Bank balance sheet optimization

Pedro Júdice
ISCTE Business Research Unit,
Avenida das Forças Armadas, 1649-026 Lisbon
pedro.judice@iscte-iul.pt

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Abstract

The management and optimization of balance sheets is one of the most important problems for banks and financial stability. We review the foundations of the general balance sheet optimization problem, specifically addressing the most important risks a bank faces.

We then review the literature on balance sheet optimization, which has been developed over several decades. The methods gained importance after the subprime crisis, with the need for stronger balance sheets, and have seen several improvements recently.

Keywords: asset-liability management, balance sheet optimization, banking, credit risk, finance, financial stability, interest rate risk, liquidity risk, optimization, risk management.

Keypoints:

- Managing balance sheets properly is crucial for the financial sustainability of banks and financial stability.
- Balance sheet optimization consists of trading-off return with the different risks on the balance sheet, namely interest rate, credit, and liquidity risks.
- We formulate the general balance sheet model with the most important building blocks.
- We then survey the literature on bank balance sheet optimization, starting with research from the sixties.
- Balance sheet models gained importance after the subprime crisis, which highlighted the need for stronger balance sheets.
- We also review the state of the art, with applications such as the inclusion of recent accounting standards, large-scale optimization, or multidimesional efficient frontiers.

1 Introduction

The management of bank balance sheets is one of the most critical management challenges, with far-reaching implications for the performance of banks, financial stability and even economic sustainability.

Banks have to carefully select how to allocate their assets and liabilities according to segments, maturities or credit ratings. A bank that allocates too much to riskier loans may be profitable in the short term, but will risk its solvency once the first financial crisis hits the door. Having a "fortress balance sheet", as mentioned for example in J.P. Morgan (2021), that can navigate through turbulent times is one of the most important aspects of bank management.

At a financial stability level, the allocation of balance sheets and the deployment of credit is of the utmost importance. Several studies have shown that poor allocation of credit has been linked to poor financial stability and low economic growth (Caballero et al. (2008), Hsieh & Klenow (2009), Schivardi et al. (2022)). The excessive reliance on short-term wholesale funding has been identified as a culprit of financial crises (Hahm et al. (2013)).

Therefore, banks and regulators need to have models to allocate their assets and liabilities. These models are typically multi-criteria and seek to maximize the expected return for the bank while keeping in check the many different risks that a bank faces.

This survey paper reviews some of the most important bank balance sheet models. We start by reviewing the main balance sheet risks. Subsequently, we review the literature on balance sheet optimization, starting from the sixties until the present day.

2 The generic balance sheet optimization model

Financial intermediation is the core business of commercial banks, and consists in obtaining funds and allocating them to different assets. The bank obtains funds from liabilities, on which it pays interest. Shareholders invest capital and obtain dividends as a function of the bank's profit. The funds are allocated to assets, and the bank receives an interest on these assets. The bank profits from the net interest margin.

Assets and liabilities are recorded through the balance sheet of the bank. Let us give an example of a bank's balance sheet. For ease of exposition, we will first focus on a one-period model, assuming a horizon of one-year – yielding a one-period optimization.

Definition 1. *A balance sheet is a vector $x = (x_j)$, with j varying in $\{-m, \ldots, -1\} \cup \{1, \ldots, n\}$, where m denotes the number of liabilities and n the number of assets. We asume that $x_j \geq 0$. For ease of notation we assume that shareholder's capital is represented by x_{-1}.*

Given a balance sheet $x = (x_j)$, $j \in \{-m, \ldots, -1\} \cup \{1, \ldots, n\}$, assets

$j \in \{1, \ldots, n\}$ receive an estimated return r_j given by interest received minus the expected credit losses, whereas liabilities $j \in \{-m, \ldots, -1\}$ have a cost r_j, which is typically the fixed rate on these instruments.

The estimated return on the balance sheet can assume a linear structure, such as

$$\mu(x) = \sum_{j=1}^{n} r_j x_j - \sum_{j=1}^{m} r_{-j} x_{-j}. \tag{1}$$

Estimated returns can also assume a non-linear structure. For example, r_j can be a function of the balance sheet x.

The balance sheet typically has several risks. We highlight the most commonly discussed: interest rate risk, credit risk, and liquidity risk.

Interest rate risk stems from the fact that banks fund themselves in short-term liabilities to invest in long-dated assets, such as mortgages (maturity transformation). There are several ways to measure interest rate risk, that account for the mismatch of the maturities between assets and liabilities. The first examples that come to mind are linear measures. Let τ_j be the maturity for asset j, and D_τ the modified duration corresponding to maturity τ. Assume a yield curve shock of (s_τ), where τ varies across the set of possible maturities on the yield curve. Then one can construct a measure of interest rate risk based on the interest rate shock given by

$$\sigma_1(x) = \sum_{j=1}^{n} x_j D_{\tau_j} s_{\tau_j} - \sum_{j=1}^{m} x_{-j} D_{\tau_{-j}} s_{\tau_{-j}} \tag{2}$$

The measure above can be extended over a set of several scenarios by taking the maximum over the scenarios, guaranteeing convexity. Interest rate risk can also be measured using other measures such as Value at Risk (Jorion (2007)).

Credit risk is also very present in balance sheets. For the purpose of capital requirements, linear credit risk measures are frequently used, based on Vasicek (2002) and Gordy (2003):

$$\sigma_2(x) = \sum_{j=1}^{n} x_i LGD_i N\left(\frac{N^{-1}(p_i) + \sqrt{\rho_i}}{\sqrt{1-\rho_i}}, \right) \tag{3}$$

where ρ_i is the systematic correlation among assets of type i, p_i is the probability of default of asset type i, and LGD_i is the loss given default for asset i. Other approaches for measuring credit risk include CreditMetrics (J.P. Morgan et al. (1997)), Credit Portfolio View (Wilson (1998)), and approaches using copulas (Li (2000)).

A bank run occurs when depositors or creditors suddenly ask for their funds back from the bank. If the bank does not have enough liquid assets (cash and securities) that it can sell quickly, it will face bankruptcy. Liquidity risk is thus the risk from withdrawals from creditors. It is mitigated by the amount of liquid securities that the bank has. Linear measures for liquidity risk compare the realizable value of assets $(1-l_j)x_j$ to the potential withdrawals on liabilities $l_{-j}x_{-j}$:

$$\sigma_3(x) = \sum_{j=1}^{m} l_{-j}x_{-j} - \sum_{j=1}^{n}(1-l_j)x_j, \tag{4}$$

where l_j are haircuts on assets and l_{-j} are run-off coefficients for liabilities.

One can also develop other kinds of liquidity risk measures, such as quadratic liquidity at risk (similar to normal Value-at-Risk (VaR), but the risk factor consists of withdrawals from creditors instead of the loss in asset values).

There are many other other risks: foreign exchange risk, operational risk, market risk, etc. Since banks are subject to many risks, how do you measure the total risk of the bank? This question is very important question because the answer dictates the amount of capital the bank should hold for the potential combined losses. Possible approaches include summing the risks (easy but over-estimates risks, due to no diversification effects), assuming a normal correlation between the risks, use copulas (Rosenberg & Schuermann (2006)), or simulate time series processes by developing stochastic processes that simulate the joint behaviour of the risk factors such as credit losses or interest rates (Drehmann et al. (2010)).

Using all these tools we can now formulate the generic balance sheet optimization problem in the one-period formulation

$$\begin{aligned} max \quad & \mu(x) && (5)\\ s.t. \quad & \sigma_k(x) \leq L_k && (6)\\ & \sigma_{agg}(x) \leq L_{agg} && (7)\\ & x_j \geq 0 && (8)\\ & x_{-j} \leq 0. && (9) \end{aligned}$$

The objective function (5) corresponds to the estimated return on the balance sheet, whereas equation (6) corresponds to the individual limits for credit, interest rate, and liquidity risks. The limit on aggregate risk is specified by equation (7).

The model that we show above is a generic one-period model on optimal balance sheets, which we used to understand the construction of the optimal balance sheets. It is also possible to prescribe limits on regulatory ratios such as those prescribed by Basel III. Based on this generic model, we now review the literature on bank balance sheet management.

3 Survey of models

There are many references on bank balance sheet management, also known as asset-liability management. In this short piece, we cannot include all the references in the literature, so we will try to include some of the most important papers.

Some of the early papers on bank balance sheet management include Chambers & Charnes (1961), Pyle (1971), Bradley & Crane (1972), Brodt (1978), Eatman & Sealey (1979), or Giokas & Vassiloglou (1991). Kusy & Ziemba (1986) and Oguzsoy et al. (1997) applied stochastic techniques to solve the bank optimization problem. In Güven & Persentili (1997), the authors develop a linear programming approach to the asset-liability management problem, maximizing a bank's balance sheet profit subject to several risk constraints. Kosmidou & Zopounidis (2004) used Monte-Carlo simulation on interest rates to develop several scenarios to compute the optimal balance sheet.

The subprime crisis brought a public attention to the excessive risks of the financial system and to the need to build better balance sheets. The excessive reliance on short-term wholesale funding as in the case of Bear Stearns, Lehman Brothers, or Northern Rock, led to liquidity crunches and bank failures. As a response to the crisis, the Basel Committee for Banking Supervision enforced new solvency and liquidity restrictions, known as Basel III Basel Committee on Banking Supervision (2009), that enforced new liquidity and solvency ratios.

Building better balance sheets that simultaneously complied with sustainable risk limits and generated profit became more and more important. As a consequence, both academia and the industry became more focused on what J.P. Morgan called the "fortress balance sheet" (J.P. Morgan (2021)). Birge & Júdice (2013) created a long-term scenario methodology for managing the risks of the balance sheet, which later was complemented with an asset-liability optimization in Júdice et al. (2021). Hałaj (2016) devised a bank balance sheet model with stochastic liquidity, while Schmaltz et al. (2014) created a model for a bank to maximize return and comply with Basel III. Mencía (2012) analyzed the trade-off between risk and return for a portfolio of loans.

Balance sheet management has shown to have multiple ramifications. In Júdice & Zhu (2021) the authors have shown the relation between optimal balance sheets and the prices of credit and interest rate risk, using linear programming duality. Brito & Júdice (2021) have looked into the optimal credit allocation problem under IFRS 9, the new accounting regime for credit losses based on the lifetime expected credit loss. Continuous-time balance sheet optimization has been formulated by Lipton (2016) and Mukuddem-Petersen & Petersen (2006), although the authors had to make several simplifications to solve the problem. Sirignano et al. (2016) studied a large-scale credit allocation problem, and Yan et al. (2021) devised a robust banking asset allocation methodology. A practicioner's perspective for balance sheet optimization problems is treated in the book by Lubinska (2020).

A consequence of the bank management models has been the theory of efficient frontiers with more than one risk. Recall that in portfolio theory one studies the optimal allocation of assets, trading off return versus one risk measure. In the case of balance sheet management, one trades off the optimal return versus different risk measures, typically interest rate, credit, climate, or liquidity risks, amongst other risks. The efficient frontier is no longer a curve, but rather a hypersurface with several dimensions. A thorough treatment of these solutions, with several applications, is conducted in Maier-Paape et al.

(forthcoming).

4 Conclusion

In this survey paper, we reviewed balance sheet optimization models, starting from the building blocks, including the measurement of risks and the maximization of return. We then proceeded to review some of the main references in balance sheet management. We hope that this paper stimulates further research on this important problem, with far-reaching implications for financial stability.

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