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RESEARCH PAPER

Multi-Objective Programming for Asset-Liability Management: The Case of Iranian Banking Industry

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ABSTRACT
Practically, Islamic banking in Iran is not much different from conventional banking principles. Many paradigms of commercial banking are considered in the Islamic-Iranian banking. Owing to the fact that asset and liability optimization is an important issue in the banking industry, the present paper investigates balance sheets and income statements to constitute a structure for measuring each asset's risk. The author uses the method of multiple objective programming to solve the problem of a commercial bank's diversified pursuit of low risk and high profit by considering the so-called duration constraint. To test the proposed model, data were collected from an Iranian commercial bank named Mellat bank from June 2009 to December 2016. The results suggest that Mellat bank, as the biggest private bank in Iran, should reform its asset-liability allocation to achieve the optimal level.

KEYWORDS: *Asset-liability management; Commercial banking; Optimization; Iranian banking industry.*

1. Introduction

Asset-liability management (ALM) is a challenging dilemma for financial institutions. ALM makes an allusion to a process in which enterprises try to optimize their asset and liability to achieve the desired level of profit and liability. This problem is confronted by commercial institutions such as banks and financial services companies whose endeavors ae directed at maximizing stakeholders' profit. In other words, considering the increasing pressure of competitive markets and resource limitations, maximization of income along with the minimization of cost is the primary goal of banks and financial companies. To achieve these aims, banks need to manage their risks and, also, identify risk factors. The condition of asset and liability in Islamic banking is one of the important factors in ALM that deals with restructuring two sides of a balance sheet to minimize risk and achieve plausible profitability.

Arewa [1] contends that banks become involved in ALM in order to seek three main purposes: (i) to achieve high profitability, (ii) to retain desired liquidity level, and (iii) to ensure security. Since these goals are in contrast, classic methods such as simple linear programming seem to be inefficient; therefore, the application of multi-objective approaches may be more productive. For this purpose, the author studied the performance of a multi-objective programming model for handling the optimal allocation of asset and liability, a traditional conundrum in ALM, while the focus is on practical application for a shariah-complaint bank in Iran. ALM deals with the handling of miscellaneous risks derived from incongruity between liability class and asset class in the banking industry. That is to say, ALM functions as an instrumental mechanism to optimize the risks of both interest rate and liquidity [2].

ALM puts forward the concept of fair management of financial resources by setting up exclusive risk indicators. For these reasons, ALM is referred to as the backbone of effective risk management [3]. Accordingly, managers can easily access and analyze all information pertaining to the risk indicators, interpret the impact of their future decisions on the bank risk profile, and design the prospective financial plan according to their policies. This shows the significance of the present studies, especially when it comes to the vague status of Iranian

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banks. Therefore, the objective of this study is to explore the optimal level of asset and liability allocation in a bank profile in terms of Iranian constraints and regulations by proposing a multi-objective model whose focus is on risk minimization and profit maximization.

In a seminal paper, Machiel [4] propounded that a bank's balance sheet efficient management led to the goal of maximizing returns and, concurrently, taking into account conflicting goals such as minimizing risk. Thus, the present paper investigates balance sheets and income statements to constitute a structure for measuring each asset’s risk. The author used the multiple-objective programming method to solve the problem of banks’ low risk and high profit with respect to Iranian banking regulations.

In order for this study to be directed, asset and liability structure in Iranian banking system must be considered on the basis of Islamic Shariah and non-usuric law. According to Islamic banking precepts, the bank’s income is derived from loans and facilities provided, while deposits represent the source of costs. In conventional banking, the former is categorized under the asset class and the latter is subsumed under the liability class in the balance sheet. By classification asset and liability classes, the author can translate the regulations into the model constraints to find the optimal allocation for each class. Accordingly, the empirical structure of the research can be formulated, as shown in Fig. 1.

This paper adds three contributions to the literature. Unlike previous studies that applied stochastic programming models to solve ALM in the banking industry, the present study uses a mathematical model with a multi-objective approach by taking into consideration the special constraints associated with Iranian banks to ascertain the optimal allocation of asset and liability. Second, the proposed model includes duration constraint, which was neglected in the previous studies. Duration constraint is a criterion to measure asset or liability sensitivity to interest rate fluctuations. Finally, the author models asset returns and interest rates applying a value at risk (VaR) process. VaR is of capacity to make a more precise estimation of risk with respect to the fact that yield curve shifts unparallelly.

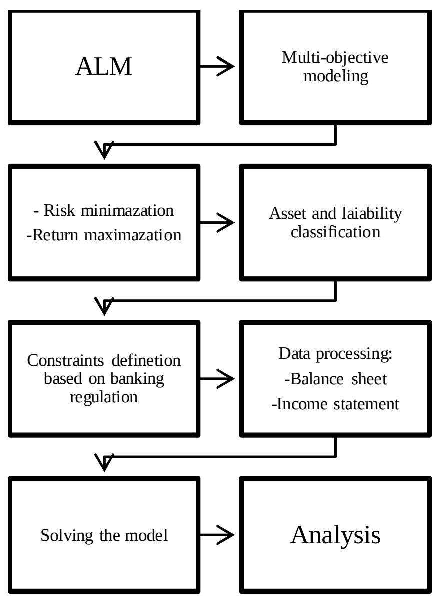

Fig. 1. Structure of the present research

The paper is organized as follows. Section 2 presents a literature review pertaining to this study. Section 3 introduces the optimization multi-objective programming model. Section 4 presents the empirical approach, and this is followed in by empirical results. Section 5 concludes the paper.

2. Literature Review

ALM is referred to as a holistic tool for quantifying and recording market risks. Various types of risks such as interest rate, liquidity risk, exchange rate, etc., constitute the market risks [5]. Since ALM is of a prodigious impact on the bank’s risk profile, it must align with specific policies germane to a bank [6]. Obviously, financial policies are unique based on the markets and their atmospheres [7,8]; thus, banks and other

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financial entities must act to maintain their investors' confidence [9]. For this reason, financial institutions and banks apply ALM to organize their risk profile that gives rise to the development of ALM techniques. This cardinal property of ALM has stimulated numerous researchers to focus on this field; however, literature shows that conceptual frameworks have been in the center of attention. Be that as it may, there are a variety of papers that have concentrated on ALM application in both banking industry and other financial entities.

Chambers and Charnes [10] introduced one of the first models for ALM as a deterministic linear programming model associated with calculating an optimal level for a bank's asset and liability. They considered the level of existing risk in bank as model constraints. However, their investigations were further developed by Cohen and Hammer [11], Robertson [12], Lifson and LoBlackman [13], and Fielitz and Loeffler [14]. However, later studies have presented various approaches such as dynamic programming [e.g. 15, 16] and simulation-based programming [17-19].

Kuritzkes and Schuermann [20] scrutinized market risk, credit risk, operational risk, business risk, and asset-liability risk for the major U.S. banks by setting a correspondence between the profit and loss accounts of income statement and risks. Furthermore, considering 51 European banks' asset data in 2006, Kretzschmar et al. [21] constructed a hypothetical bank and obtained the risk-driven factors thorough classifying the assets. They also simulated changes in the value of assets via Economic Scenario Generation model (ESG), accessed the distribution of bank assets, and calculated the overall risk. From other studies, using the income statement data seems the current common practice, while, in fact, there are cash flow statement, balance sheet, and other information. Furthermore, incorporating balance sheet with other information might reflect the risk of assets more accurately.

Abou-El-Sood and El-Ansary [22] discussed ALM structure in Islamic banking by applying canonical correlation analysis, and found that the interdependence between asset and liability classes was stronger for smaller banks. Wai et al. [23] applied the goal programming to ascertain the optimal levels of asset and liability for a Malaysian bank. They also proposed possible improvements for the bank's asset, liability, and equity. Zhang [24] investigated the asset and liability nexus in China banking system, and found that some modifications for loan ratio and deposit ratio were necessary. Said and Rim [25] studied ALM structure in the Tunisian banking industry between 2000 and 2014 using canonical correlation analysis. They reported some mismatches between asset and liability classes.

Barmuta et al. [26] proposed a mathematical model for asset-liability optimization in the Russian banking industry, taking into consideration foreign exchange rate. They compared the results obtained with actual data and recommended the optimal asset and liability allocation. Inshira and Jahfer [27] investigated the ALM effect on financial problems for commercial banks in Sri Lanka. They found that the severity of liquidity risk gave rise to dire problems like a decline in customer's trust and unusual withdrawals. They suggested the banks should control their risk factors such as capital adequacy ratio, loans to deposits ratio, and return on equity. Arora and Kohli [28] studied the ALM in selected private and public banks in India through stock and flow approach and found that public banks were more susceptible to improper position due to mismatches and lack of accountability, whereas private banks were more efficient in organizing their assets and liabilities.

To be in line with literature developed so far, this paper tries to posit a model for decreasing a bank's portfolio risk and augmenting its return using data from financial statements of an Iranian commercial bank, Mellat Bank, over a period of 2009 to 2016. While stochastic programming is the most popular technique for solving ALM problems [e.g., 29-34), the present study proposes a mathematical model with the multi-objective approach considering the constraints of Iranian banks to determine the optimum allocation of asset and liability. Volatile status of the Iranian banking industry necessitates a thorough investigation of asset-liability structures in Iranian banks as similar studies are lacking in the literature. Therefore, this study aims to address the gap of how ALM works in the Iranian banking industry as the proposed model is designed for numerical experiments to ascertain the position of asset and liability with respect to Iranian banks' constraints and regulations.

3. Optimization Model Based on Multi-Objective Programming

3.1. Objective functions

In this subsection, the linear integrated model of risk and its calculation approach are presented. The author uses Value at Risk approach to estimate the risk. The purposes are to minimize the overall risk and maximize the assets' return.

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Therefore, the function of the integrated risk is as follows:

$$Risk\ (x) = \sum R_i(x) \quad (1)$$

where $x = (x_1, x_2, \dots, x_3)$ represents the asset portfolio of a bank, and $R_i(x)$ denotes the i^{th} risk. The aim is to minimize the overall asset risk. The second objective function is profit function, which is equal to the difference between profit and loss of the liability and asset:

$$ret(X, Y) = \sum p_i x_i - \sum p_j y_j \quad (2)$$

where $Y = (y_1, y_2, \dots, y_j)$ denotes the liability in bank portfolio, p_i and p_j represent the profit and loss of the i^{th} and j^{th} asset or liability.

3.2. Model constraints

After constituting the integrated risk function, the author presents constraints of assets or liabilities as follows.

I. Capital Adequacy Ratio: This constraint compels banks to have the ratio of total regulatory capital to risk-weighted assets more than 8%. Therefore,

$$\frac{Capital}{RWA} \geq \%8 \quad (3)$$

where Capital and RWA denote shareholders' equity risk-weighted assets, respectively.

II. The deposit reserve constraint: Under the law of the Iranian Central Bank, commercial banks are obliged to deposit a certain amount of their gathered deposits to the Central Bank to control banks' lending. The central bank sets the percentage of the required deposit known as the deposit reserve ratio derived from Islamic-Iranian law:

$$0.1 \sum y_j \leq X_c \leq 0.13 \sum y_j \quad (4)$$

Eq. (4) signifies that the deposit reserve ratio (x_c) of large financial institutions is between 0.1 and 0.13 of banks' gathered deposits (y_j).

III. Loans constraint: In accordance with Islamic-Iranian law, banks' loans cannot exceed 80% of the deposits, meaning that the constraint for deposits will lead to a constraint for loans.

$$0.75 \sum y_j \leq \sum x_{loan} \leq 0.85 \sum y_j \quad (5)$$

IV. Cash scale constraint: Banks should assign a certain proportion of liquid assets to meet the needs of customers' withdrawal and the cash flow. This constraint is defined as follows:

$$0.01 \sum y_j \leq X_{cash} \leq 0.02 \sum y_j \quad (6)$$

where X_{cash} represents the amount of cash.

V. Expected growth of asset constraint: Expecting assets to grow more than the previous period is a natural expectation. Therefore, this constraint is defined as follows:

$$Assets\ in\ previous\ period \leq \sum x_i \leq \alpha \times Assets\ in\ previous\ period \quad (7)$$

where α is the average growth of the i^{th} period.

VI. Deposit from other banks and financial institutions constraint: This constraint is related to interbank transactions. By studying Mellat Bank balance sheet, 10 to 20 percentages of assets are associated with this constraint; therefore,

$$0.1 \sum y_j \leq X_b \leq 0.2 \sum y_j \quad (8)$$

where X_b represents the deposit from other banks.

VII. Duration constraint: Duration is a measure to calculate the time value of liabilities and assets with a fixed income. The difference between assets duration and liabilities duration is known as the duration gap that is defined as follows:

$$D_{gap} = D_A - \frac{L}{A} D_L \quad (9)$$

where D_{gap} represents the duration gap, and L and A are the values of assets and liabilities, respectively. D_A and D_L denote the durations of assets and liabilities, respectively, and their formulations are as follows:

$$D_A = \sum w_i D_{Ai} \quad (10)$$

$$D_L = \sum w_j D_{Lj} \quad (11)$$

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where w_i and w_j are the weights of the i^{th} asset and the j^{th} liability. Hence, the last constraint is given below:

$$D_A - D_L \frac{\sum y_j}{\sum x_i} \leq 1 \quad (12)$$

3.3. Multi-objective programming model

At a glance, the formulation of the multi-objective programming model proposed by the present study is defined as follows:

$$Min\ Z \begin{cases} Risk(X) = \sum\sum r_i x_i \\ ret(X, Y) = -(\sum p_i x_i - \sum p_j y_j) \end{cases}$$

s.t.

$$\frac{Capital}{RWA} \geq \%8 \quad (13)$$

$$0.1 \sum y_j \leq X_c \leq 0.13 \sum y_j$$

$$Assets\ in\ previous\ period \leq \sum x_i \leq \alpha \times Assets\ in\ previous\ period$$

$$0.01 \sum y_j \leq X_{cash} \leq 0.02 \sum y_j$$

$$0.75 \sum y_j \leq \sum x_{loan} \leq 0.85 \sum y_j$$

$$0.1 \sum y_j \leq X_b \leq 0.2 \sum y_j$$

$$D_A - D_L \frac{\sum y_j}{\sum x_i} \leq 1$$

4. Empirical Study

The author chose Mellat Bank in order to evaluate the performance of the proposed model. In so doing, the quarterly income statements and balance sheets from June 2009 to December 2016 were used. The present study separates interest-earning assets and interest-bearing liabilities. Loans and advances to customers are subdivided into personal loans, bill discount, and lending of the public sector. Investment is divided into bonds and the deposit is divided into the long time, short time, special short time, and Qard al-hasan deposits. The Qard al-hasan deposit is a type of loan in Islamic banking without any interest. Table 1 shows the parameters extracted from Mellat bank balance sheet and their initial values besides yield rate or interest rate.

Tab. 1. Asset and liability initial values and yield/interest rate for Mellat bank in 2015 (in IRR)

Assets	Symbol	Initial value	Quality yield rate	Annually yield rate
Cash	X_1	18,635,786	0	0
Deposit in the central bank	X_2	165,531,428	0	0
Storage and lending of banks and other financial institutions	X_3	157,387,578	0.0625	0.25
Lending of public sector	X_4	254,364,192	0.05	0.20
Personal loans	X_5	754,280,828	0.05	0.20
Bill discount	X_6	17,879,286	0.05	0.20
Bonds	X_7	27,127,002	0.045	0.18
Liability	Symbol	Initial value	Quality interest rate	Annually interest rate
Qard al-hasan deposit	Y_1	199,035,767	0	0
Long-time deposit	Y_2	414,950,638	0.045	0.18
Short-time deposit	Y_3	386,668,328	0.025	0.10
Special short-time deposit	Y_4	4,548,797	0.035	0.14
Other deposits	Y_5	62,799,313	0.025	0.10

Basically, this paper considers the market risk of Mellat bank from net interest income. The author adopts a confidence level of 95% with respect to the definition of VaR, and the (30 × 05%=) 15^{th} number is the VaR re-sorting data in an ascending order, which means the probability that risk is greater than $VaR_{0.95}$ (or the yield rate is less than VaR95%) is 5%. The market risk of each asset is shown in Table 2.

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Tab. 2. Assets' market risk for Mellat bank in 2015

Asset	Symbol	Market risk
Cash	X_1	0
Deposit in the central bank	X_2	0.00033
Storage and lending of banks and other financial institutions	X_3	0.00043
Lending of public sector	X_4	0.012
Personal loans	X_5	0.032
Bill discount	X_6	0.012
Bonds	X_7	0.0002

Liquidity risk, which is net investment income divided by risk-weighted assets, equals -0.00021. Thus, each asset from x_4 to x_7 will have the liquidity risk of -0.00021. Moreover, the credit risk is equal to 0.02, which is calculated by the similar VaR method with loan impairment divided by risk-weighted assets. Loan impairment corresponds to the personal loans; therefore, the author confirms the existence of the credit risk in personal loans (x_5). Operational risk is the remainder of the overall risk except for three kinds of risks which are -0.00975; the author considers that it exists in all the assets from x_4 to x_6. Furthermore, the constraints of the model and their equations are presented in Table 3.

Tab. 3. Constraints and their equations of the multi-objective optimization model

Constraint	Equation
Capital adequacy ratio	$\frac{84000000 \times 0.80}{0.2x_3 + 0.2x_6 + x_5} \geq \%8$
Deposit reserve	$0.1\sum_{j=1}^{5} Y_j \leq X_2 \leq 0.13\sum_{j=1}^{5} Y_j$
Expected growth of asset	$1395206100 \leq \sum_{i=1}^{8} X_i \leq 1.06 \times 1395206100$
Cash scale	$0.01\sum_{j=1}^{5} Y_j \leq X_1 \leq 0.02\sum_{j=1}^{5} Y_j$
Loans	$0.75\sum_{j=1}^{5} Y_j \leq X_4 + X_5 + X_6 \leq 0.85\sum_{j=1}^{5} Y_j$
Deposit from other banks and financial institutions	$0.1\sum_{j=1}^{5} Y_j \leq X_3 \leq 0.2\sum_{j=1}^{5} Y_j$
Duration	$0.75 - \frac{\sum_{j=1}^{5} Y_j}{\sum_{i=5}^{6} X_i} \times 0.8 \leq 1$

Based on the above criteria and analysis, the multi-objective optimization model for our case is formulated as follows:

$$\text{Min} \quad \text{Risk}(X) = 0.00033x_2 + 0.00043x_3 + 0.012x_4 + 0.032x_5 + 0.012x_6 + 0.0002x_7$$

$$\text{ret} = \%6.25x_3 + \%5x_4 + 5\%x_5 + \%5x_6 + \%4.5x_7 - \%4.5y_2 - \%2.5y_3 - \%3.5y_4 - \%2.5y_5$$

s.t.

$$0.016x_3 + 0.016x_6 + 0.08x_5 <= 67200;$$
$$0.1y_1 + 0.1y_2 + 0.1y_3 + 0.1y_4 + 0.1y_5 - x_2 <= 0;$$
$$x_2 - 0.13y_1 - 0.13y_2 - 0.13y_3 - 0.13y_4 - 0.13y_5 <= 0;$$
$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 >= 1395206;$$

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$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 <= 1478919;$
$0.01y_1 + 0.01y_2 + 0.01y_3 + 0.01y_4 + 0.01y_5 - x_1 <= 0;$
$x_1 - 0.02y_1 - 0.02y_2 - 0.02y_3 - 0.02y_4 - 0.02y_5 <= 0;$
$0.75y_1 + 0.75y_2 + 0.75y_3 + 0.75y_4 + 0.75y_5 - x_4 - x_5 - x_6 <= 0;$
$x_4 + x_5 + x_6 - 0.85y_1 - 0.85y_2 - 0.85y_3 - 0.85y_4 - 0.85y_5 <= 0;$
$0.1y_1 + 0.1y_2 + 0.1y_3 + 0.1y_4 + 0.1y_5 - x_3 <= 0;$
$x_3 - 0.2y_1 - 0.2y_2 - 0.2y_3 - 0.2y_4 - 0.2y_5 <= 0;$
$0.8y_1 + 0.8y_2 + 0.8y_3 + 0.8y_4 + 0.8y_5 + 0.25x_5 + 0.25x_6 >= 0;$
$x_1 >= 15000;$ $x_1 <= 20000;$ $x_2 >= 100000;$ $x_2 <= 180000;$ $x_3 >= 100000;$ $x_3 <= 170000;$ $x_4 >= 200000;$ $x_4 <= 300000;$ $x_5 >= 600000;$ $x_5 <= 900000;$ $x_6 >= 10000;$ $x_6 <= 20000;$
$x_7 \geq 10000;$ $x_7 \leq 50000;$ $y_1 \geq 150000;$ $y_1 \leq 250000;$ $y_2 \geq 300000;$ $y_2 \leq 450000;$ $y_3 \geq 250000;$ $y_3 \leq 400000;$ $y_4 \geq 3000;$ $y_4 \leq 10000;$ $y_5 \geq 45000;$ $y_5 \leq 80000;$

To find the optimal allocation of asset and liability, the author solved the multi-objective problem using Lingo software, and the results are presented in Tables 4 and 5.

Tab. 4. Realized and optimal assets of Mellat bank (in IRR)

Asset	Symbol	Realized	Optimal	Difference	Deviation (%)
Cash	X_1	18,000	13,000	5,000	28
Deposit in the central bank	X_2	165,000	153,000	12,000	7
Storage and lending of banks and other financial institutions	X_3	157,000	160,000	3,000	2
Lending of public sector	X_4	254,000	227,000	27,000	11
Personal loans	X_5	754,000	650,000	104,000	14
Bill discount	X_6	17,000	16,000	1,000	6
Bonds	X_7	27,000	15,000	12,000	44

According to the results, the cash and bonds are 28% and 44% more than the optimum levels in the asset class, respectively. That is to say, there are remarkable mismatches in these classes where managers must reduce the cash and bonds. The findings also indicate that Mellat bank should reduce the amount of deposit in the central bank and lending of the public sector by 7 and 11 percent, respectively, in order to attain the optimal levels. Storage and lending of banks and other financial institutions is the nearest asset group to the optimal level by only 2 percent deviation, while the bill discount and personal loans should be reduced by 6 and 14 percent, respectively. According to the results presented in Table 4, Mellat bank needs to revise its asset class to meet the optimal levels and achieve proper profitability.

Along within liability class, Qard al-hasan deposit must be increased by 21 percent, whereas the special short time deposit, which is the most egregious suboptimal liability, must be decreased by 75 percent. Short time deposit and also the other deposits are 26% and 19% less than the optimum levels, respectively. On the other hand, the long-time deposit is the closest amount to the optimal level with 11 percent negative deviation in the liability class.

Tab. 5. Realized and optimal liability of Mellat bank (in IRR)

Liability	Symbol	Realized	Optimal	Difference	Deviation (%)
Qard al-hasan deposit	Y_1	250,000,000	199,000,000	51,000,000	21
Long-time deposit	Y_2	438,781,600	414,000,000	24,781,600	11
Short-time deposit	Y_3	400,000,000	386,000,000	14,000,000	26
Special short-time deposit	Y_4	10,000,000	4,000,000	6,000,000	75
Other deposits	Y_5	80,000,000	62,000,000	18,000,000	19

In this study, management policy constraints are realistic; hence, the risk-avoiding features are more accurate than and closer to actual preferences. The similarity between the results of the analysis and actual bank performance is explicitly observed. The results presented in both Tables 4 and 5 convey the degree to which Mellat bank has to adjust its allocation of the asset and liability in order to minimize risk and maximize profit simultaneously. In other words, the managers can adjust the portfolio of asset to reduce the risk according to the changes of each asset's value. For example, in order to reduce the risk, Mellat bank should augment the proportion of storage in the central bank so as to elevate the capability to resist risk; besides, they can enhance the proportion of loans and bonds and reduce the proportion of personal loans.

5. Conclusion

This paper proposed a multi-objective programming model for decreasing banks' portfolio risk and augmenting its return by using the data from financial statements of an Iranian commercial bank, Mellat bank, covering 2009-2016. This model was found to be more practical in the case of Iranian banks than others because the model constraints capture Iranian regulations, while these constraints can be adjusted according to different rules. The results obtained showed

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that Mellat bank should decrease the amount of its cash and bonds in the asset class to approach the optimum level. Increasing Qard al-hasan and decreasing other deposits in the liability class represent another way to achieve the optimal allocation.

It is difficult to make progress by extracting data between assets, profit, and loss accounts from the balance sheets of commercial banks. Therefore, one way for extending this study is to look for other ways that accurately establish relationships among assets, profit, and loss accounts. Then, working on the assets' risks and applying them to the proposed model is a pivotal point to be studied in the future asset and liability management problem.

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