity risk at the individual bank level. The main liquidity ratios are:

1. *Temporary Assets Ratio*: This ratio measures the proportion of a bank's temporary (short-term) assets[26] relative to its total assets. A higher ratio indicates a more liquid balance sheet, meaning the bank has a higher proportion of short-term assets that can be easily converted into cash. A lower ratio suggests that the bank's assets are more tied up in long-term investments or loans, which may limit its ability to meet immediate financial obligations.

$$\frac{Temporary\ Assets}{Total\ Assets} \quad [3.44]$$

2. *Liquidity Buffer Ratio*: This ratio measures the bank's ability to cover volatile liabilities (short-term obligations or unstable funding sources) using its temporary (liquid) assets. A higher ratio indicates that the bank has a strong liquidity position and is better prepared to handle unexpected withdrawals or funding disruptions. A lower ratio suggests that the bank relies heavily on volatile liabilities, which may pose a liquidity risk if those liabilities need to be repaid quickly.

$$\frac{Temporary\ Assets}{Volatile\ Assets} \quad [3.45]$$

3. *Current Ratio*: This ratio measures a company's or bank's ability to pay off short-term liabilities with its short-term assets. It indicates liquidity and financial health over a short-term period. If the Current Ratio > 1, the bank has more current assets than liabilities, meaning it can cover short-term obligations. If the Current Ratio < 1, the bank may have liquidity issues and might struggle to meet short-term liabilities. The ideal range is typically between 1.5 and 3, depending on the industry.

[26] Highly liquid assets that can be quickly converted into cash, such as cash equivalents, short-term investments, and marketable securities.

$$\frac{Current\ Assets}{Current\ Liabilities} \quad [3.46]$$

4. *Quick Ratio*: This ratio evaluates a bank's capacity to fulfil its short-term obligations using its most liquid assets (excluding inventory and prepaid expenses). It indicates how well an entity can meet immediate financial obligations without relying on asset sales. If Quick Ratio > 1, the bank has enough liquid assets to cover its current liabilities. If the Quick Ratio < 1, the entity may struggle to cover short-term obligations without selling long-term assets.

$$\frac{Cash + Marketable\ Securities + Accounts\ Receivable}{Current\ Liabilities} \quad [3.47]$$

5. *Cash Ratio*: This ratio measures a bank's ability to pay off short-term liabilities using only its most liquid assets (cash and cash equivalents). It is a more conservative liquidity measure compared to the current ratio and quick ratio since it excludes accounts receivable and inventory. If the Cash Ratio > 1, the bank has more cash and equivalents than liabilities, meaning it can cover all short-term obligations immediately. If the Cash Ratio < 1, the bank may not have enough cash readily available to meet short-term liabilities. The ideal range is generally 0.5-1.0, but it depends on the industry.

$$\frac{Cash + Cash\ Equivalents}{Current\ Liabilities} \quad [3.48]$$

6. *Loan-to-Deposit Ratio (LDR)*: This ratio measures a bank's liquidity and ability to cover withdrawals from deposits. It denotes how much of a bank's deposits are being used for lending rather than held in reserves, and it helps assess credit risk and liquidity risk in banking institutions. If LDR < 1, the bank has more deposits than loans, meaning it has higher liquidity and lower risk. If LDR > 1, the bank has fewer deposits than loans, meaning it has lower liquidity and higher risk. In this case, the ideal range is 0.7-0.9, depending on regulatory and market conditions.

$$\frac{Total\ Loans}{Total\ Deposits} \quad [3.49]$$

3.2.3 Liquidity Gap Indicators

Structural liquidity risk is monitored by constructing a maturity ladder, where assets and liabilities are allocated to their respective time buckets. The cash flow projections for the different time buckets will be a function of the maturity profile, or, alternatively, for items without contractual maturity, it is necessary to model their corresponding cash flow profile through quantitative or behavioural models that are validated regularly. The structural liquidity analysis should encompass all balance sheet items that generate cash flows at the cut-off date, under some internally agreed-upon assumptions (such as a balance sheet in run-off, under a growth assumption, or a constant balance sheet). From a practical standpoint, the structural limits can be defined using the following formulas (Lubinska, 2020):

- *Structural Limit*: Gap ratio between cash inflows and outflows beyond 12 months must be higher than the threshold level established by the board of directors (usually 100%).

$$\frac{\sum Cash\ Out\ T > 1Y + Equity}{(\sum Cash\ In\ T > 1Y)} \geq b\% \quad [3.50]$$

  where *b%* is the threshold of structural ratio established by the board of directors. Taking into consideration the Basel III requirements related to the maintenance of a healthy balance between stable funding and medium long-term assets, this threshold is supposed to be above 100%.

- *Structural Warning 1*: Gap ratio between cash inflows and outflows beyond 3 years must be higher than the threshold level (usually lower than 100%).

$$\frac{\sum Cash\ Out\ T > 3Y + Equity}{(\sum Cash\ In\ T > 3Y)} \geq c\% \quad [3.51]$$

  where *c%* is the warning threshold level for the time buckets beyond 3 years. It is suggested, under a prudent approach, to keep it at or above 70%.

- *Structural Warning 2*: Some banks set up additional warnings for time buckets beyond 5 years. For commercial banks, it is common to see it at or above 60%.

$$\frac{\sum Cash\ Out\ T > 5Y + Equity}{(\sum Cash\ In\ T > 5Y)} \geq d\% \quad [3.52]$$

  where *d%* is the warning threshold level for time buckets beyond 5 years. It is suggested, under a prudent approach, to keep it at or above 60%.

The gap indicators aim to ensure consistency between the strategy established to fund medium to long-term assets and liabilities with the same maturity. A gap ratio value below the defined thresholds suggests that the volume of medium to long-term assets financed by short-term liabilities exceeds the level stipulated by the bank's policy.

CHAPTER IV

CASE STUDY: THE RISE AND FALL OF SILICON VALLEY BANK

On March 10, 2023, Silicon Valley Bank (SVB), a subsidiary of Silicon Valley Bank Financial Group (SVBFG), was closed by the California Department of Financial Protection and Innovation (CDFPI) (Federal Reserve System, 2023). The sudden collapse of SVB[27] has surprised numerous investors and industry experts, given the bank's recent accolades and longstanding reputation as one of the leading national and regional banks in the U.S. for several years.[28] Only a few weeks before its collapse, Forbes ranked SVB among the top American banks, praising its strong growth, solid credit quality, and profitability, positioning it as the 16th largest bank in the country and a symbol of strength within the financial sector.[29] Notably, there had been no bank failures during the COVID-19 pandemic from 2020 to 2022. The collapse of SVB, the second-largest bank failure in U.S. history, has raised numerous questions about the underlying issues and the unexpected failure of such a prosperous institution.

Probably the most important one is: Why do banks fail? Bank failures can result from a variety of factors, including inadequate regulation (Acharya and Richardson, 2009; Laeven and Valencia, 2013), economic instability (Aubuchon and Wheelock, 2010), weak corporate governance (Berger et al., 2016), and flawed risk management (Beltratti and Stulz, 2012). Analysing global systemic banking crises from 1970 to 2011, Laeven and Valencia (2013) identified poor regulatory oversight and weak supervision as key contributors to banking crises. Similarly, Aubuchon and Wheelock (2010) observed a direct correlation between economic downturns and bank failures. While Acharya and Richardson (2009) emphasised that excessive risk-taking plays a significant role, Berger and Bouwman (2013) identified inadequate capital levels as another leading cause.

Following the global financial crisis of 2008, the United States experienced a sharp rise in bank failures, peaking at 157 in 2010: the highest figure since the savings and loan crisis of the 1980s and early 1990s. Since then, the number of failures has steadily declined. One likely reason for this improvement is the introduction of regulatory reforms aimed at strengthening the banking

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27 Throughout this paper, Silicon Valley Bank Financial Group, the holding company, is referred to as "SVBFG", while Silicon Valley Bank, the state-chartered member bank, is referred to as "SVB." Where context requires, the term SVBFG refers to both.

28 More detailed information can be found at https://www.svb.com/newsroom/.

29 On February 14th, 2023, Forbes released a list of America's best banks. SVB was ranked as the 20th-best bank. More information can be found at https://www.forbes.com/lists/americas-best-banks/?sh=737e931dc0de.

sector. The Dodd-Frank Wall Street Reform and Consumer Protection Act, for example, introduced higher capital and liquidity requirements, as well as enhanced risk management frameworks (Le et al., 2016). These measures have contributed to the improved stability and resilience of the banking sector, reducing the likelihood of bank failures.[30] Additionally, the overall economic recovery and the banking industry's recovery from the financial crisis have also contributed to the decline in bank collapses.

This chapter is organised as follows. Section 4.1 introduces the SVB's case and illustrates its 40-year history. Section 4.2 continues with a deep analysis of the American Regulatory System and its application in the SVB's case, with a focus also on the Trump administration's impact on the DFAST and EGGRCPA. Section 4.3 discusses the CAMELS analysis results about SVB. Sections 4.4 and 4.5 are focused on SVB's ALM. In particular, Section 4.4 outlines SVB's liquidity strategy and management through the analysis of the available data from financial statements. Section 4.5 highlights the Board's interest rate risk mismanagement. Finally, Section 4.6 compares the EU regulation to the American one, illustrating similarities and differences.

4.1 40 years of Silicon Valley Bank: 1983-2023

Silicon Valley Bank was founded in 1983 in Santa Clara and, over its 40-year history, provided substantial support for the development of innovation, becoming a leading financial institution for numerous successful start-ups in the United States. The California-based bank is widely recognised, from a financial and strategic point of view, for its development of numerous entrepreneurial initiatives in the technology, healthcare and private equity sectors. The bank often financed these initiatives through mortgages with real estate guarantees and with long-term public securities. Its leading lenders, who operated mainly in the wholesale and short-term markets, were venture capital firms that deposited millions of dollars at the financial institution, which, in most cases, were not protected by any collateral (Montanaro, 2022).

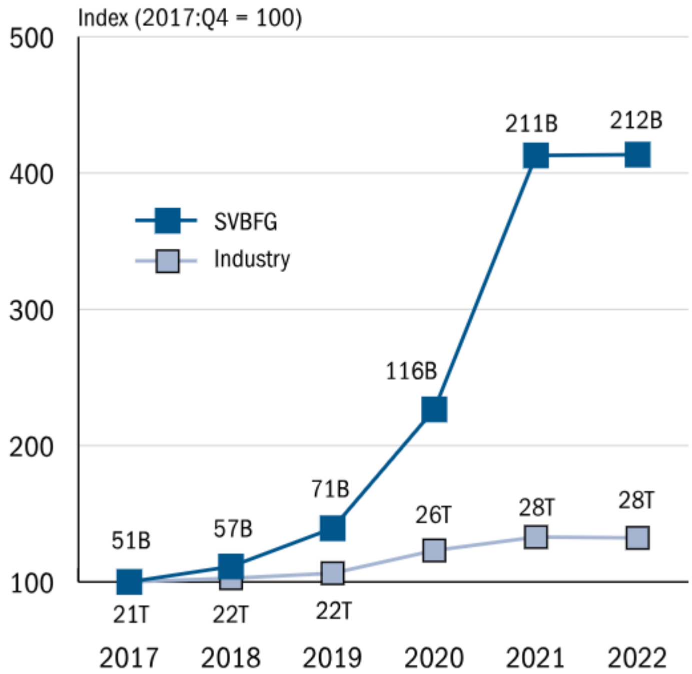
Throughout its existence, Silicon Valley Bank (SVB) underwent remarkable growth on multiple fronts. Structurally, it developed into a bank holding company, Silicon Valley Bank Financial Group (SVBFG), with its principal branch remaining in California. This transformation enabled the opening of several branches worldwide, particularly in India and China, to facilitate substantial financial intermediation to the growing number of customers located outside of

[30]https://fordschool.umich.edu/news/2020/barr-dodd-frank-strong-foundation-more-financial-reforms-needed-postpandemic.

Silicon Valley and the US territory. This organisational evolution was accompanied by rapid asset expansion. The value of the bank's assets grew dramatically, from roughly \$956 million in 1992 to nearly \$70 billion by 2019. During the COVID-19 pandemic, while much of the economy experienced a sharp downturn, many technology companies thrived due to rising demand for digital services. As these firms saw profits rise, they deposited increasing amounts of capital with banks. SVB, with its client base composed mainly of high-tech firms, was at the centre of this influx.

Consequently, SVBFG's growth accelerated further, peaking in the first quarter of 2022 with assets totalling \$212 billion. From the end of 2018 to the end of 2021, SVBFG's assets grew by an extraordinary 271%, compared to a 29% increase across the wider banking sector. However, in 2022, asset growth slowed significantly as the technology sector lost momentum amid a rising interest rate environment (Figure 10).

Figure 10. SVBFG and the banking industry total assets



Source: Board of Governors of the Federal Reserve System (2023)

SVBFG experienced substantial asset expansion during the COVID-19 pandemic due to several converging factors. The economic landscape, characterised by low interest rates and government stimulus measures, created an ideal environment for rapid expansion. Furthermore, in 2021, there was a marked increase in liquidity-generating events, including initial public offerings (IPOs), subsequent stock offerings, special purpose acquisition company capitalisations, venture capital allocations, corporate acquisitions, and diverse fundraising initiatives. While these events impacted the entire financial industry, SVBFG, with its focus on venture capital and start-up clients, experienced a disproportionately positive effect. SVBFG's 2021 annual report emphasises the bank's growth through new businesses, the integration of Boston Private, expansion in private banking, and its move into technology investment banking with SVBFG Securities. These strategic moves have played a significant role in driving SVBFG's growth during the pandemic. This can be partly attributed to the substantial increase in venture capital funding, which often supports the development of technology companies, leading to a sudden influx of large sums into the SVBFG's deposits during 2021. Figure 11 shows how the increase in deposits at SVBFG resulted in a rise in its share price, from $150 in March 2020 to $730 in January 2022.

Figure 11. SVBFG share price (US$) 2018-2023

Source: Economics Observatory (2023)

As with most banks, SVBFG invested a significant portion of the funds it received, allocating a large share to long-term US government bonds, which were generally regarded as low-risk. However, while long-term bonds are a safe investment, they are also susceptible to interest rate risk. SVBFG poured billions into bonds during the pandemic when interest rates were close to zero. The abrupt spike in rates dictated by the Fed's monetary policy, in line with other central banks around the world, caused SVBFG's bond portfolio to lose significant value. This decline occurred because higher interest rates made newly issued bonds far more attractive to investors than the older, lower-yielding ones SVB had acquired during the pandemic. Although these losses were technically unrealised, since the bonds would not have needed to be sold before maturity, SVBFG was ultimately compelled to sell a portion of its long-term holdings due to a surge in customer withdrawals. The end of the tech boom from the end of 2021 onwards, in fact, resulted in many of SVBFG's clients drawing down their deposits, thus reducing the bank's reserves. The economic pressures facing tech firms (falling revenues, tighter access to funding, and widespread cost-cutting, including layoffs) were the main forces behind the increased withdrawals. SVBFG's close ties to the tech industry are further illustrated by the timing of its share price collapse, which closely mirrored the broader decline in the valuations of US technology companies (Economics Observatory, 2023).

The crisis began on 8 March, when Silicon Valley Bank reported a $1.8 billion loss on its bond portfolio and announced plans to raise $2.25 billion through a stock offering. As a result, Moody's downgraded the bank's credit rating. The following day, 9 March, SVB Financial Group's share price plummeted by 60% at market open, with valuations of other banks also falling sharply. In response, SVB clients rushed to withdraw their deposits, totalling $42 billion. Trading in SVB's shares was suspended, and as no buyer could be secured, the bank was placed into receivership under the Federal Deposit Insurance Corporation (FDIC). It was announced that insured deposits would be accessible by the following Monday. In the days that followed, federal authorities introduced emergency measures in response to the bank's collapse, guaranteeing that all deposits, including those not covered by insurance, would be fully returned to customers.

On March 10, SVBFG management anticipated further losses exceeding $100 billion. The scale and speed of this deposit outflow were extraordinary, amounting to approximately 85% of the bank's total deposits. For context, estimates indicate that during the collapse of Wachovia in 2008, approximately $10 billion was withdrawn over eight days, while Washington Mutual experienced outflows of $19 billion over sixteen days (Federal Reserve System, 2023).

In response to these actual and expected deposit outflows, its collapse officially took place in the morning of 10 March 2023, when the California Department of Financial Protection and Innovation decreed the closure of the Bank: the decision taken by the Department became inevitable in the face of the enormous losses that SVB suffered over the previous two days. This scenario led to the later bankruptcy of SVBFG.

The Federal Reserve's report (April 2023) examines the range of factors that contributed to the collapse of SVBFG and evaluates the Federal Reserve's role as the primary federal supervisor for both the parent company and the bank itself. In addition, the report outlines the Federal Reserve's supervisory and regulatory responsibilities concerning its overarching objective of ensuring financial stability and soundness.

The report finds that four key factors contributed to the failure of SVBFG, which are (Board of Governors of the Federal Reserve System, 2023):

1. Silicon Valley Bank's board of directors and management failed to manage their risks;
2. Supervisors did not fully appreciate the extent of the vulnerabilities as Silicon Valley Bank grew in size and complexity;
3. When supervisors did identify vulnerabilities, they did not take sufficient steps to ensure that Silicon Valley Bank fixed those problems quickly enough;
4. The Board's tailoring approach in response to the Economic Growth, Regulatory Relief, and Consumer Protection Act (EGRRCPA) and a shift in supervisory policy stance impeded adequate supervision by reducing standards, increasing complexity, and promoting a less assertive supervisory approach.

4.2 Regulation and its application on SVB

Following 2010, the U.S. banking sector underwent key regulatory changes aimed at enhancing financial stability and addressing weaknesses exposed by the global financial crisis. The Dodd-Frank Consumer Protection Act of 2010, in part due to the introduction of the stress test of the same name, made significant contribution to the recovery of U.S. banks through enhanced oversight and the implementation of mandatory stress testing (Peirce, 2013).

This Act established a tiered framework based on a bank's asset size. Banks with over $10 billion in assets were required to carry out internal capital stress testing. Those with more than $50 billion were subjected to reinforced prudential requirements covering capital, leverage, and liquidity, along with the submission of resolution plans and participation in supervisory stress tests, namely the Dodd-Frank Act Stress Test (DFAST) and Comprehensive Capital Analysis and Review (CCAR). The most stringent requirements apply to institutions with over $250 billion in consolidated assets or over $10 billion in off-balance sheet foreign exposure (Dodd-Frank Act, 2010). These were classified as Systemically Important Financial Institutions (SIFIs), justifying enhanced prudential standards (EPS) due to their potential to pose a risk to the broader financial system. In terms of liquidity, the Act required SIFIs to maintain a Liquidity Coverage Ratio (LCR) above 100%, while banks with assets over $50 billion had to maintain at least a 70% ratio.

Even before the onset of the pandemic, criticisms emerged regarding the regulatory burden on smaller banks. This led to a deregulatory shift under the Trump administration, beginning with executive order in 2017 that called for a comprehensive review of financial regulations. The process culminated in the Economic Growth, Regulatory Relief, and Consumer Protection Act (EGRRCPA), which was enacted on May 24, 2018. This reform significantly amended Dodd-Frank, aiming to tailor regulatory expectations for banks with assets under $250 billion.

The changes proposed by the amendment act were officially integrated within the FED's practices on 10 October 2019, with the adoption of the Domestic Tailoring Rule, which can thus be defined as the combination of the Economic Growth, Regulatory Relief, and Consumer Protection Act of 2018 and the implementation of its regulations. This regulatory intervention redefined supervisory expectations and categorised banks according to risk, which, as we shall see, has also affected the fate of the SVB.

This rule brought about three significant changes in stress tests: the revision of the minimum threshold for the applicability of the tests; the revision of the frequency with which financial institutions, falling within the new parameters, are required to conduct stress tests; and the reduction of stress test scenarios from three to two.

Regarding the first point, the introduction of the EGRRCPA Final Rule led to a redefinition of the term "covered institution."[31] Under the original Dodd-Frank Act (DFA), this classification applied to U.S. financial institutions holding more than $50 billion in assets. However, with the implementation of the new regulations, the definition was narrowed to apply only to national banks and Federal Savings Associations (FSAs) with assets exceeding $250 billion. As a result, two separate classifications of covered institutions were established: those with assets between $10 billion and $50 billion, and those with assets exceeding $50 billion. Concerning the second aspect (namely, the frequency with which stress testing procedures were to be conducted) the notion of periodicity was not initially specified in the regulation, thereby granting supervisory authorities considerable discretion in determining how often such assessments should be carried out (Joo, 2019).

In the same effort to reassess banking regulation, the Federal Reserve Board introduced the 2019 Tailoring Rule, which proposed a division of large holding companies into four standard risk-based categories. This initiative aimed to apply the principle of proportionality to the implementation of stress test procedures. Accordingly, four distinct banking categories were defined to help minimise the regulatory burden on non-systemic banks: Category I

[31] Federal Register, vol. 84, n. 197, p. 2.

encompassed U.S. Global Systemically Important Banks (GSIBs); Category II included all financial institutions with total assets exceeding $700 billion, as well as large bank holding companies with more than $75 billion in off-balance sheet foreign exposures; Category III comprised banks with over $250 billion in total consolidated assets or more than $75 billion in non-banking assets, weighted short-term wholesale funding, or off-balance sheet exposures; and Category IV consisted of firms with total consolidated assets between $100 billion and $250 billion. A residual group was also identified, including financial institutions with total assets ranging from $50 billion to $100 billion: a category that initially included Silicon Valley Bank (Makafui, Yangyang, and Lixin, 2024).

When examining the impact of this legislation on stress testing, it becomes evident that for institutions classified within the first three categories (I, II, III), the 2019 Domestic Tailoring Rule did not alter the frequency of supervisory stress tests as established under the Dodd-Frank Act of 2010. These institutions remained subject to both supervisory DFAST and quantitative CCAR assessments on an annual basis. However, the revised Rule had a significant effect on Category IV banks, particularly those in the residual group. Under the updated regulatory framework, Category IV institutions were still required to undergo stress testing, albeit in a simplified form (continuing with annual Quantitative CCAR assessments), but only needed to perform the Supervisory DFAST every two years rather than annually. Nonetheless, the Tailoring Rule also stipulates that if a Category IV institution is part of a consolidated holding company, it must complete an annual Supervisory DFAST exercise (Polk, 2019). As for the residual category, the changes introduced by the revised Rule were even more substantial: all system-wide and firm-specific stress testing obligations for these banks were eliminated. This broader exemption, with respect to the group previously defined by Dodd-Frank, reflects the regulators' intention to focus more attention on those banking firms deemed most dangerous to systemic stability and to reduce the financial burden on other non-systemic firms.

Regarding the variation in the frequency of the Supervisory DFAST exercise for Category IV institutions, the concept of a "reporting year" was introduced, defined as the year in which the covered institution is required to submit and publish the results of its stress testing. As a result, an institution may fall under either an annual or biennial reporting cycle. However, the reforms introduced by the EGRRCPA not only altered the approach to capital adequacy stress tests but also impacted liquidity risk management requirements. For banks within the first two categories, the LCR requirement remained unchanged. These institutions are still required to maintain a ratio above 100%, meaning that their stock of High-Quality Liquid Assets (HQLA) must exceed total net cash outflows. In contrast, for Categories III and IV, reduced requirements were introduced, with a daily LCR set at 85% and a monthly LCR at 70% of the full standard. As for the residual category of banks, the regulatory reform granted them a full exemption from the LCR requirement—an exemption that, as will be discussed later, may have played a role in the eventual collapse of Silicon Valley Bank.

Table 6. Application of stress tests for each category

Category	Stress Test			
	Supervisory DFAST	Company-run DFAST	Quantitative CCAR	LCR
Category I – U.S. GSIBs	Annual	Annual	Annual	100%
Category II	Annual	Annual	Annual	100%
Category III	Annual	Biennial (even years)	Annual	Reduced daily (85%)
Category IV	Biennial	Exempted	Annual	Reduced monthly (70%)
Residual (< $50 billion in total assets)	Exempted	Exempted	Exempted	Exempted

Source: Polk (2019)

Regarding the third point (the removal of the adverse scenario from the supervisory DFAST exercise), the decision to revise the structure of the stress test, limiting it to just two scenarios (the baseline and the severely adverse), was informed by prior experience. According to the Federal Reserve and the Office of the Comptroller of the Currency, the inclusion of an intermediate adverse scenario had not yielded any meaningful additional insights beyond what was already captured by the baseline and severely adverse scenarios. Consequently, the adverse scenario was deemed redundant and excluded from the revised framework.

The introduction of the EGRRCPA within the framework of the Dodd-Frank Act certainly helped to reshape the US banking framework. While globally systemically important banks (G-SIBs) continued to be subject to supervisory stress testing by the Federal Reserve, the reform simultaneously excluded institutions like SVB from being classified as systemically important. As a result, these firms were no longer required to carry out the stress testing procedures previously mandated under the original Dodd-Frank framework.

As previously noted, SVB underwent significant expansion between 2019 and 2022. At the start of 2019, the bank's total assets stood at a relatively modest $64 billion. By 2020, this figure had nearly doubled to $113 billion, followed by a further substantial increase in 2021, when total assets reached $208 billion, before levelling off the following year. A further relevant aspect concerns the gradual increase in off-balance sheet foreign exposures, which surpassed $10 billion in the second quarter of 2020. This increase was important not only from an accounting perspective but also in terms of regulatory implications, particularly concerning stress testing requirements.

Indeed, based on the Federal Reserve Board's criteria set out in the implementation of the EGRRCPA, SVB met the thresholds to be classified as a Category IV institution as early as 2020. At that point, its total assets had surpassed $100 billion, and its off-balance sheet foreign exposures also exceeded the required limit. Consequently, the bank ought to have been subject to the Enhanced Prudential Standards (EPS) outlined in the EGRRCPA for this category, and in particular, it should have been included in the group of banks required to undergo the supervisory DFAST. According to the regulatory guidelines governing the transition period between becoming a covered institution and the obligation to undergo the first stress test, Silicon Valley Bank was expected to report its results in the Federal Reserve's 2022 DFAST exercise. However, the Federal Reserve did not conduct this supervisory review for SVB (most likely due to non-prudential considerations), choosing, for unclear reasons, not to apply the same standards to smaller institutions as to their systemically important counterparts.

Before the enactment of the EGRRCPA and the 2019 tailoring rule, several additional regulatory obligations applied to institutions with total consolidated assets exceeding $250 billion or with on-balance sheet foreign exposures above $10 billion. These included full compliance with the LCR, the incorporation of unrealised gains and losses on Available-for-Sale (AFS) securities into capital calculations, adherence to advanced approaches for determining capital requirements, and maintaining a supplementary leverage ratio. As previously noted, SVB's on-balance sheet foreign exposures had surpassed the $10 billion threshold as early as the second quarter of 2020. Therefore, had the original regulatory framework remained in place and, in the absence of any strategic alterations to its business model, SVB would have been subject to these more stringent requirements prior to its collapse.

Had the EGRRCPA, the 2019 tailoring rule, and the associated regulatory amendments not been enacted, SVB would have been obliged to comply with more comprehensive liquidity risk management protocols, including conducting Internal Liquidity Stress Tests (ILST)[32], and

[32] ILST is a regulatory requirement for large banks (those with over $100 billion in assets) to assess their liquidity needs and ensure they can meet cash outflows under various stress scenarios. These tests, conducted monthly, simulate different market disruptions and estimate the bank's liquidity buffer required to cover potential net cash outflows.

meeting standardised liquidity requirements. These enhanced obligations would have entailed setting explicit liquidity risk thresholds, performing weekly monitoring of collateral, and overseeing intraday liquidity exposures. Rather than a quarterly ILST, SVB would have been subject to this requirement on a monthly basis[33] as well as monthly liquidity reporting to supervisors. Furthermore, SVBFG would have been required to meet the full LCR and Net Stable Funding Ratio (NSFR) requirements. Additionally, SVBFG would have been required to disclose its LCR and NSFR on a quarterly basis.

According to SVB's liquidity reports submitted to Federal Reserve supervisors, the bank would not have satisfied the full LCR requirement during the 2022-2023 period. For example, SVB's December 2022 full LCR would have been approximately 91%, a shortfall relative to the 100% requirement. To comply, the bank would have needed to secure around $8 billion in additional high-quality liquid assets. By February 2023, this estimated shortfall had grown to roughly $14 billion. It is also likely that these figures underestimate the bank's actual needs, as institutions typically maintain a buffer above the minimum requirements to absorb potential fluctuations in the ratio and to remain competitive in terms of public disclosure and industry comparisons (Board of Governors of the Federal Reserve System, 2023).

The LCR rule also requires a firm to have the operational capability to monetise its liquid assets and regularly test this ability. Furthermore, it imposes restrictions on the types of assets that qualify as high-quality liquid assets. Had SVBFG been subject to the LCR requirements, it might have engaged in more rigorous monitoring and management of its liquidity position and the composition of its liquid asset portfolio.

Regarding capital, in the absence of those regulatory requirements, SVB would have fallen under the Advanced Approaches capital framework. This includes stricter capital standards such as recognising unrealised gains and losses on AFS securities within regulatory capital, applying advanced methodologies for calculating risk-based capital requirements, and adhering to a supplementary leverage ratio.

Including unrealised gains and losses on AFS securities in SVB's Common Equity Tier 1 (CET1) capital would have lowered its capital by approximately $1.9 billion. This adjustment would have reduced SVB's CET1 capital ratio from 12.1% to 10.4% by the end of the fourth quarter of 2022 (Board of Governors of the Federal Reserve System, 2023). Such a decline in

[33] See 12 C.F.R. § 252.34–35 (2019).

regulatory capital might have prompted the bank to alter its operations, potentially by raising additional capital or reconsidering its strategic and investment decisions.

According to the capital framework in place prior to 2019, SVB would have been obliged to calculate its risk-based capital ratios under both the standardised and advanced approaches, applying the more stringent of the two. However, SVB was never subject to the calculation of advanced approaches, so it remains uncertain whether this would have further impacted its capital levels. Additionally, SVB would have been required to maintain a minimum supplementary leverage ratio of 3% from 2021 onwards, a threshold it would have satisfied based on the relevant regulatory reporting estimates.

Under the regulatory framework in place prior to 2019, SVB would have been required to meet more stringent stress testing obligations, including: (1) annual and mid-year company-run stress tests, and (2) annual supervisory stress testing, capital planning, and application of the stress capital buffer, starting from 2020. The absence or postponement of these requirements may have weakened SVB's ability to plan capital needs effectively and conduct robust stress testing.

Had EGRRCPA and the Federal Reserve's 2019 tailoring rule not been implemented, and following SVB's crossing of the $50 billion asset threshold (along with the applicable transition periods), the bank would have been required to carry out both annual and mid-cycle internal stress tests. These would have involved developing bespoke stress scenarios to identify specific vulnerabilities. Moreover, SVB would have been subject to stricter ongoing oversight and regulatory scrutiny over its stress testing practices.

In conclusion, a comprehensive assessment of changes from EGRRCPA, the 2019 tailoring rule, and related rulemakings reveals that they collectively created a weaker regulatory framework for a bank like SVB. Without these modifications, SVB would have been subject to stricter liquidity risk management obligations, complete standardised liquidity requirements (including the LCR and NSFR), more robust capital standards, mandatory internal and supervisory stress testing at an earlier stage, and more detailed resolution planning. These requirements may have resulted in SVB having increased capital and liquidity that would have bolstered its resilience. Moreover, the requirements may also have encouraged closer scrutiny of the bank's financial position, and SVB may have more proactively managed its liquidity and capital positions or maintained a different balance sheet composition. Furthermore, the lengthy transition periods stipulated by the applicable rules further delayed the implementation of requirements such as stress testing, which may have contributed to the firm's resiliency (Acharya *et al*., 2023).

4.3 Observations from CAMELS analysis results

To better understand why regulators did not fully recognise the vulnerabilities of Silicon Valley Bank (SVB), it is helpful to examine the bank's assessments under the CAMELS rating system. These evaluations, conducted by the Federal Reserve Bank of San Francisco, remained relatively positive even during SVB's peak years. The ratings cover the period 2019 to 2021, as the bank collapsed before the 2022 review could take place, a review that would likely have led to a downgrade in light of the worsening conditions.

Table 7. CAMELS ratings

	Year of examination		
	2019	2020	2021
Uniform composite rating	2	2	2
Component ratings:			
Capital	2	2	2
Asset Quality	2	2	2
Management	2	2	3
Earnings	2	2	2
Liquidity	1	1	2
Sensitivity to Market Risk	2	2	2

Source: Federal Reserve Board (2020 and 2021)

In 2019, SVB's CAMELS ratings indicated an overall satisfactory financial situation, in line with the bank's significant growth that year. It received an overall CAMELS rating of 2. The Federal Reserve assigned the bank a rating of 2 for both asset quality and management, and a rating of 1 for liquidity, the highest score, reflecting the bank's perceived stability, partly due to its effective risk management practices (Federal Reserve Board, 2020).

In 2020, the CAMELS rating system results for SVB continued along the same lines as the previous year, with the bank receiving an overall rating of 2. Liquidity, again scored at 1, continued to be rated significantly positively by the supervisory authority, which considered the bank to have sufficient liquid assets to absorb financial fluctuations. This outcome may have been influenced by the influx of capital, primarily from venture capital financing, which ensured a substantial cash supply available for investment in long-term securities (Federal Reserve Board, 2021).

The first signs of a change in SVB's condition appeared in the following year's ratings, partly due to the evolving scenario of the COVID-19 pandemic: liquidity was downgraded from its

2020 rating, and the Management area was downgraded from satisfactory to unsatisfactory, indicating weaknesses in risk management. Despite this, the Bank still received an overall CAMELS rating of 2, which is consistent with its previous years' ratings. The limited identification of early weaknesses was not enough for supervisors to revise their strategy for SVB (Kupiec, 2023). This shows that supervisors did not appreciate the severity of the liquidity risk the bank was exposing itself to through its aggressive investment strategy. Despite the CAMELS system still having a positive assessment, supervisors preferred not to intervene, considering the identified weaknesses not severe enough to warrant action.

While the CAMELS framework could be a helpful way to provide an overall analysis of a bank's health, its assessments offer only a partial picture of vulnerabilities and problems that may arise. The underlying methodology is simple, based on the consideration of financial and operational indicators for the bank's internal level risk assessment, which highlights this tool's static profile, providing only a partial view of potential threats. This lack of elasticity in the measurement mode makes it difficult to capture those dynamic aspects that may affect the bank's different areas of activity. Moreover, by focusing solely on the internal characteristics of the institution, the CAMELS system does not enable supervisors or the institution to assess the impact of systemic risks on its business areas. Therefore, the assessments for SVB appear unreliable, as rapid advances in technology and rising interest rates had significant implications for the quality of assets and liquidity available to SVB. This aspect makes the judgment produced by the CAMELS rating system difficult to believe.

Indeed, the experience of the Californian Bank is further testimony to the importance of conducting bank assessments that reflect changes in economic conditions and capture the complex interrelationship between various risk factors, as well as their combined impact on bank health. As a result, in the current rapidly changing financial environment, it is essential to have instruments that can easily adapt to different situations to anticipate and mitigate the difficulties that could threaten the stability of individual institutions.

However, the considerations just made do not imply that the CAMELS methodology should be considered ineffective or outdated: its limitations do not diminish the importance of its role within the U.S. supervisory system. In this context, incorporating stress tests into the assessments provided by the CAMELS rating system could enhance the reliability of banking institutions' financial and operational condition assessments.

4.4 SVB's Liquidity Risk Management

Liquidity risk arises when a bank cannot honour its financial commitments on time. For SVB, this became a reality when depositors panicked and initiated massive withdrawals. This was intensified because SVB depended on a limited, largely uninsured deposit base, coupled with long-term investments that could not be quickly converted to cash. SVB's key issue was its vulnerability to maturity transformation, as it used short-term deposits to fund long-term loans. SVB couldn't meet these demands due to poor planning and weak liquidity management.

The bank's misuse, inattention, or indifference to gap analysis regarding maturity mismatch and interest rate sensitivity played a significant role in SVB's collapse. An effective gap analysis would have identified the mismatch; however, SVB's risk management failed to adequately control liquidity risk. Most of the bank's liabilities, primarily deposits, were overnight or very short-term. At the same time, its assets were illiquid and long-dated, meaning they could not be quickly converted to cash without losses.

To analyse the SVB's Liquidity Risk Management, it is helpful to focus on the financial statements data regarding the SVBFG situation over the last four years.

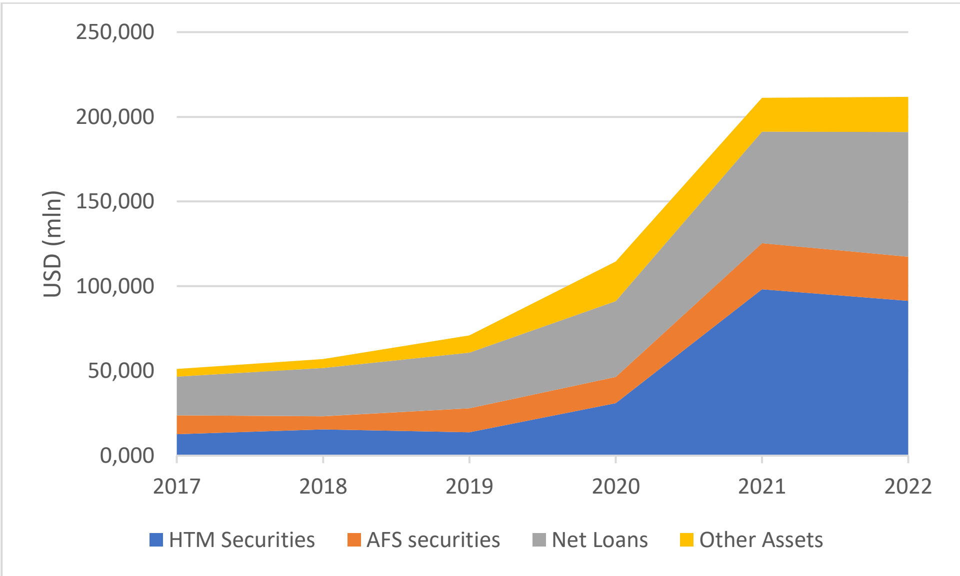
Table 8. SVBFG's selected financial statement items

Balance sheet items (mln)	2022	2021	2020	2019	2022-2019
Cash and Cash equivalents	$13,803	$14,586	$17,675	$6,782	104%
Securities	$120,054	$127,959	$49,307	$29,072	313%
HTM Securities	$ 91,321	$98,195	$30,912	$13,843	560%
AFS Securities	$26,069	$27,221	$16,592	$14,015	86%
Net Loans	$73,614	$65,854	$44,733	$32,860	124%
Other Assets	$20,789	$20,038	$23,274	$10,287	102%
Total Assets	$211,793	$211,308	$115,511	$71,005	198%
Total Deposits	$173,109	$189,203	$101,982	$61,758	180%
Other Liabilities	$22,389	$5,496	$5,096	$2,626	753%
Total Liabilities	$195,498	$194,699	$107,078	$64,384	204%
Total Equity	$16,295	$16,609	$8,433	$6,621	146%

Source: Author's elaboration. Data is sourced from the 10-K statements (31-12-2021 and 2022)

Table 8 outlines the leading financial indicators from the bank's balance sheet between 2019 and 2022. Among the asset components, the proportion of cash and cash equivalents relative to total assets declined markedly, falling from 8.83% in 2019 to 5.99% in 2022. The ratio of net loans and leases to total assets also dropped, from 46.96% to 35.22% over the same period. In the same way, the other assets ratio decreased slightly from 4.53% to 2.68%. Conversely, the proportion of securities within the bank's asset composition increased notably, rising from 39.69% to 56.12%. Looking at absolute numbers, the bank's securities jumped from $28 billion to $117 billion. This surge indicates a significant strategic shift towards investing in securities, particularly those offering fixed income. The data implies a notable decrease in the deposit-to-asset ratio in 2022, potentially indicating customer withdrawals. However, rising other liabilities, such as borrowing, offset this drop in total deposits. As a result, equity increased slightly throughout 2022. Figure 12 illustrates the SVBFG's asset composition over the period 2017-2022.

Figure 12. SVBFG composition of assets



Source: Author's elaboration. Data is collected from the 10-K statements (31-12-2019, 2020, 2021 and 2022)

Table 9 outlines the bank's performance ratios from 2019 to 2022. It seems evident a decline in its overall financial performance. The yield on earning assets fell from 3.83% to 2.77%. On the other hand, the cost of funding earning assets increased from 0.30% to 0.53%. The bank's net interest margin also declined significantly, dropping from 3.53% to 2.23%. The low percentage of loans and leases, combined with large investments in securities, may be the cause of this decline in net interest margin.

Table 9. SVB's Performance Ratios

Performance ratios (%)	2022	2021	2020	2019
Yield on Earning Assets	2.77	2.09	2.68	3.83

Cost of Funding Earning Assets	0.53	0.04	0.08	0.30
Net Interest Margin	2.23	2.05	2.61	3.53
Net Charge-Offs to Loans and Leases	0.10	0.21	0.20	0.24
Return on Assets	0.96	0.80	0.95	1.65
Return on Equity	13.43	11.88	13.94	21.47

Source: Author's elaboration. Data is sourced from the 10-K statements (31-12-2021 and 2022)

In addition, Table 9 highlights a fall in the bank's return on assets and return on equity. Return on assets declined from 1.65% to 0.96%, while return on equity dropped from 21.47% to 13.43% over the same timeframe. An analysis of SVBFG's performance between 2019 and 2022 reveals a significant decline in 2021, despite the bank experiencing substantial growth. We can notice that SVB's total assets have tripled since 2019, but the net interest margin has decreased from 3.53% to 2.05%. This decline can be associated with the reduction in interest rates. The U.S. government lowered interest rates to nearly 0% in late 2020 and 2021. Consequently, this decrease in interest rates resulted in lower yields on earning assets to 2.09% and reduced the cost of funding earning assets to 0.04%, the lowest in the analyzed period.

Finally, Table 10 focuses on some of the liquidity risk management ratios already illustrated in Chapter III.

Table 10. Liquidity risk ratios

Liquidity Risk Ratios (%)	**2022**	**2021**	**2020**	**2019**
Current Ratio	1.083	1.085	1.079	1.103
Quick Ratio	0.671	0.719	0.609	0.538
Cash Ratio	0.070	0.075	0.165	0.105
Loan-to-Deposits Ratio	0.429	0.350	0.443	0.54

Source: Author's elaboration. Data is collected from 10-K statements (31-12-2021 and 2022)

As illustrated in Table 10, the current ratio remained relatively stable over the four years, ranging narrowly from 1.103 in 2019 to 1.083 in 2022. A ratio above one means that the bank has more current assets than liabilities, meaning it can cover short-term obligations. However, the slight downward trend could be interpreted as a marginal weakening in liquidity coverage.

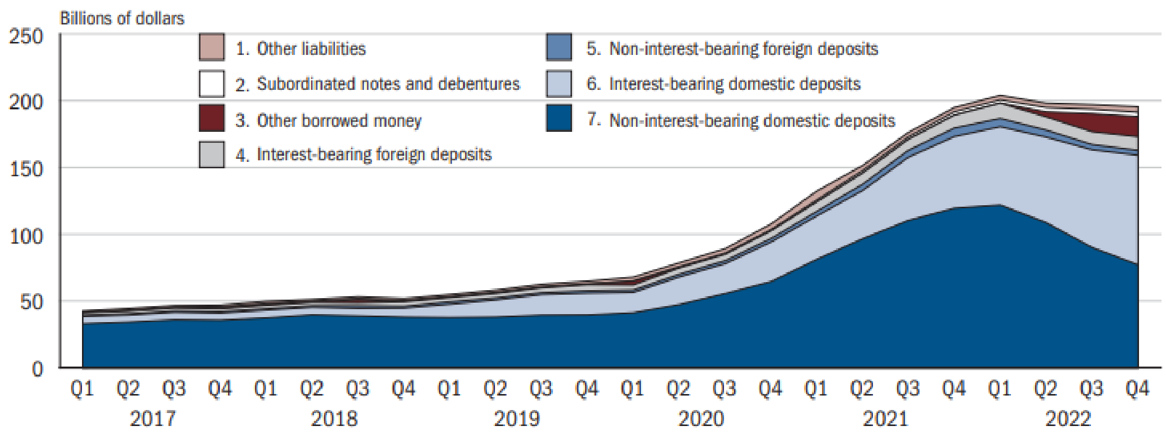
The quick ratio, a measure of liquid assets excluding inventory, initially rose from 0.538 in 2019 to 0.719 in 2021, before decreasing to 0.671 in 2022. The earlier increase likely indicates careful liquidity management during the peak of the pandemic and the period of quantitative easing. However, the 2022 decline suggests an increase in liquidity issues, resulting in fewer liquid assets to cover immediate debts.

Much more concerning is the trend observed in the cash ratio, which measures the proportion of cash and cash equivalents to current liabilities. This ratio is the one that has decreased the most: from 0.165 in 2020 to just 0.070 in 2022. It means that the bank may not have enough cash readily available to meet short-term liabilities, such as satisfying quick withdrawal requests.

Lastly, the loan-to-deposit ratio provides further insight into the bank's structural shifts. It fell from 0.54 in 2019 to 0.35 in 2021, likely due to a massive influx of deposits during the low-interest-rate period, meaning a smaller share of those deposits was being lent out. However, in 2022, the ratio climbed again to 0.429. This means that the bank has more loans than deposits, and so lending has picked up; however, it is more plausible that it reflects a drop in deposits, which aligns with early signs that customers are starting to withdraw their money.

Examining the evolution of the SVBFG's liabilities reveals that they also experienced a growth trend, similar to that of the bank's assets. The exponential rise in deposit volumes during the period in question is notable: deposits grew by 66% between 2019 and 2020 and surged by a further 86% from 2020 to 2021. Over just three years, the volume of deposits tripled. This growth was driven mainly by SVBFG's core clientele (start-ups and venture capital firms), who, capitalising on the Federal Reserve's quantitative easing (QE) policy and the accompanying near-zero interest rates, placed record levels of funds with the bank (Acharya et al., 2023). Figure 13 shows how SVBFG's liabilities are structured.

Figure 13. Composition of SVBFG liabilities



Source: Board of Governors of the Federal Reserve System (2023)

The bank's management subsequently opted to allocate a substantial portion of client deposits into long-term, held-to-maturity (HTM)[34] securities, primarily consisting of government or agency-issued mortgage-backed securities (as illustrated in Figure 13). Quantitatively, this investment strategy was the main contributor to the significant increase in SVBFG's total consolidated assets: the Bank's holdings in such securities soared from $13 billion in 2019 to $98 billion in 2021, an almost 500% increase over the previous year. The decision to invest in HTM securities, which are recorded on the balance sheet at amortised cost, can be understood for several reasons: firstly, due to the limited alternative investment options available given the Bank's specialised client base; secondly, due to the relatively low credit risk of these instruments, their predictable long-term returns, and the fact that unrealised gains or losses do not affect financial statements unless the securities are sold.

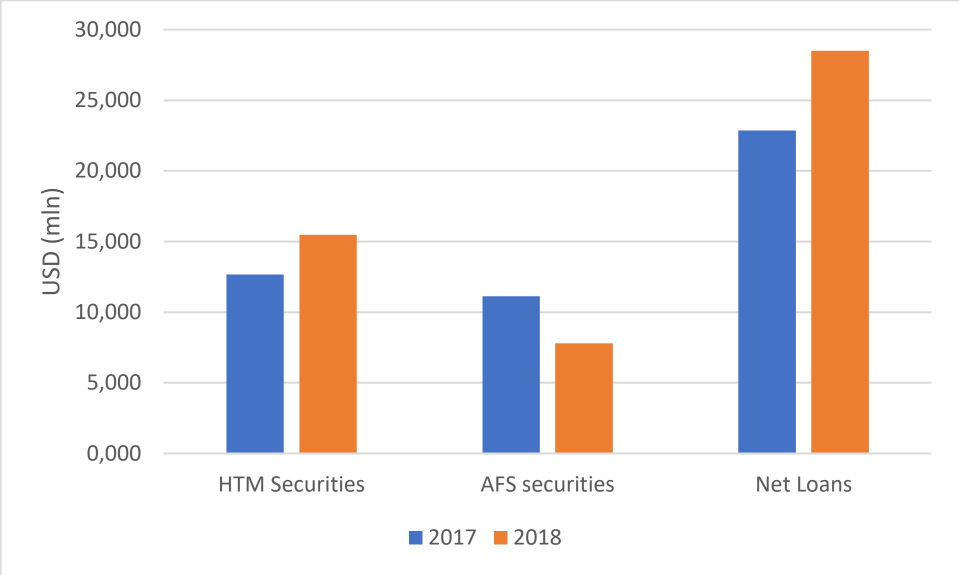
In 2022, however, the situation underwent a major change, due to the rise in interest rates: this economic policy intervention had a negative impact on the technology sector, which first suffered a sharp slowdown in growth and then a drastic drop in the activity of venture capital firms, with consequences also on the value of HTM securities, which, performing inversely to the interest rate, began to decline progressively. Depositors, faced with the bank's difficulties in dealing effectively with interest rate changes, began to demand repayment of their deposits (Acharya et al., 2023).

Examining the 2022 balance sheet values, we can observe this trend shift and the first signs of bank fragility, as the values of securities and deposits have decreased compared to the previous year. Within the securities portfolio, AFS securities appeared largely unaffected, as they are more liquid and less exposed to interest rate risk. However, the same cannot be said for HTM securities and deposits, both of which registered a decline relative to 2021.

As illustrated in Figure 14, the reductions in HTM securities and deposits were modest in percentage terms (falling by 7% and 8.51% respectively), yet the absolute decreases were substantial. HTM securities fell by $7 billion, and deposits dropped by a notable $16 billion.

[34] These securities carry minimal credit risk and offer a predictable return determined by the interest rate at the time of acquisition. As of 31 December 2022, SVBFG's total hold-to-maturity (HTM) securities portfolio had a weighted average duration of 6.2 years, with the bulk of the portfolio comprising agency mortgage-backed securities (MBS) with maturities of ten years or more.

Figure 14. Comparison of HTM Securities, AFS Securities, and Deposits: 2021 vs 2022



Source: Author's elaboration. Data is collected from the 10-K statement (31-12-2022)

To be classified as HTM, securities must be acquired with both the intention and the capacity to retain them until their maturity date. This designation allows such assets to be recorded at amortised historical cost, rather than being subject to ongoing market revaluation. Typically, if a bank decides to sell even a portion of its HTM securities, it is then obliged to reclassify the entire portfolio as AFS, which must be marked to market. Given this accounting restriction and the substantial expansion of its HTM portfolio, SVBFG had limited flexibility to modify its investment holdings in response to changes in interest rates. As rates began to rise in 2022, the bank faced a sharp increase in unrealised losses across both its HTM and AFS portfolios (Acharya et al., 2023).

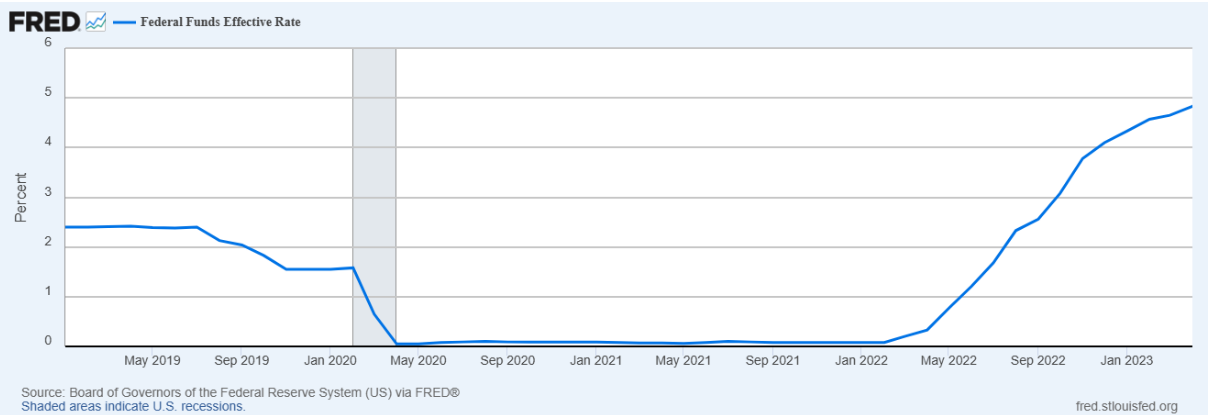
Through 2020, around three-quarters of banks' securities portfolios were held as AFS, bringing unrealised gains of $38 billion across banks' AFS portfolios. According to SVBFG's Annual Report of 2021, the weighted average duration of the AFS securities portfolio was 3.5 years, and this figure for the HTM securities portfolio was 4.1 years. This led to a weighted average duration of the bank's debt securities of 3.97 years at the end of the year. As rates went up, the unrealised losses of SVBFG snowballed from 0 to $16 billion, surpassing the $11.8 billion in tangible common equity that supported SVBFG's balance sheet. On a mark-to-market basis, this rendered the bank technically insolvent. Accessing its HTM securities was not viable: the sale of a single bond would have triggered a reclassification of the entire portfolio, forcing all assets to be marked to market, an adjustment the bank lacked sufficient capital to absorb. Instead, to bolster its financial position, SVBFG sold $21 billion of AFS securities and announced a balance sheet restructuring to cover a $1.8 billion realised loss. However, as is well known, the subsequent capital raise was never completed.

4.5 SVB's Interest Rate Risk Management

Sensitivity to market risk reflects the degree to which changes in interest rates, foreign exchange rates, commodity prices, or equity prices can adversely affect a financial institution's earnings or capital. For SVB and SVBFG, market risk primarily reflects exposure to changing interest rates (Board of Governors of the Federal Reserve System, 2023).

In particular, in response to the disproportionate increase in prices, the Federal Reserve began raising interest rates at the start of 2022 to curb inflation and maintain the stability of the dollar's value (Figure 15). The U.S. central bank raised interest rates on multiple occasions, increasing them from 0% to 5% within a year. As a result, the decline in overall demand led to a reduced inflationary effect; however, financial markets responded adversely.

Figure 15. Increase in interest rates from 01-01-2019 to 01-01-2023



Source: Federal Reserve Bank of St. Louis via FRED

This unstable environment increased SVB's interest rate risk. However, how can it be managed and measured? SR letter 10-1 (2010)[35] highlights the significance of strong corporate governance, policies, risk assessment, monitoring systems, stress testing, and internal controls for managing institutions' IRR exposures. The outlined framework commences with sound corporate governance and encompasses strategies, policies, risk controls, measurement methodologies, reporting protocols, independent review mechanisms, and risk-mitigation strategies. Notably, proficient IRR management encompasses both the identification and

[35] SR 10-1 is an interagency advisory on interest rate risk issued by the Federal Reserve and other financial regulators on January 11, 2010. It focuses on the need for sound management of interest rate risk within financial institutions and highlights sound practices.

measurement of IRR, as well as the implementation of suitable measures to control this risk effectively.

As we saw in the previous chapter, two of the key metrics used to measure IRR include:

1. *Earnings at risk (EaR) or net interest income (NII) at risk;*
2. *Economic value of equity (EVE).*

As of 31 March 2022, just before interest rates began to rise significantly, SVB's balance sheet exhibited the typical pattern in which rate increases reduce the economic value of equity (EVE) while simultaneously enhancing profitability from a net interest income (NII) standpoint. Figure 14, taken directly from the bank's 10-Q report for that quarter, illustrates this clearly: a +200 basis point rate shock results in a $5.4 billion reduction in EVE but leads to a $1 billion gain in NII. It is also worth noting that the imbalance in SVB's asset-liability structure was even more pronounced at the end of the previous year. As of 31 December 2021, a +200 bp shock would have led to an EVE loss of $5.7 billion. Such a balance sheet composition would likely have triggered earlier and more stringent supervisory measures had SVB been subject to European regulation.

In the European Union, supervisory authorities employ a Supervisory Outlier Test to detect excessive interest rate risk. In the case of a 200 basis point shock, institutions are required to assess the potential impact on their economic value of equity. If the decline in EVE exceeds 20% of the institution's funds, it must promptly notify the relevant supervisory authority (European Banking Authority, 2018). In practice, a 15% threshold acts as an early warning indicator.

Given that a potential $5 billion loss represented over 40% of SVB's $12 billion in Tier 1 capital at the time, the bank had already far exceeded this early warning threshold by May 2022. However, unlike in the EU, where this kind of interest rate risk monitoring is mandatory for all institutions, no such requirement applies to U.S. banks with total assets below $700 billion, leaving SVB outside the scope of this kind of proactive regulatory scrutiny.

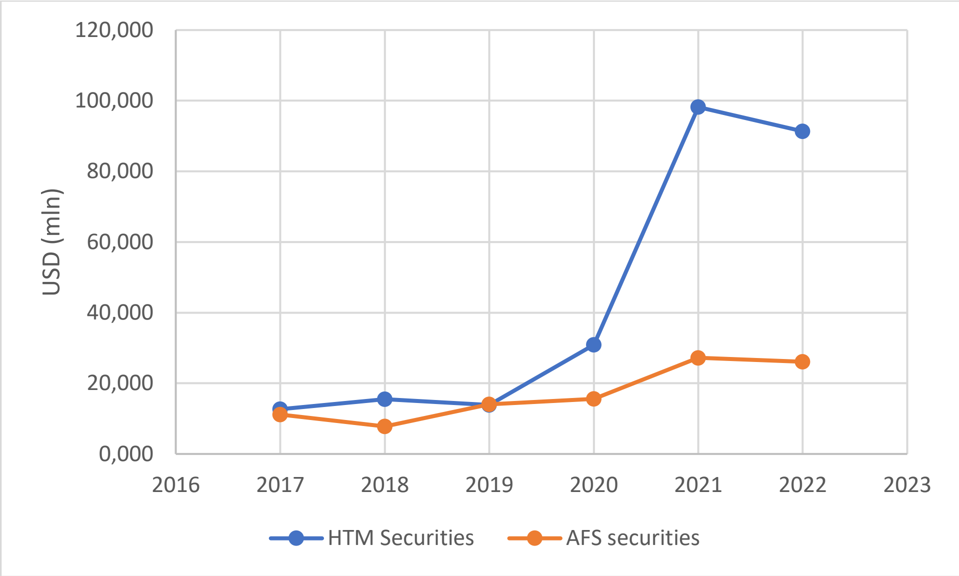
Figure 16. EVE and NII sensitivity exposure related to an instantaneous and sustained parallel shift in market interest rates of 100 and 200 bps at March 31, 2022 and December 31, 2021

	Estimated	Estimated Increase/(Decrease) in EVE		Estimated	Estimated Increase/(Decrease) in NII	
(Dollars in millions)	EVE	Amount	Percent	NII	Amount	Percent
March 31, 2022:						
+200	$ 12,380	$ (5,401)	(30.4)%	$ 5,777	$ 1,004	21.0 %
+100	14,863	(2,918)	(16.4)	5,262	489	10.2
–	17,781	–	–	4,773	–	–
-100	20,621	2,840	16.0	4,378	(395)	(8.3)
-200	22,392	4,611	25.9	4,287	(486)	(10.2)
December 31, 2021:						
+200	$ 14,950	$ (5,722)	(27.7)%	$ 5,258	$ 981	22.9 %
+100	17,799	(2,873)	(13.9)	4,745	468	10.9
–	20,672	–	–	4,277	–	–
-100	21,904	1,232	6.0	4,002	(275)	(6.4)
-200	21,308	636	3.1	3,911	(366)	(8.6)

Source: SVB's 10-Q (2022)

Figure 16 shows how the value of this portfolio changed from 2017. Significantly, many more assets were bought in 2020, greatly increasing the bank's mortgage securities. The rationale for this increase, as explained in SVBFG's 10-K report dated 31 December 2021 (p. 92), was that "rapid deposit growth exceeded the pace of our loan growth, and as a result, a significant amount of excess deposits not used to fund loan growth have contributed to the growth of investment balances."

Figure 17. Composition of SVBFG's Residential Mortgage-Backed Securities (HTM vs AFS), 2017–2022



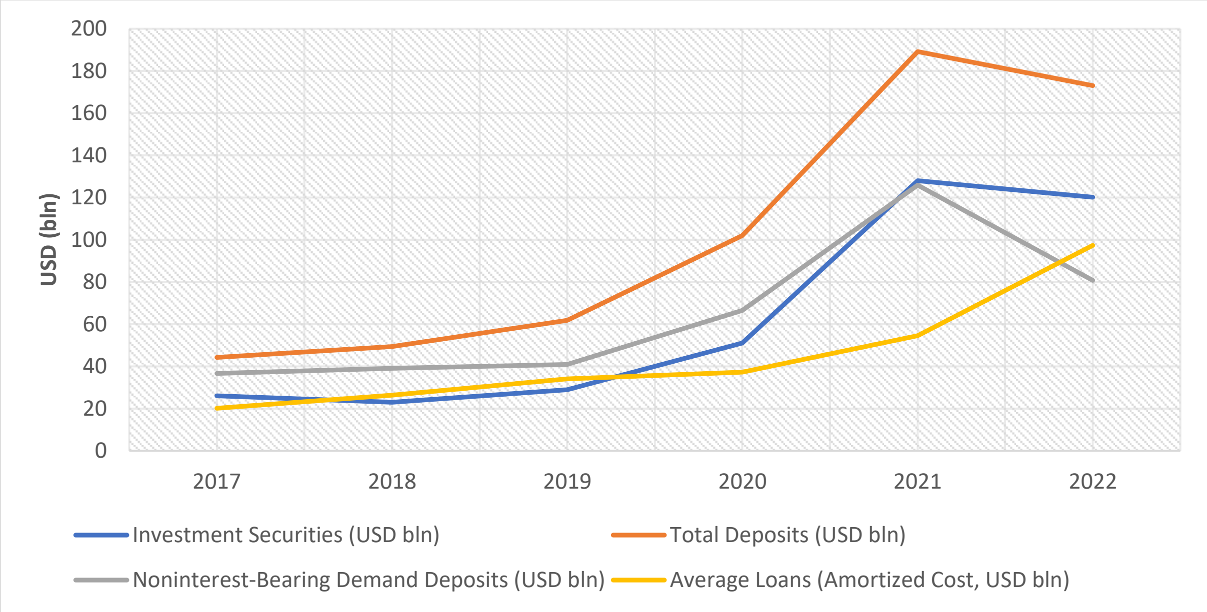
Source: Author's elaboration. Data is sourced from the 10-K statements (31-12-2019, 2020, 2021 and 2022) and refers to SVBFG

Figure 17 illustrates how a deposit increase of $87 billion was closely mirrored by a rise of approximately $79 billion in investment securities. These investments included both available-for-sale and held-to-maturity positions, consisting of U.S. Treasury securities, U.S. agency bonds, foreign sovereign debt, equities, and predominantly residential mortgage-backed securities (RMBS). During the same period, average loan volumes also grew significantly by over 56% from 2020 to 2021. However, the total increase in loans amounted to just $20.8 billion, which was less than one-quarter of the total deposit growth.

To avoid a scenario where nearly zero net interest income might result from investing all excess liquidity in short-term money market instruments, management likely opted to allocate at least part of those funds into longer-term, interest-bearing RMBS. Interestingly, this situation closely echoes the situation faced by many German banks between 2001 and the 2007-2008 financial crisis. In both cases, banks pursued yield by locking up deposits in long-duration and often illiquid buy-and-hold securities, which severely limited their flexibility when markets deteriorated (Bleuel, 2009).

From a narrow, front-office point of view, the move may have appeared justifiable. However, from a risk management standpoint, it was a decision that should have been questioned or even halted. It remains unclear why the bank's Asset and Liability Committee (ALCO) did not act at that time. According to SVBFG's 2021 10-K, interest rate risk was supposedly monitored through established metrics and guidelines approved by the Board's Finance Committee and outlined in the bank's Interest Rate Risk Policy. However, it appears that the Economic Value of Equity (EVE) was not given meaningful consideration among these key performance indicators.

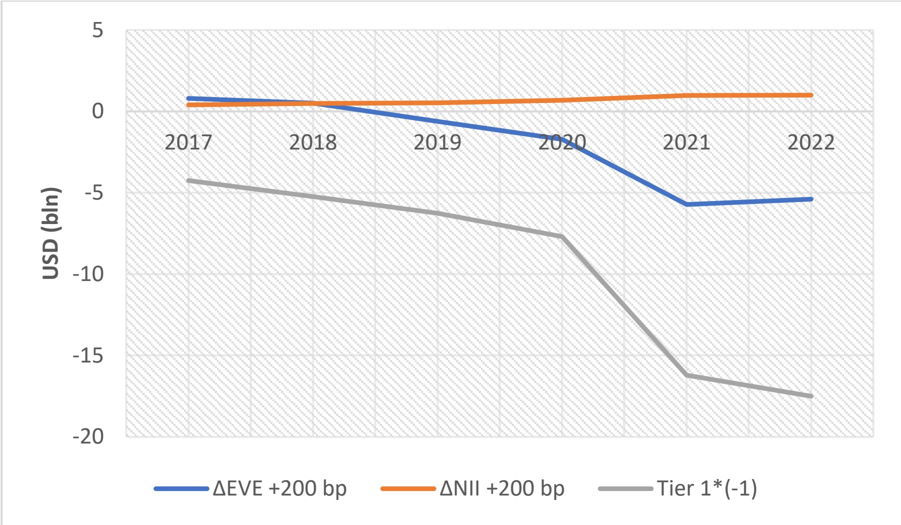
Figure 17. SVBFG Balance Sheet Trends: Investment Securities, Deposits, and Loans (2017–2022)



Source: Author's elaboration. Data is sourced from the 10-K statements (31-12-2019, 2020, 2021 and 2022) and refers to SVBFG

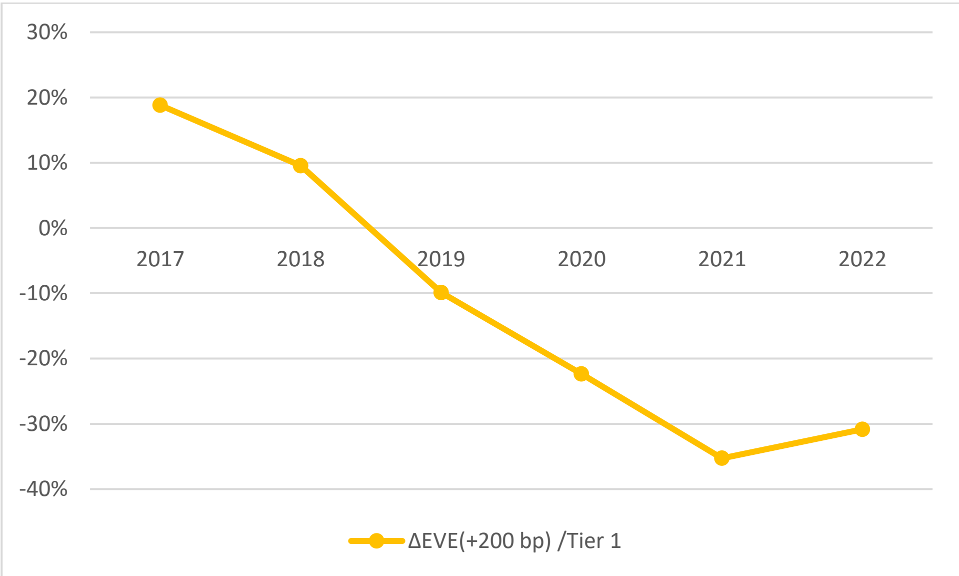
Figures 18 and 19 show how changes in ΔEVE and ΔNII occurred over time. These figures reveal that SVB's investment portfolio changes significantly affected the bank's response to interest rate changes. In 2017, the bank could have still benefited from a 200 basis point increase in interest rates, as demonstrated by a positive ΔEVE of $805 million. However, this position had shifted drastically by the end of 2021. The Board later projected that the company would lose $5.7 billion in the same rate shock scenario. Meanwhile, Tier 1 capital did not grow sufficiently to offset the increasing exposure. The decision to enter a prominent RMBS position in 2020 had a significant impact: by 2021, a 200 basis point rate rise would have effectively wiped out around 30% of the group's Tier 1 capital, reducing it from $16.2 billion to roughly $11.4 billion. The situation remained critical in 2022, when capital at risk due to interest rate shocks reached as high as $17.6 billion.

Figure 18. SVBFG Interest Rate Sensitivity and Tier 1 Capital Impact, 2017– 2022



Source: Author's elaboration. Data is sourced from the 10-K statements (31-12-2019, 2020, 2021 and 2022) and 10-Q of 30-09-2022

Figure 19. SVBFG ΔEVE (+200 bps) as a Percentage of Tier 1 Capital (2017–2022)

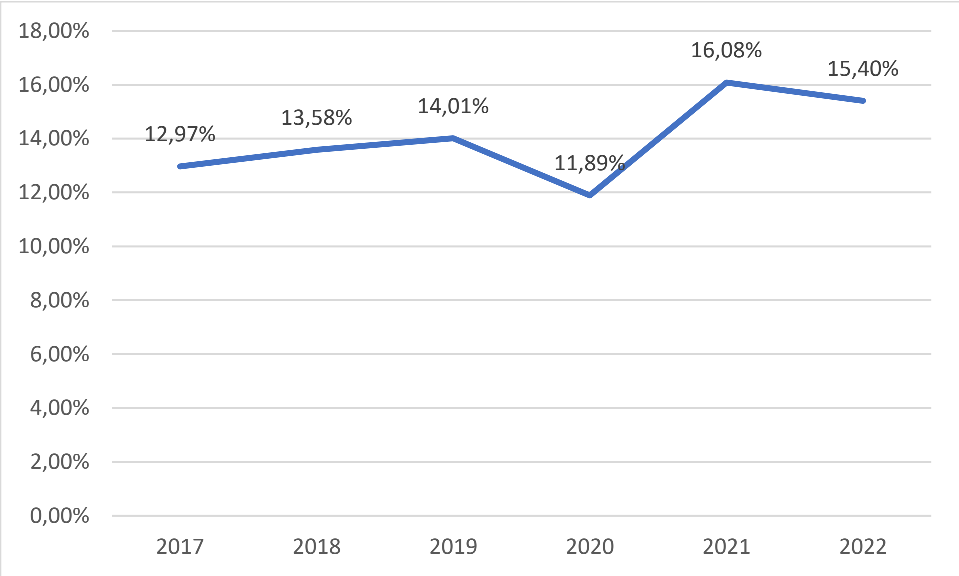


Source: Author's elaboration. Data is sourced from the 10-K statements (31-12-2019, 2020, 2021 and 2022) and 10-Q of 30-09-2022

It is also notable that, according to the 10-K report dated 31 December 2022, SVBFG's Tier 1 capital had increased to $17.5 billion, even as the Federal Reserve's effective rate stood at 4.1%. If appropriate EVE modelling assumptions had been applied—and assuming no mitigating measures were taken, SVB should theoretically have incurred capital losses of approximately $10.8 billion due to a cumulative 400 basis point rise in interest rates (double the $5.4 billion estimated at the end of March 2022). This would have reduced Tier 1 capital from $16.6 billion to $5.8 billion, assuming all other factors remained constant. However, despite these theoretical losses, we still see a relatively high and comforting Tier 1 capital at the end of 2022. This discrepancy raises questions: How was such capital stability possible under these conditions?

As reported in SVB's 10-Q, the Tier 1 Capital (Risk-Weighted Assets) of SVBFG stood at USD 16.6 billion (USD 104.7 billion) as of 31 March 2022, and USD 16.2 billion (USD 100.8 billion) at the end of December 2021. These figures reflect capital ratios, such as 16.6 divided by 104.7, which equates to 15.8%, a key indicator of a bank's financial health. Notably, these ratios remained comfortably above the regulatory minimums and did not raise any immediate concerns. On the contrary, SVB's capital position appeared to improve over time, as illustrated in Figure 20. This kind of scenario deceived SVBFG's board.

Figure 20. SVBFG Tier 1 Capital Ratio (2017–2022)



Source: Author's elaboration. Data is sourced from the 10-K statements (31-12-2019, 2020, 2021 and 2022) and 10-Q of 30-09-2022

From what we have been able to observe, SVBFG's management seemed to focus too much on immediate interest rate risks, especially the NII metric, while ignoring long-term risks indicated by the EVE measure. The assumption that the bank was asset-sensitive led them to believe that net interest income would increase with rising interest rates. However, they did not consider the particular susceptibilities of SVBFG's customer base and how they might respond to a shifting rate environment.

Moreover, the bank's approach to risk management had significant shortcomings. Internal audits revealed weaknesses in governance and control structures. SVBFG did not conduct back-testing of its models, performed only limited sensitivity analyses, and lacked a robust second line of defence to review and challenge key assumptions and decisions independently. The IRR policy did not specify scenarios to be run, how assumptions should be analysed, how to conduct sensitivity analysis, or articulate model back-testing requirements. Further, it did not describe how limits were set and calibrated.

SVBFG's board-approved Risk Appetite Statement (RAS), which defines the boundaries for managing risk, focused exclusively on the NII metric and entirely excluded the EVE measure. Even the use of NII was limited; it only considered a gradual 100 basis point decrease over 12 months rather than a broader range of plausible interest rate shocks. These ramp scenarios, which assume a slow adjustment in rates, are far less stressful than immediate shocks and reflect a short-term perspective on risk (The Federal Reserve Bank of San Francisco and the California Department of Financial Protection and Innovation, 2022). The 2017 RAS made clear that interest rate risk was to be managed within defined policy limits to support profitability and enhance shareholder value. This suggests that management was primarily focused on short-term earnings, with NII, and not broader interest rate risk, at the centre of decision-making.

Because EVE was not included in the bank's risk appetite, there is no indication that the whole board was ever made aware of how far out of bounds the EVE metric had drifted, even though it had been breaching limits for years. While these breaches were communicated to the board's Risk Committee, best practice dictates that the entire board should have oversight of interest rate risk (IRR) management, including regular review of exposure levels and trends.

SVBFG also relied on rudimentary tools for measuring the Interest Rate Risk (IRR). Their models only captured parallel shifts in the yield curve, failing to include non-parallel changes, which are crucial for understanding how different curve shapes could affect the bank's portfolio. The Asset/Liability Committee (ALCO) rarely conducted sensitivity analyses. When they were conducted, these reports focused only on occasional shifts in key assumptions, thereby limiting the committee's ability to grasp the bank's interest rate risk exposure fully.

Previous IRR assessments also highlighted a misalignment in the timing of asset and liability repricing on SVBFG's balance sheet. Historically, the bank had been considered asset-sensitive, meaning that its net interest income (NII) tended to rise in tandem with increases in interest rates. SVBFG's vulnerability was due to the structure of its balance sheet, which was composed mainly of non-interest-bearing deposits on the liabilities side, while the assets consisted of a combination of floating-rate loans and fixed-rate securities. SVBFG anticipated gaining from a rising interest rate environment, largely based on the assumption that deposit betas would remain low.

4.5 Could Europe experience its own SVB?

Starting from a broader perspective, one of the key differences between the U.S. and European banking systems lies in the structure of their balance sheets. While certain U.S. banks, like SVB, experienced unchecked balance sheet expansion due to a rapid increase in deposits and corresponding investment decisions, European banks have generally maintained more stable deposit bases and held fewer long-term bonds in their portfolios. A contributing factor to this difference may be found in the distinct regulatory frameworks applied by banking supervisors in the two regions.

A major distinction is how the principle of proportionality is interpreted. In the U.S., the adoption of the EGGRCPA and the Tailoring Rule exempted banks with under $100 billion in assets from participating in system-wide stress tests. In contrast, EU regulations have pursued a more uniform application of rules across all banks, including small and non-complex institutions, although with simplified stress test methodologies depending on size and complexity (Arrigoni and Restelli, 2023). Maintaining the requirement for the applicability of stress tests also for firms that should be placed in Category 4, according to the EBA guidelines, ensures that these institutions gain access to valuable insights about their financial health and the viability of their business models. The results of these tests help banks evaluate whether their internal strategies and operations are aligned with their risk appetite by identifying risk thresholds and highlighting scenarios that could threaten their stability. Because it is often challenging to accurately quantify the risks a bank is exposed to, the qualitative evaluation of stress test outcomes becomes especially important. This kind of analysis helps shed light on how a bank is managed and whether its approach to risk is sound, often offering insights that go beyond what numbers alone can reveal. In light of what happened with the Silicon Valley Bank, therefore, we can argue that the information contribution provided by stress tests becomes fundamental for small and mid-sized banks. It not only supports the development of more resilient business models but also enables supervisory authorities to take timely action when risks emerge.

As a consequence, most European banks tend to adopt more diversified business models across both their trading and banking activities compared to their U.S. counterparts. The ongoing oversight, through stress testing, even for small and less complex banks, plays a key role in discouraging riskier, highly concentrated strategies. These concentrated models can lead to the rapid growth of individual banks, but also make them vulnerable to large deposit withdrawals if they suddenly need to raise liquidity, for small and mid-sized banks. It not only supports the development of more resilient business models but also enables supervisory authorities to take timely action when risks emerge. In the case of SVB, the absence of such continuous oversight was a key weakness. If SVB had been a European institution, its asset size from 2019 to 2022 would have classified it as a large bank, either in Category 1 or 2, requiring full compliance with the European Banking Authority's (EBA) stress testing framework. It would also have been supervised directly by the European Central Bank (ECB), offering another layer of scrutiny (Arrigoni and Restelli, 2023).

Another key difference between the European and U.S. banking systems, one that helps explain the stronger position of many European banks, is the broader application of capital and liquidity requirements in the EU. In the United States, the EGGRCPA significantly rolled back regulations for smaller banks, exempting institutions with assets under $100 billion from participating in system-wide stress tests and from calculating key ratios, such as the Liquidity Coverage Ratio (LCR). In contrast, European prudential regulation has chosen to maintain nearly all capital and liquidity requirements, even for small and less complex banks, thereby fostering a more level playing field across the system (Enria, 2023). This approach has benefited both supervisors, such as the EBA and ECB, and the banks themselves, as it ensures continued access to valuable data generated through these regulatory requirements. European authorities not only emphasise the importance of these measures for static analysis, which must, in any case, be calibrated according to the current risk undertaken by each institution, but also the possible consequences of their removal or weakening in terms of transparency and potential distortions in the investment strategies implemented by individual entities.

In terms of capital strength, European banks, especially the smaller ones, tend to be better capitalised than their U.S. counterparts. While large banks (G-SIBs) on both sides of the Atlantic show similar capital levels due to aligned global standards, the gap widens considerably when comparing smaller institutions, with European banks showing significantly higher capital ratios.

In this context, it is important to emphasise that the risk of unrealised losses, which is a major concern for many US banks, appears to be much lower in European banks, which, although they have experienced a similar increase in deposits as US financial institutions, have opted to invest in cash positions rather than in long-dated securities. This trend line in favour of European banks was also confirmed for liquidity, with particular reference to the LCRs calculated within the two financial systems: European banks, both G-SIBs and small ones, were shown to possess HQLAs of 160%, while US banks, especially those falling within Categories I and II, recorded average HQLAs amounting to 125% of the net cash flows needed to face adverse market conditions over a 30-day time horizon (Arrigoni and Restelli, 2023).

The financial institutions within the Banking Union, especially the small and medium-sized ones, appear to be in a much better solvency condition, also due to the large availability of cash and central bank reserves within their existing reserves, which allows them to effectively manage the risk of mark-to-market losses and the resulting possible liquidity demands. However, the case of Silicon Valley Bank also serves as a reminder of a missing piece in the European framework: the European Deposit Insurance Scheme (EDIS), the third pillar of the Banking Union, has yet to be implemented. Currently, there is no unified mechanism in EU regulation to manage the potential negative effects of stress test disclosures. In times of crisis, this could make it harder to restore market confidence or, alternatively, push regulators to withhold stress test results, each with its own risks and implications.

Overall, however, given the different interpretation of the proportionality principle in stress tests and the better situation of European banks in terms of capital and liquidity, we can consider a European SVB unlikely at present, although this situation should not distract regulators and authorities from the continuous and necessary process of improving banking supervision practices in order to ensure a resilient EU financial system.

Conclusion

The sudden downfall of Silicon Valley Bank created fear across financial markets and affected the valuation of banks worldwide. In this unstable environment, rising interest rates were seen as the key factor behind SVB`s collapse, and the question quickly arose about which bank would fall next. In examining SVB's balance sheet, Jiang, Matvos, Piskorski, and Seru (2023) identified other banks as being in a more precarious position in terms of capital adequacy or unrealised losses.

This thesis reveals that by the close of 2021, the economic value of equity was already signalling excessive risk-taking. In this regard, it asserts that the reasons behind SVB's swift collapse can be attributed to three primary factors: lax regulatory supervision, a lack of market control, and poor risk management practices within the bank itself.

Concerning regulatory oversight and market discipline, the financial crisis was largely due to failures in regulatory oversight. When the Economic Growth, Regulatory Relief, and Consumer Protection Act was passed in 2018, institutions such as SVB were exempted from critical supervisory stress tests. SVB was able to engage in high-risk investment strategies without proper supervision because it was not subject to more stringent oversight despite exceeding asset and exposure thresholds that should have triggered it. Even if SVB had been subject to the 2022 Dodd-Frank Act Stress Tests, the impending liquidity crisis might not have been revealed based on the tests' erroneous assumptions, such as assuming a decline in interest rates. However, such a result would have initiated an earlier regulatory response or a reassessment of SVB's CAMELS ratings, potentially providing an essential early warning. More broadly, SVB's collapse underscores the pressing need for regulation that looks ahead. Regulators tend to have a backwards-looking approach, fixing problems only after a crisis instead of anticipating future vulnerabilities and doing something about them despite increasingly complicated reporting requirements. Pressure from lobbying and poorly written regulatory frameworks can essentially put the brakes on reforms, even for urgent issues such as liquidity risk. Furthermore, the broader consequences for other institutions beg the question of whether banks could benefit from peer-based monitoring systems. A formalised whistleblowing system for qualifying institutions, monitored by supervisory authorities, could be an idea to explore despite potential reputational concerns.

Concerning a bank's risk management: It is in every bank's own fundamental interest to manage its risks not merely to the minimum standards required by regulators but to ensure the institution can operate sustainably, even under crisis conditions. To achieve this, best risk management practices must be adopted and embedded across the entire organisation. In today's highly interconnected environment and fast-paced social media landscape, it just takes one and a half days from the first signs of stress to the loss of trust to a bank run to default, an incredibly short time, leaving little time to implement effective countermeasures or emergency interventions. Consequently, maintaining robust and proactive risk management is not optional; it is essential.

SVB's collapse demonstrates that regulatory frameworks need to keep up with modern challenges. Several reforms are necessary:

1. *Enhanced Oversight and Risk Identification*: Even under the proportionality principle, comprehensive supervision must extend to all banks, regardless of size. Waivers that exempt smaller institutions from key requirements, such as the Liquidity Coverage Ratio (LCR), can conceal dangerous risks. SVB's heavy dependence on venture capital-related deposits went unnoticed due to inadequate monitoring of funding concentration. Banks should perform granular analysis of liquidity sources and identify correlated risks, not just asset-side concentration;

2. *Remove Accounting Distortions in Risk Ratios*: Regulatory tools like EVE (Economic Value of Equity) and the LCR should incorporate mark-to-market valuations to reflect real-time vulnerabilities. Current practices, which allow amortised cost accounting in liquidity assessments, obscure the true risk. This approach did not reflect SVB's huge unrealised losses, which were hidden by outdated accounting conventions;

3. *Move Beyond Ratio-Based Regulation*: While risk ratios offer a useful baseline, they must be complemented with institution-specific assessments. SVB's unique business model, focused heavily on venture capital, meant it faced different risks than traditional banks. Yet standardised frameworks often overlook such nuances, particularly in the supervision of non-systemically important institutions. Regulatory processes such as the Supervisory Review and Evaluation Process (SREP) must be applied rigorously across all bank sizes, with tailored measures based on the business model and risk profile;

4. *Scrutiny During Periods of Rapid Growth*: Exponential growth, as SVB experienced between 2019 and 2022, can mask emerging risks. Monitoring systems frequently fail to keep pace with such expansion, while overconfidence among management can lead to critical oversight failures. Supervisory systems should flag sudden increases in deposits or lending as potential red flags and initiate trend-based risk reviews;

5. *Maintain Strong Risk Governance*: Operating without a Chief Risk Officer, as SVB did during a crucial period, is inexcusable. Banks must ensure that risk management is deeply embedded in their operational culture and not merely a regulatory requirement. Management should embrace proactive risk practices that exceed minimum standards, especially in a world where a bank can go from stress signs to default in just over a day.

Furthermore, the systemic spillover of SVB's failure points to the dangers of neglecting mid-sized banks. The subsequent financial contagion demonstrated that crises are not limited to large, globally important banks.

Under an extremely interconnected international financial environment, vulnerabilities in smaller banks can rapidly propagate, causing widespread instability. The European Union’s stricter regulatory standards, including universal application of the 100% LCR and more robust stress testing, have contributed to a more stable banking sector compared to the United States. Nevertheless, the SVB case reminds us of an important lesson on how to maintain an effective financial backstop and stress-testing regime for all banking institutions, regardless of size.

In conclusion, SVB's failure is a clear reminder of the vulnerability of rapidly expanding, insufficiently diversified, and lightly regulated institutions. It emphasises the necessity of strict stress testing, dynamic, forward-thinking regulations, and an accountable culture in risk management. Before the first signs of stress become a worldwide panic, the financial system must respond to crises and predict and prevent them.

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