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Generating interest rate scenarios for bank asset liability management

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Abstract Over the last years the Second European Directive on Banking and Financial services demand that financial institutions develop asset liability management tools to identify and measure the various financial risks they encounter. The present paper develops a goal programming ALM model with a simulation analysis, to assist a commercial bank in managing its exposure to interest rate risk taking into account a duration gap framework. An application of the ALM model takes place on a large commercial bank of Greece.

Keywords Asset liability management · Interest rate · Goal programming · Simulation · Duration-gap

1 Introduction

In their effort to manage effectively their assets and liabilities, financial institutions try to find the best choice among the most available and appropriate methods that could provide them with the most efficient asset liability management (ALM) tools.

Since ALM depends on the changes of interest rates in the market, it becomes obvious that it is very important for a financial institution to measure, manage and control interest rate risk. New laws imposed by the Second Directive on Banking

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and Financial services demand financial institutions to declare their interest rate risk exposure and to develop rapidly tools for ALM. Deregulation of the financial industry, the entrance of new players in investment banking, the creation of innovative new products and the overall increase in competition force financial institutions to focus on risk management and more precisely on asset liability management.

Many are the studies that have been developed concerning the bank asset liability management techniques. Kosmidou and Zopounidis [16] present an overview of these techniques. They indicate that asset liability management models can be either deterministic or stochastic. Cohen and Hammer [5], Robertson [27], Lifson and Blackman [21], Fielitz and Loeffler [10] are successful applications of the deterministic linear programming model of Chambers and Charnes‘ model. Referring to the deterministic models Eatman and Sealey [9] and Giokas and Vassiloglou [12] developed a multiobjective linear programming model for commercial bank balance sheet management and a multiobjective programming for bank assets and liabilities management respectively. Apart from the deterministic models, several stochastic models have been attempted [1,3,4,8,14,15,19,22–25,28,31,35].

Among the above models there are other stochastic programming models that have been applied to financial planning problems. These models are developed by Carino et al. [2], Consigli and Dempster [6], Golub et al. [13]. Moreover, Kouwenberg [18] proposed a stochastic programming model for asset liability management for pension funds based upon Carino et al. [2] and Dert [7]. Moynihan et al. (2002) developed a decision support system for asset and liability management. The authors incorporated "what-if" analysis features into the system to determine the favorable alternatives in changing market environments. Kosmidou and Zopounidis [17] developed an Asset Liability Management model, that combines a goal programming model with a simulation analysis and permit the bank managers to proceed to the consideration of various optimal ALM strategies related to their future economic process.

Concerning interest rate risk, over the last decade a significant number of models have been developed to measure and assess a bank's interest rate risk. The most common are gap analysis and duration. Gap analysis is a technique that measures the impact of changes in interest rates on the net interest income of financial institutions [32]. Duration is a measure of time weighted average maturity resulting from the cash flows of a financial instrument [20]. However, gap analysis is a short-term measure of interest rate risk [11,34] and duration considers the time value of money but it is difficult to comprehend and apply [26,34] . In order to avoid the limitations of these techniques, simulation techniques could be considered to measure interest rate risk.

The purpose of the present study is to develop a goal programming ALM model with a simulation analysis, to assist a commercial bank in managing its exposure to interest rate risk taking into account a duration gap framework.

The rest of the paper is organized as follows. The next section outlines the data and the methodology used to develop an ALM model. Section 3 presents the results of the analysis by applying the development of the ALM model to a commercial bank of Greece. Finally, the last section presents the conclusions of the study and discusses future research perspectives.

Table 1 The decision variables of the goal programming formulation

X_1:	Cash and balances with the Central Bank	Y_1:	Due to credit institutions
X_2:	Teasury bills and other securities	Y_2:	Due to credit institutions with agreed maturity
X_3:	Interbank deposits and loans repayable on demand	Y_3:	Customer amounts
X_4:	Other interbank deposits and loans	Y_4:	Other customer amounts
X_5:	Deposits and loans arising out of sale and repurchase transactions	Y_5:	Commitments arising out of sale and repurchase transactions
X_6:	Loans and advances to customers	Y_6:	Debt securities in issue
X_7:	Securities issued by the Greek state	Y_7:	Other debts evidenced by certificates
X_8:	Securities-corporate bonds	Y_8:	Other liabilities
X_9:	Other securities	Y_9:	Accruals and deferred income
X_{10}:	Shares and other variable-yield securities	Y_{10}:	Provisions for liabilities and charges
X_{11}:	Investments in non-affiliates	Y_{11}:	Withholdings in favor of social security funds and other third parties
X_{12}:	Investments in affiliates	Y_{12}:	Liabilities of reduced indemnity
X_{13}:	Intangible assets	Y_{13}:	Share capital
X_{14}:	Tangible assets	Y_{14}:	Paid-up capital
X_{15}:	Same shares and variable-yield securities	Y_{15}:	Reserves
X_{16}:	Other assets	Y_{16}:	Fixed assets revaluation reserve
X_{17}:	Deferred charges	Y_{17}:	Retained earnings

2 Data and methodology

2.1 Data

The present paper, using data from a commercial bank of Greece, develops a goal programming model of a one-year time horizon (2002). The financial statements of the bank, such as balance sheet and income statement for 2002 were used in order to produce a future course of ALM strategy for the year 2003. Variables familiar to management were selected to form the goals of liquidity, return, risk and solvency.

The variables used in the specification of the model were taken directly from the 2002 financial statement of a commercial bank of Greece. 34 variables were used, of which 17 correspond to assets ($X_i,\ i = 1, \ldots, 17$) and 17 to liabilities ($Y_j,\ j = 1, \ldots, 17$)

2.2 Constraints and goals

Several constraints and goals were imposed to formulate the goal programming model. More precisely, certain constraints are imposed by the monetary authorities, the market and legal system.

The following constraints

$$X_6 \geq 19,017,751 \tag{1}$$
$$X_6 \leq 1.14 * 19,017,751 \tag{2}$$

indicate that loans are expected to maintain at least the previous year's levels (that is 19,019,751) and cannot rise by more than 14% in relation to these levels.

Similarly, the following constraints

$$Y_3 + Y_4 \geq 33,444,449 \tag{3}$$
$$Y_3 + Y_4 \leq 1.08 * 33,444,449 \tag{4}$$

indicate that deposits are not expected to increase by more than 8% above the previous year's levels (that is 33,444,449).

The following constraint

$$Y_{13} \geq 1,147,761 \tag{5}$$
$$Y_{17} \geq 0.0024 * \sum_{i=1}^{17} X_i \tag{6}$$

imposes restriction on the upper limit of capital (Y_{13}) and on the proportion of retained earnings to total assets (Y_{17}).

Moreover, there are constraints (7)–(12) that refer to the structure of the banks' balance sheet. More specifically, constraints (7)–(9) are derived from the obligation of the bank to reserve a specific amount of its deposits in a special interest-bearing account at the Bank of Greece.

$$(Y_3 + Y_4) - 33.94 * X_1 = 0 \tag{7}$$
$$(Y_3 + Y_4) - 1.97 * \left(X_2 + \sum_{i=7}^{10} X_i \right) = 0 \tag{8}$$
$$(Y_3 + Y_4) - 1.76 * X_6 = 0 \tag{9}$$

The equality relationship between assets, liabilities and net worth is reflected to the following constraint

$$\sum_{i=1-17} X_i - \sum_{j=1-12} Y_j = 2,544,565 \tag{10}$$

whereas constraints (11)–(12) indicate that total assets cannot rise by more than 10% above the previous year's levels.

$$\sum_{i=1-17} X_i \leq 1.10 * 49,116,764 \tag{11}$$

$$\sum_{i=1-17} X_i \geq 49,116,764 \tag{12}$$

The goal constraint

$$(Y_{13} + Y_{14} + Y_{15} + Y_{16} + Y_{17}) - 8\% * \sum_{i=1-17} X_i + d_1^- - d_1^+ = 0 \tag{13}$$

involves the solvency goal which is related to the risk exposure of the bank. The solvency ratio is used as a risk measure and is defined as the ratio of the bank's equity capital to its total weighted assets. The weighting of the assets reflects their respective risk and greater weights correspond to a higher degree of risk. According to the proposal of the Commission of the European Community, this ratio must be greater than or equal to 8% in order to guarantee the required solvency.

$$\sum_{\substack{i=1-12,\\15-17}} X_i - 0.6 * \sum_{j=1-12} Y_j - d_2^+ + d_2^- = 0 \tag{14}$$

The above constraint (14) defines the liquidity goal, specified as the ratio of liquid assets to current liabilities which is used as a liquidity risk measure. According to the Bank policy this ratio should be approximately 0.60.

$$X_6 - d_3^+ + d_3^- = 1.14 * 19,017,751 \tag{15}$$

$$Y_3 + Y_4 - d_4^+ + d_4^- = 1.08 * 33,444,449 \tag{16}$$

Constraints (15) and (16) define the goals for the growth of the loans (14% higher than the previous year's loans) of the deposits (8% above the previous year's level). Finally, the following constraint

$$\sum_{i=1-17} r_i^X X_i - \sum_{j=1-12} r_j^Y Y_j - d_5^+ + d_5^- = 10\% * 49,116,764 + 2,544,565 \tag{17}$$

defines the goal for the overall expected return of the selected asset-liability strategy over year of the analysis. This goal is set at 10% and is defined on the basis of the expected returns for all assets r^X and liabilities r^Y.

Moreover, there are goals

$$X_1 - (-0.16) * 49,116,764 + d_6^- - d_6^+ = 0 \tag{18}$$

$$X_2 - 0.74 * 49,116,764 + d_7^- - d_7^+ = 0 \tag{19}$$

$$(X_{13} + X_{14}) - (0.21) * 49,116,764 + d_8^- - d_8^+ = 0 \tag{20}$$

reflecting that variables such as fixed assets, cash, cheques receivables and deposits with the Bank of Greece should remain at the levels of previous years. Finally, the goal

$$\mathrm{DA} - \frac{\sum_j Y_j}{\sum_i X_i} * \mathrm{DL} + d_9^- - d_9^+ = 0,$$

where

$$\mathrm{DA} = \left(\sum_{t,i=3,\ldots,6} \frac{(X_i * i_L) * t}{(1+i_L)^t} + \sum \frac{(X_i * i_0) * t}{(1+i_o)^t} \right) \Big/ \sum_{i=1,\ldots,17} X_i \tag{21}$$

$$\mathrm{DL} = \left(\sum_{t,j=1,\ldots,7} \frac{(Y_j * i_D) * t}{(1+i_D)^t} \right) \Big/ \sum_j Y_j$$

denotes the duration gap framework of assets and liabilities. The duration of each balance sheet item is first calculated and then the market value weighted average duration for assets and liabilities.

2.3 Methodology

Taking into account all the above the proposed goal programming formulation is described below[1]:

$$\min z = \sum_{k=3}^{9} d_k^+ + \sum_{k=3}^{9} d_k^- + 2d_2^- + 3(d_1^- + d_1^+) \tag{22}$$

Subject to

$$X_6 \geq 19,017,751 \tag{23}$$

$$X_6 \leq 1.14 * 19,017,751 \tag{24}$$

$$Y_3 + Y_4 \geq 33,444,449 \tag{25}$$

$$Y_3 + Y_4 \leq 1.08 * 33,444,449 \tag{26}$$

$$Y_{13} \geq 1,147,761 \tag{27}$$

$$Y_{17} \geq 0.0024 * \sum_{i=1}^{17} X_i \tag{28}$$

$$(Y_3 + Y_4) - 33.94 * X_1 = 0 \tag{29}$$

[1] The decision variables of the model are described in Table 1

$$(Y_3 + Y_4) - 1.97 * \left(X_2 + \sum_{i=7}^{10} X_i \right) = 0 \tag{30}$$

$$(Y_3 + Y_4) - 1.76 * X_6 = 0 \tag{31}$$

$$\sum_{i=1-17} X_i \leq 1.10 * 49,116,764 \tag{32}$$

$$\sum_{i=1-17} X_i \geq 49,116,764 \tag{33}$$

$$\sum_{i=1-17} X_i - \sum_{j=1-12} Y_j = 2,544,565 \tag{34}$$

$$(Y_{13} + Y_{14} + Y_{15} + Y_{16} + Y_{17}) - 8\% * \sum_{i=1-17} X_i + d_1^- - d_1^+ = 0 \tag{35}$$

$$\sum_{\substack{i=1-12,\\ 15-17}} X_i - 0.6 * \sum_{j=1-12} Y_j - d_2^+ + d_2^- = 0 \tag{36}$$

$$X_6 - d_3^+ + d_3^- = 1.14 * 19,017,751 \tag{37}$$

$$Y_3 + Y_4 - d_4^+ + d_4^- = 1.08 * 33,444,449 \tag{38}$$

$$\sum_{i=1-17} r_i^X X_i - \sum_{j=1-12} r_j^Y Y_j - d_5^+ + d_5^- = 10\% * 49,116,764 + 2,544,565 \tag{39}$$

$$X_1 - (-0.16) * 49,116,764 + d_6^- - d_6^+ = 0 \tag{40}$$

$$X_2 - 0.74 * 49,116,764 + d_7^- - d_7^+ = 0 \tag{41}$$

$$(X_{13} + X_{14}) - (0.21) * 49,116,764 + d_8^- - d_8^+ = 0 \tag{42}$$

$$\text{DA} - \frac{\sum_j Y_j}{\sum_i X_i} * \text{DL} + d_9^- - d_9^+ = 0,$$

where

$$\text{DA} = \left(\sum_{t,i=3,\ldots,6} \frac{(X_i * i_L) * t}{(1 + i_L)^t} + \sum \frac{(X_i * i_0) * t}{(1 + i_o)^t} \right) \Big/ \sum_{i=1,\ldots,17} X_i \tag{43}$$

$$\text{DL} = \left(\sum_{t,j=1,\ldots,7} \frac{(Y_j * i_D) * t}{(1 + i_D)^t} \right) \Big/ \sum_j Y_j$$

The objective function involves the minimization of the deviations d^+ and d^- from the target values of goals, where d^+ denotes the over-achievement of a goal and d^- the under-achievement. The deviations corresponding to different goals are weighted in the objective according to the significance of the goals. It should be mentioned that the above goal programming formulation is based on the version that gives first priority level to the solvency goal, second priority level to the liquidity goal and third priority level to the rest goals (version 1). More precisely, the selected weighted scheme assigns higher weight to under-achievement of the solvency goal (d_1^-), considering that it is achieved with a priority rank 3/2 higher than the priority rank that is imposed to the over achievement of the liquidity goal (d_2^+) and three times higher than the priority rank of the remaining goals ($(d_k^+ + d_k^-),\ \forall k = 3, \ldots, 9$).

Once the optimal solution z^* of the goal programming problem (22)–(43) is obtained, a post-optimality stage is performed to investigate the sensitivity and the robustness of the optimal solution. This is achieved through the investigation of the existence of sub-optimal solutions that correspond to objective function values lower than $z^* + k(z^*)$, where $k(z^*)$ is a small portion of the optimal solution z^*. In this case study $k(z^*)$ is set equal to 5% of z^*. This additional constraint is incorporated into the initial goal programming formulation and the new goal programming formulation is solved 34 times. Each of the 34 obtained solutions corresponds to the maximization of the asset and liability variables. The final ALM solution is specified as the average of the 34 solutions obtained during the post optimality analysis.

2.4 Simulation analysis

The major unknown element in the above goal programming formulation which is of interest to the bank's managers is the return of the assets and liabilities used in the goal constraint (39) and the duration gap framework denoted by goal (43). These goals involve the bonds' interest rates, the interest rates of the loans and the interest rates of the deposits to the bank. In order to encounter the uncertainty raised by these parameters the Monte Carlo simulation technique is employed. Monte Carlo simulation consists in the development of various random scenarios for the uncertain variable (interest rates) and the estimation of the essential statistical measures (expected return and variance), which describe the effect of the interest rate risk to the selected strategy. In the present study, 2,500 scenarios were considered on the aforementioned interest rate variables. 50 scenarios are generated for the deposit's interest rates (i_D), which are log-normally distributed random [29,30]. For each deposit's interest rate scenario, 50 scenarios are also generated for the bond's interest rates (i_O), which are considered as log-normally distributed random variables. Moreover, taking into account that banks determine the loans' interest rates (i_L) at higher levels than those of the deposits, the loans' interest rates are determined as follows:

$$i_L = i_D + s$$

where s is the spread between the loans' interest rates and the deposits' interest rates.

3 Analysis of results

The goal programming formulation (22)–(43) is solved for each of the 2,500 interest rate scenarios and 2,500 different solutions are obtained. Each of these solutions is

Table 2 Results of the scenario simulation

Solutions	Expected return	Standard deviation
ND_1	346,153,533.50	24,760,558.09
ND_2	344,895,243.00	24,685,961.67
ND_3	344,586,190.10	24,880,693.28
ND_4	342,857,881.90	24,527,996.69
ND_5	341,517,531.90	24,657,985.62
ND_6	341,114,634.50	24,679,192.81
ND_7	340,740,173.10	24,471,088.67
ND_8	340,213,160.30	24,629,321.23
ND_9	338,860,971.30	24,373,597.50
ND_{10}	338,016,364.90	24,323,407.02

evaluated to calculate the expected present value and the corresponding risk of return (standard deviation) among the solutions, resulting in 207 solutions, non-dominated by any other solution in terms of their expected present value and risk.

Table 2 presents the results (expected return and standard deviation) for the 10 (out of the 207 non-dominated solutions) ND_1, $ND_2, \ldots, ND_{10}$ solutions, that are best in terms of expected return.

Tables 3 and 4 present the final values of the asset and liability variables respectively. Each of these solutions can be considered as equivalent ALM strategies to implement during the year 2003.

If we analyse the content of Tables 3 and 4, we observe that although the bank's financial statement does not change among the 10 aforementioned ALM strategies, the values of the variables that concern the partial accounts differ from most of the solutions and especially from the most basic categories of the balance sheet accounts. This is due to the fact that during the formulation and development of the model, the asset and liability management is related to the uncertainty of the risk management and especially of the interest rate risk. The simulation analysis on the ALM strategy and the duration gap goal through the scenario generation becomes essential for the values of deposits', loans' and bonds' interest rates. The consideration of these scenarios contributes to the choice for the bank's optimal solution. In case different interest rate scenarios are considered, different optimal solutions may arise.

4 Conclusions and future perspectives

The present paper deals with the development of a goal programming model for the asset liability management of a commercial bank by generating interest rate risk scenarios through a combined technique of simulation and duration-gap analysis.

Taking into account the preferences of the bank managers as well as the policy and the strategy that the bank plans to follow, several constraints and goals were imposed in order to develop the proposed model. The analysis of the results indicated that there are significant differences from the variables of the accounts of demands and liabilities

Table 3 Results of the decision variables (asset variables)

Variables	ND_1	ND_2	ND_3	ND_4	ND_5	ND_6	ND_7	ND_8	ND_9	ND_{10}
X_1	25,247,661.28	25,153,441.21	25, 272,598.48	25,796,004.38	25,214,217.82	25,809,560.17	25,302,206.45	25,124,873.03	25,753,982.58	25,797,952.98
X_2	5,113,850.19	4, 937,316.99	5,134,714.75	5,432,894.01	5,091,395.10	5,496,948.59	5,154,683.94	4,903,953.75	5,429,055.25	5,422,680.12
X_3	514,061.13	103,565.88	509,838.57	410,397.49	95,970.24	293,493.36	505,703.78	121,901.32	88,835.75	398,338.20
X_4	95,335.86	100,615.11	94,830.52	88,184.59	95,970.24	59,821.75	94,334.05	102,016.64	88,835.75	86,773.61
X_5	95,335.86	100,615.11	94,830.52	88,184.59	95,970.24	59,821.75	94,334.05	102,016.64	88,835.75	86,773.61
X_6	17,404,835.86	18,182,800.29	17,404,330.52	17,397,684.59	17,833,192.84	17,369,321.75	17,403,843.05	18,297,990.93	17,757,021.19	17,396,273.61
X_7	293,496.74	425,267.59	280,573.74	125,292.60	305,520.58	64,260.15	269,383.31	451,866.82	119,763.01	135,940.91
X_8	73,790.90	81,709.76	72,996.78	64,260.15	74,782.58	64,260.15	72,270.79	81,841.43	64,260.15	64,260.15
X_9	73,790.80	81,709.76	72,996.78	64,260.15	74,782.58	64,260.15	72,270.79	81,841.43	64,260.15	64,260.15
X_{10}	73,790.80	81,709.76	72,996.78	64,260.15	74,782.58	64,260.15	72,270.79	81,841.43	64,260.15	64,260.15
X_{11}	100,266.48	143,243.59	99,758.02	93,288.01	100,863.57	89,890.02	99,299.50	132,163.16	93,877.80	92,119.20
X_{12}	95,841.02	83,720.84	95,355.00	89,170.56	96,411.76	85,922.54	94,916.72	79,076.40	89,734.32	88,053.34
X_{13}	4,482,536.27	4,332,642.14	4,414,539.41	3,910,295.59	4,512,177.50	3,963,110.22	4,396,085.44	4,316,423.78	3,975,524.10	3,968,867.72
X_{14}	533,153.97	558,769.68	532,002.44	1,097,376.01	536,157.89	1,255,726.06	531,181.59	563,920.77	1,020,533.45	1,066,167.41
X_{15}	97,272.07	102,498.51	96,814.85	90,243.81	97,949.84	86,730.37	96,414.90	103,880.42	91,130.90	89,363.25
X_{16}	501,391.81	334,103.91	433,015.07	106,735.88	461,294.35	119,524.50	406,240.01	315,584.40	157,353.40	105,883.98
X_{17}	264,226.08	256,906.86	378,444.77	95,811.34	299,197.31	92,799.83	395,206.85	199,444.63	95,811.34	95,101.18

Table 4 Results of the decision variables (liability variables)

Variables	ND_1	ND_2	ND_3	ND_4	ND_5	ND_6	ND_7	ND_8	ND_9	ND_{10}
Y_1	1,501,481.10	992,643.75	1,565,569.46	3,105,018.97	1,401,742.56	7,444,444.42	1,626,559.06	913,104.52	1,372,981.39	4,778,861.45
Y_2	235,282.97	184,871.45	239,685.73	478,504.55	228,709.51	428,637.90	244,957.62	171,979.00	1,543,685.24	398,738.63
Y_3	33,738,230.53	33,625,896.96	33,772,643.87	34,494,944.01	33,693,507.45	34,513,651.00	33,813,502.87	33,591,516.43	34,436,953.93	34,497,633.09
Y_4	1,103,542.03	1,085,851.91	1,103,542.03	1,103,542.03	1,102,113.15	1,103,542.03	1,103,542.03	1,080,808.36	1,103,542.03	1,103,542.03
Y_5	6,716,570.64	7,468,851.36	6,638,665.75	4,791,157.23	6,841,936.38	1,951,911.84	6,561,026.81	7,627,373.45	5,406,549.24	3,612,954.24
Y_6	235,282.97	184,871.45	239,685.73	340,490.11	228,709.51	428,637.90	244,957.62	171,979.00	310,242.07	398,738.63
Y_7	235,282.97	184,871.45	239,685.73	340,490.11	228,709.51	428,637.90	244,957.62	171,979.00	310,242.07	398,738.63
Y_8	426,477.29	434,575.67	421,810.32	334,671.92	432,145.38	192,530.24	417,779.30	435,315.30	359,246.11	287,327.46
Y_9	426,477.29	434,575.67	421,810.32	334,671.92	432,145.38	192,530.24	417,779.30	435,315.30	359,246.11	287,327.46
Y_{10}	426,477.29	434,575.67	421,810.32	334,671.92	432,145.38	192,530.24	417,779.30	435,315.30	359,246.11	287,327.46
Y_{11}	426,477.29	434,575.67	421,810.32	334,671.92	432,145.38	192,530.24	417,779.30	435,315.30	359,246.11	287,327.46
Y_{12}	426,477.29	434,575.67	421,810.32	334,671.92	432,145.38	192,530.24	417,779.30	435,315.30	359,246.11	287,327.46
Y_{13}	1,557,624.92	1,557,624.92	1,557,624.92	4,536,432.42	1,557,624.92	1,332,709.62	1,555,435.94	4,673,761.26	4,516,712.72	1,427,506.85
Y_{14}	514,205.92	3,634,921.79	514,205.92	431,432.31	514,205.92	289,290.62	512,016.94	514,205.92	455, 305.70	384,087.85
Y_{15}	514,205.92	514,205.92	514,205.92	431,432.31	514,205.92	289,290.62	512,016.94	514,205.92	455,305.70	384,087.85
Y_{16}	514,205.92	514,205.92	514,205.92	431,432.31	514,205.92	289,290.62	512,016.94	514,205.92	455,305.70	384,087.85
Y_{17}	3,709,177.69	585,784.74	3,698,707.46	502,950.95	3,721,082.39	3,223,858.86	3,687,593.09	585,784.74	526,861.70	3,464,298.18

toward the customers and the financial institutions. It becomes obvious, that in a commercial bank, the largest percentage of income arises from the deposits and the loans and thus these accounts are assumed to be the most significant to the configuration of the bank balance sheet. The results of this study imply several strategies that the bank could possibly follow in order to modulate its balance sheet to accomplish an optimal asset liability management taking into account the management of interest rate risk. The service quality in banks is one of the strategies that should be taken into account. Bank managers should develop operational, human resource and marketing strategies and target those strategies in terms of the gender differences in quality perceptions among their customers [33].

Finally, although the development of an ALM model allows banks to proceed to various scenarios of their future economic process, further research in this field should be considered. The consideration of derivatives would be interesting in order to know how they hedge the interest rate risk. The development of an integrated information system for asset liability management will also give the bank manager the possibility to proceed to various scenarios of the economic process of the bank in order to monitor its financial situation and to determine the optimal strategic implementation of assets and liabilities. It would be also interesting to improve the model by incorporating multi-stage stochastic framework to deal better with the stochastic nature of returns/price fluctuations of assets and liabilities.

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