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Research Paper

# Designing the Optimal Model of Banking Assets and Liabilities Management based on the System Dynamics Approach

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ABSTRACT

Banks as the largest financial intermediaries play a vital role in collecting savings and directing them toward manufacturing activities. Hence, assets and liabilities management is crucial for them and their depositors. In this study, through a system dynamics approach, a dynamic model was proposed to manage assets and liabilities optimally. After building the model and conducting validation and sensitivity analysis, three scenarios were devised and were simulated and analyzed via the proposed model. The results revealed that taking effective decisions and actions to collect more deposits, especially time deposits as well as increasing the quality of credit assets (if allocated optimally) can be effective in improving the performance of banks. Therefore, using systems thinking and system dynamics can aid banks in managing their assets and liabilities optimally. Many of the significant items in the paper, including the results and conclusions.

## 1 Introduction

The banking industry as the main financial intermediary plays a key role in providing intermediary services between depositors and borrowers in the economy of countries. Therefore, the failure of the banking system causes serious negative consequences for other economic sectors [20]. In recent years, numerous financial crises especially the one in 2007 caused banks to face numerous challenges in playing their roles in society so that simultaneously by allocating vast amounts of financial resources through different banks around the world, most of them witness various crises and losses [19]. One of these challenges is managing assets and liabilities and their related risks. Since poor management of assets and liabilities is a recognized reason for banks' failure, the banks need to assure their sustainability by devising cautious and sensible strategies for managing assets and liabilities [14, 25]. Assets and liabilities management include strategic management of assets and liabilities in order to maximize profit, improve liquidity, and protect against banking risks [10]. Hence, it can be said that asset management is a key aspect of risk management in banks and financial institutions which is at the core of their financial management [39]. Due to the close and mutual relationship between assets and liabilities, managing both of them simultaneously requires a comprehensive and holistic approach. Most of the

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commonly used methods in different studies are not sufficiently comprehensive. Therefore, in this study system dynamics is used as an innovative approach for modeling. System dynamics is a method for understanding the behaviors of a complex system over time. This method investigates the behavior of the system over time by focusing on feedback loops inside a system, nonlinear effects, and time delays among variables as well as the accumulative and flow concept of variables.
In this study, we used this new method for the first time to design the management model of assets and liabilities and tried to design an integrated, holistic and coherent system to simultaneously focus on both (1) The composition and structure of assets (2) The composition ad structure of liabilities and the factors influencing them, and by redefining the existing model of assets and liabilities and analyzing their dynamics and devising the appropriate strategies to gain an optimal composition of assets and liabilities we seek to improve the performance of a bank and try to achieve major goals. This paper is organized into 5 sections. The second Section reviews the related literature and previous research. The third Section describes methodology and sampling. In the fourth section, after designing the circular causal model and the flow and state model, validation tests and sensitivity analysis of the model have been performed. Finally, the fifth section concludes the results and offers some recommendations.

## 2 Literature Review

### 2.1 The structure and composition of liabilities

Liabilities are one of the most important sources of funding for banks. Major kinds of liabilities include different types of deposits in terms of deposits by private and state sectors as well as natural and legal people. In Islamic banking, deposits are divided into two groups including, interest-free deposits (Qardh al-hasan) and investment deposits. The former doesn`t have any interest for the bank (both checking accounts without interest, interest-free saving deposits) and the latter are the ones that work based on profit and loss sharing to transfer cash to different economic sectors and the return is paid depending on the length and amount of participation [9].
Another part of liabilities consists of debts to other banks and financial institutions. Some of these are interbank deposits, loans, and prepayments that are considered short-term interbank sources and are utilized in a financial crisis when a bank cannot meet its obligations. Considering the role of liabilities in funding, their management is extremely vital. Managing liabilities means the use of borrowed sources to meet expected liquidity demands [26]. Liability management gives banks direct access to financial sources. Since banks have to pay interest on deposits and loans, the total amount of paid interest and other operational costs determine money cost. Bank managers should bear in mind that due to limitations in changing the interest rate on deposits interest margin increases through reducing other operational costs.

### 2.2 Composition and structure of assets

The right section of the balance sheet indicates how the sources obtained from deposits and capital are allocated. The main items in this section are cash balance, high liquidity assets, and credit facility. The composition of assets, in fact, the quality of assets, influences profitability, and analyzing without a correct understanding of the structure of the assets and the factors influencing them is useless. In examining the composition of assets, risk and their return should be investigated. Issuance of bank guarantees, a letter of credit, and so on are among permitted operations that, although not kept as assets due

to lack of definite commitment, influence the profitability and risk of a bank. Cash in banking is maintained in order to pay the bank obligations [38]. Assets with high liquidity such as bonds attract attention since they can quickly turn into cash in certain circumstances like unpredictable economic fluctuations which yield returns. Generally, assets with higher returns are more risky and less risky assets yield fewer returns. Hence, managers need to create a reasonable and optimal balance in allocating sources and assets to maintain financial flexibility in response to depositors' demands as well as to maximize income and minimize the related risks. In addition to the income from loans, the income derived from service and exchange fees and foreign currency deposits are considered income sources of banks. Regarding legal restrictions on the increasing interest rate on loans and the increasing number of nonperforming loans which has become one of the problems of banking and increases the costs, more focus on investing in related and highly profitable activities can increase the income and profitability of a bank. Precise selection of an optimal portfolio of assets is incredibly vital for asset management [17].

## 2.3 Assets and Liabilities Management in Banks

The prominent role of banks and financial institutions in applying monetary policies in the economy of countries has made them focus on operational and macro strategies to reduce the increasing pressure of competition and alleviate the destructive effects of the financial crisis. Collecting extra cash and savings as deposits and allocating these resources optimally as well as granting loans to different sectors of the economy, seek to both maximize their profitability and that of their shareholders and aid the sustainable development of a country[8]. Therefore, managing liquidity is regarded as one of the biggest challenges for the banking system [6]. Proper management of liquidity can reduce banking risks and limit the probability of the occurrence of serious problems for a bank. To manage liquidity properly identifying the appropriate devices and the factors influencing it is crucial. One of the most important factors influencing banks` liquidity is the composition of assets and liabilities. Managers attempt to achieve an optimal composition of assets and liabilities in a balance that maximizes the net wealth of a bank by quantifying the risks related to liquidity management as well as considering other requirements [27]. Due to its nature, assets and liabilities management is also called balance sheet management. As a result, the components of the financial statements of an institution and the relationship with one another and with elements of other financial statements should be completely clarified [32]. The aim of assets and liabilities management is to maximize efficiency through efficient allocation of cash so that it is acceptable regarding the structure of the risk [47]. Assets and liabilities management can realize the goals to earn profit and reduce risk by viewing both assets and liabilities in an integrated and simultaneous way. Since assets and liabilities management is a multidimensional process, determining the simultaneous interactions among its different dimensions is of great importance so that if a systematic and integrated approach is not used in devising the related strategies, reducing risk in one dimension would contribute to an unexpected increase in other risks [47].

Using a system thinking approach results in an integrated and coherent system that emphasized the three items of composition, and structure of assets, composition, and structure of liabilities, and bank risks all at once. It also aids in enhancing efficiency and accomplishing macro goals by redefining the current assets and liabilities model of the bank and in devising proper strategies for achieving an optimal composition of assets and liabilities. Today, unfortunately, many managers, by relying on a superficial attitude and using traditional paradigms, make decisions on assets and liabilities management which not only fails to increase the bank's wealth and create value for its investors but worsens the situation and causes a variety of risks for different beneficiaries. It should be noted that the system of managing assets

and liabilities has its regulations and without knowing them optimizing and managing assets and liabilities as well as designing an effective model for it seems unrealistic. Therefore, managers can identify the factors and elements influencing the assets and liabilities management system and the relationships and regulations governing them by changing their perspective and taking a systematic approach. They can also look for ways to optimize the composition of assets and liabilities with a systematic and comprehensive approach so that the performance of the system is improved, the related risks are controlled and their beneficiaries` interests are protected.

### 2.4 Research Background

The research carried out on optimizing and managing assets and liabilities can be investigated as two general categories. The first category highlights different methods of modeling assets and liabilities. For example, in international research, the following techniques were adopted such as the model of goal programming [11, 12, 28, 29, 43, 47], multiple objective models [2], linear planning [13], neural networks [49, 50], and hierarchical analysis [31]. Iranian studies also have used these techniques including the model of goal programming [33, 34, 45], linear planning [16], Dynamic Systems [4] multiple objective models [36], neural networks [15, 37], focal analysis [6], hierarchical analysis [34] and fuzzy network analysis [24].

The second category examined the performance of managing assets and liabilities. For instance, international research in this area includes managing assets, liabilities, and profitability of banks [39, 46], and the effect of managing assets and liabilities on the financial performance of commercial banks [5, 35]. In Iran similar studies include the relationship between managing assets and liabilities and the performance of banks and the quality of financial reporting in banks [41], investigating the relationship between assets-liabilities composition and liquidity risks of Iranian banks [3], managing assets and liabilities in Parsiyan Bank and its effects on the performance of that bank [40].

## 3 Research Methodology and Sampling

The present study is modeling and simulating one in the banking industry which was conducted with a mixed methodology. This research is practical-developmental in terms of purpose and focuses on identifying parameters, and variables of assets/liabilities management system as well as identifying the causal relationship of the system and aims to gain a deep understanding and general perspective on assets/liabilities management systems so that the effectiveness of these systems can be examined and confirmed through causal explanations. To do so, the system dynamics approach was utilized and an attempt was made to offer an optimal model for managing the assets and liabilities of Iranian banks.

What is important in the dynamics of the systems is to present a simple and real model based on a quantitative perspective that can achieve acceptable results at the given time[18]. In this approach, in order to study the behavior of the system under different experimental conditions and using all three common methods, namely words, graphics, and mathematics, a representation of a real-world system is presented. The main assumption in system dynamics is that the flows within a process are continuous and these flows do not follow random rules.

One of the eminent features of this methodology is that it allows the evaluation of different policies in the form of a scenario and enables learning from the system by simulating the results from applying the policy quantitatively on small scale [7]. The latter facilitates correcting problematic behavior and providing effective solutions based on systems thinking [1]. The system dynamics method performs in five repeatable steps including structuring the problem, developing the dynamic hypothesis, modeling

and formulating (drawing causal loop diagram, stock, and flow model), validating and simulating, and finally, analyzing the findings (making a scenario and evaluating policies) [21]. In this research, sampling is not conducted due to the nature of the systems thinking approach. Since the analytical unit is managing the assets and liabilities of a bank, the system is investigated. However, in order to design a mathematical model, the data from a commercial bank was used between 2015 and 2019. This bank was selected based on the index of financial health (presented by international monitoring officials) in Tehran Stock Exchange. After designing the model, different policies in the form of decision scenarios are applied in the model, and then the results of the simulation are analyzed and based on the perceived understanding of an appropriate solution to effectively manage the assets and liabilities of the given bank.

# 4 Designing the Simulation Model

## 4.1 Describing the Problem in Details

As financial institutions grew and integrate and new financial products and services emerged in the past two decades, managing assets and liabilities have changed significantly and turned into a complex system. Digitalization of the economy and the development of new activities based on financial information and innovations have increased kinds of endogenous and exogenous risks as well as the relationship between them. As a result, the structure of balance sheet devices has been more complex and fluctuations in the banking system are increased [47]. These revolutions lead to an increase in the importance of managing assets and liabilities and managing bank risks. Hence, professional and academic institutions seek to develop a comprehensive and extensive approach to managing assets and liabilities in an integrated manner and managing bank risks simultaneously. In the current circumstances, achieving this approach will only be possible with systems thinking [30]. This is because due to the complexity of the system of managing assets and liabilities, identifying different factors creating this complexity is vital. These factors include the number and wide variety of assets and liabilities and their internal interactions, dynamics, their nonlinear interactions, and casual relationships among them. In these conditions, using innovative methods for managing assets and liabilities, and banking risks more objectively and in turn enhancing the performance of banks are inevitably necessary.

Therefore, taking strategic decisions in these areas only by relying on insight and management understanding may have unacceptable results. In today`s complex and doubtful circumstances which involve numerous challenges in all areas, managers need to change their perspective, quit their linear thinking, and face the challenges using systems thinking to make reasonable decisions. They should remember that today the complex business environment and systematic structures governing them are nonlinear. Trying to make them linear to facilitate the process of decision-making, even if possible, is not often a good idea. Managers need to bear this fact in mind that these nonlinear relationships and the existing delays in the processes may create unpredictable and surprising conditions for them. Managers should quit their one-dimensional thinking and use systems thinking by knowing the structure of assets and liabilities and the factors influencing them and understanding economic conditions and the competitive environment governing the banks' look for effective management of assets and liabilities. The aim of adopting systems thinking and modeling managing assets and liabilities based on this thinking is that a new perspective is created toward this subject and more effective solutions for managing them are offered which finally minimizes bank risks and also enhances its performance and maximizes the wealth of shareholders. Devising strategic plans and defining the organization plans based on global concepts and standards, benefiting from the most advanced technologies and so on, despite the relative effect on

many banks, does not lead to favorable results without systems thinking.

## 4.2 Time Horizon and Model Boundary

Considering the subject of the study and system dynamics pattern, the time horizon is a 15-year period from 2016 (due to the availability of real data extracted from financial statements based on international accounting standards) to 2030 and the simulation started in 2020. The conceptual border of the model is studying variables such as equity investment deposits, net Income, non-performing loans, and term loans and policymaking needs to be done considering the effects of variables such as the average growth of investment deposits, the average withdrawal of depositors, and delay rate. To this end, various variables are used in the pattern of this study which is indicated separately as endogenous and exogenous variables in table 1.

In providing the stock and flow model, the following variables were used in this study:

- State variables: these variables indicate accumulation in the system and determine the state of the system at every moment. This study considered some of the items in the balance sheet as state variables that are as follows: Interest-free loans, Term loans, Past due loans, Deferred loans, Doubtful loans, Legal deposits, Equity investment deposits, Fixed assets, Investment in securities, Interest-Free Saving Deposits, Checking Account without Interest, Interest-free resources, and Term resources.
- Rate variables: rate variables are flows that enter and exit from a state variable. These variables influence state variables over time. In the stock and flow model of this study, some rate variables are: Attracting investment deposits, Withdrawal of depositors, Purchase of fixed assets, Sale of fixed assets, Attracting savings deposits, Withdrawal of savings deposits, Attracting Checking Accounts, and Withdrawal from checking account.
- Auxiliary variables: auxiliary variables are fixed and exogenous variables which affect the system but do not receive any feedback and are outside the border of a system. For instance, in this study legal deposit rate, average withdrawal of depositors, delay rate, the average growth of fixed asset purchases, lending rate, and collateral rate are some examples of auxiliary variables.

**Table 1:** Type of Variables Used in the Model

| Variables | Type | Variables | Type |
|---|---|---|---|
| Customer deposits | Endogenous | Bank assets | Endogenous |
| Equity investment deposits | Endogenous | Net Income | Endogenous |
| Basic capital | Endogenous | Operating income | Endogenous |
| Capital adequacy | Endogenous | performing loans | Endogenous |
| Degree of leverage | Endogenous | Interest on deposits | Endogenous |
| Shareholders equity | Endogenous | General doubtful debt provision | Endogenous |
| Legal deposit | Endogenous | Specific doubtful debt provision | Endogenous |
| Bankruptcy risk | Endogenous | Bank Debts | Endogenous |
| Collaterals | Endogenous | Granted loans | Endogenous |
| Accumulation ratio | Exogenous | Retained earnings | Endogenous |
| Reserve ratio | Exogenous | Reserves | Endogenous |
| General reserve rate | Exogenous | Non-performing loans | Endogenous |
| Dedicated reserve rate | Exogenous | Lending power | Endogenous |
| Deposit interest rate | Exogenous | Cash resources | Endogenous |
| Lending ratio | Exogenous | Liquidity provision | Endogenous |
| Other expenses | Exogenous | Financial flexibility | Endogenous |
| Legal deposit ratio | Exogenous | Purchase of fixed assets | Endogenous |
| Number of shares | Exogenous | Capital | Endogenous |
| Liquidity reserve rate | Exogenous | Weighted assets based on risk | Endogenous |

## 4.3 Investigating Reference Mode

Managing assets and liabilities is one of the most important duties of bank managers to help banks carry out their financial intermediary role which has great importance and it covers a wide variety of their activities. Managing assets and liabilities is the dynamic process of planning, organizing, coordinating, and controlling assets and liabilities, composition, volume, due date, efficiency, and costs in order to maximize the wealth of a bank. Hence, banks try to increase their profit and make value for their shareholders by attracting financial resources from depositors, to increase their liabilities and allocate these resources. The major financial credit resources of banks are term deposits which last longer compared to other deposits. Studying the process of attracting term deposits and grating term loans in the -understudy bank (Fig.1) indicates a growth in attracting these types of deposits and, in turn, a relative increase in granting term loans during the past 5 years.

In the process of allocating financial resources, the quality of assets is vital, that is assets with inadequate quality poses risk. This leads to identifying the loss, it prevents the realization of a part of the expected income from the granted loans. As Figure 2 shows, this bank, by reasonable management of its assets and liabilities, was able to facilitate the cash flow. This indicates that the bank was able to successfully manage the portfolio of credit assets and take reasonable credit policies as well as the optimal allocation of resources.

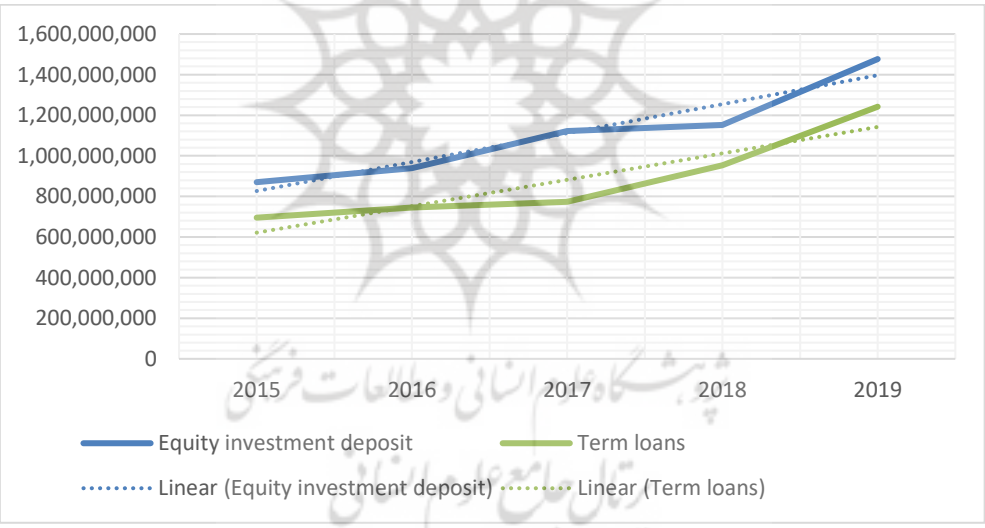


**Fig. 1:** Term Loans and Equity of Investment Deposits in the Research Period

## 4.4 Dynamic Hypothesis and Casual Loop Structure of the Problem

The economy of the country in recent years has been influenced by numerous foreign and domestic factors. The presence of these factors and the increasing pressure of the competitive market and limited resources all result in the emphasis of banks and financial institutions on managing assets and liabilities. The main goal of managing assets and liabilities as one of the most important subjects in strategic planning facilitates cash flow and managing the balance sheet to ensure optimal performance, offering better services and growth in the profitability of a bank. Thus, banks try to provide finances from different resources to achieve their goals. They need to preserve sufficient resources against possible future shocks and losses, in addition to the investment of shareholders, there are other financing tools such as

the customers' deposits, and borrowing from the central bank or other banks that are reflected as liabilities in a balance sheet. Among these, investing deposits are one of the most Sustainable resources of finance. Attracting deposits as the main part of a bank`s activities provides the necessary conditions for playing the role of allocating resources. Optimal allocation of these resources is considered one of the most important subjects in banking and if the peripheral risks are managed, the maximum value is produced for shareholders. This indicates the necessity of managing assets and liabilities and in turn managing bank risks.

In order to optimally manage assets and liabilities, the quality of credit assets of a bank is vital since reducing the quality of these assets and increasing non-current receivables blocks some of the bank`s resources and contributes to many consequences including lack of liquidity, deficiency in loan cycle, reduction in flexibility, reduction in loan-granting power and increase in credit risk and liquidity risk. Hence, it can be challenging for both banks and financial institutions and customers and shareholders and in the long term affects economic growth adversely and disrupts the production cycle. Moreover, increasing the quality of assets requires receiving more credit liabilities and ongoing monitoring of loans which increases the bank`s expenses. Therefore, identifying the variables influencing the management system of assets and liabilities and the interrelationship among them is incredibly important which is impossible without a systematic and comprehensive perspective. In Fig. 2 using the system dynamics approach, the causal loop diagram indicates the structure of the management system of assets and liabilities in which the interrelationship of variables and their influences on banking risks and performance indices are shown.

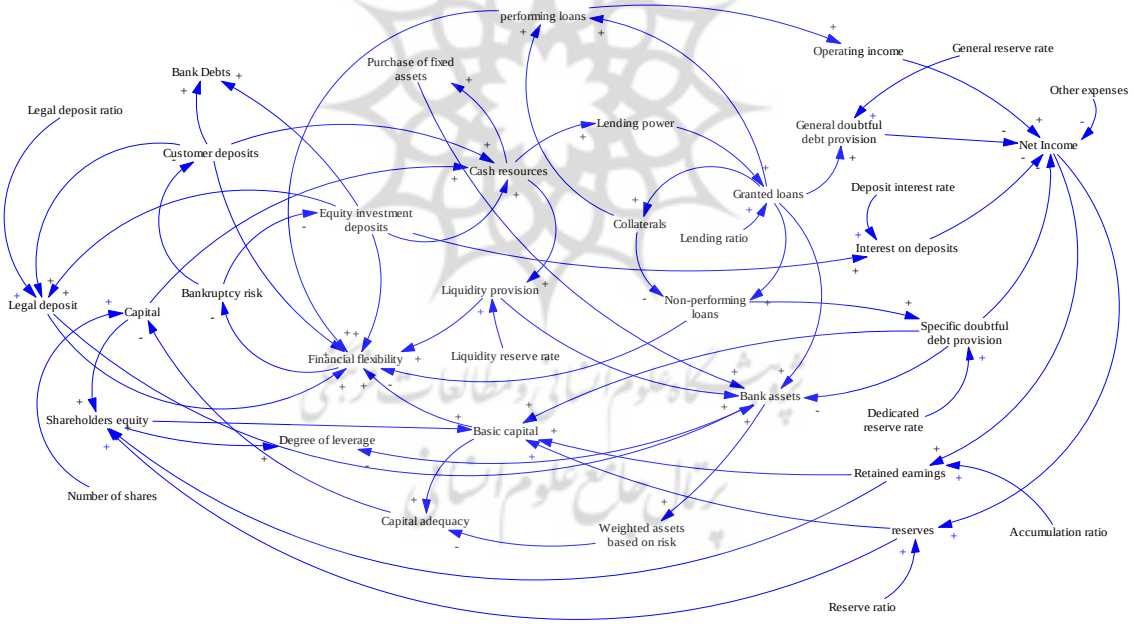


**Fig. 2:** Causal Loop Model of Bank Assets and Liabilities Management

## 4.5 The Structure of the Stock and Flow of the Problem

After devising the dynamic hypothesis and presenting the causal loop diagram of the structure of the assets and liabilities management system, to examine the behavior of the system during the given time frame, a stock and flow model was first made from the problem and then, using the data of the given bank, the mathematical equations were devised and the variables are simulated based on them during

the specified period of time.in Figure. 3 regarding the presented casual loop diagram the model of stock and flow of managing assets and liabilities is produced.

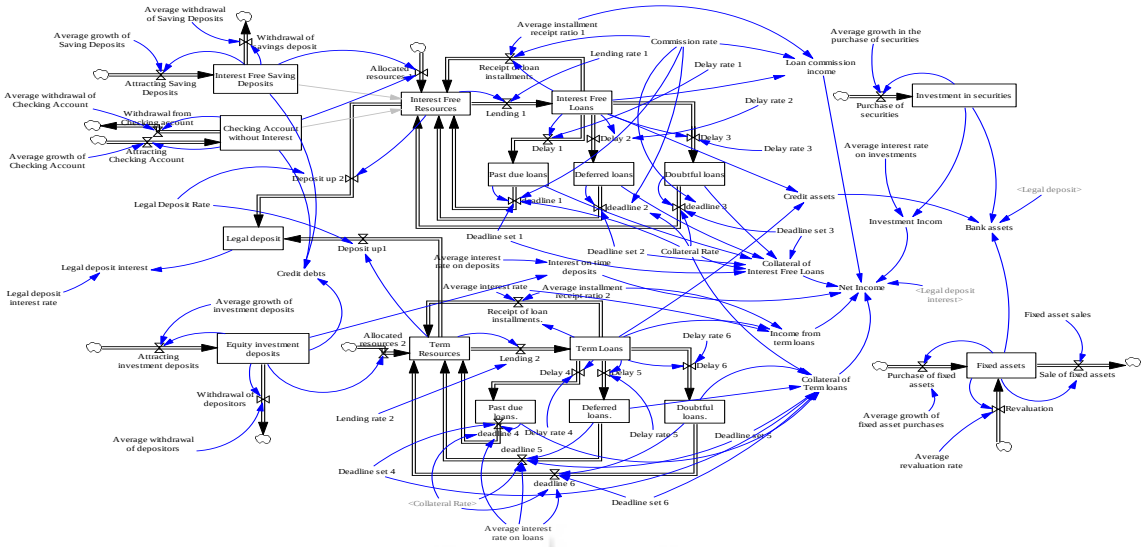


**Fig. 3:** Stock and Flow Model of Bank Assets and Liabilities Management

## 4.6 Validating and Analyzing the Sensitivity of the Model

### 4.6.1 Validating the Model

Models are made for solving problems and they are a representation of reality or our perception of reality. Therefore, before using these models, we should ensure the proper performance of the model. In the system dynamics approach, after devising the stock and flow model and before presenting the scenario and analyzing the results, the given model should be evaluated through a number of validating tests in order to ensure the accuracy and validity of the model under different conditions. To do so, with the aid of bank managers and experts, a structure verification test was conducted to ensure that the model is consistent with the existing model in the structure of the real system.

Then boundary-adequacy Test was done to guarantee that the generalizability of the model is sufficient and theoretical saturation was reached for both tests. Moreover, to examine if the equations and values of the variables are significant, extreme conditions test was done so that some parameters and initial data of the model were remarkably changed. Redoing the model indicated that after making these changes, the behavior of the model is still significant in all parts. Finally, to ensure that the pattern behavior has an appropriate performance and the behavior of the model is consistent with real data, a behavior reproduction test was adopted. In this test after reproducing the simulated behavior for the model, the results were compared with real data. In addition to these tests, the error of key variables of the model was investigated to make sure that the behavior of the model is consistent with real data and to increase the reliability of the simulation results.

A) Calculating and estimating prediction error: one of the most common criteria for prediction error is mean squared error (MSE) which is calculated as follows:

$$MSE = \frac{1}{n}\sum_{t=1}^{n}(S_t - A_t)^2 \qquad (1)$$

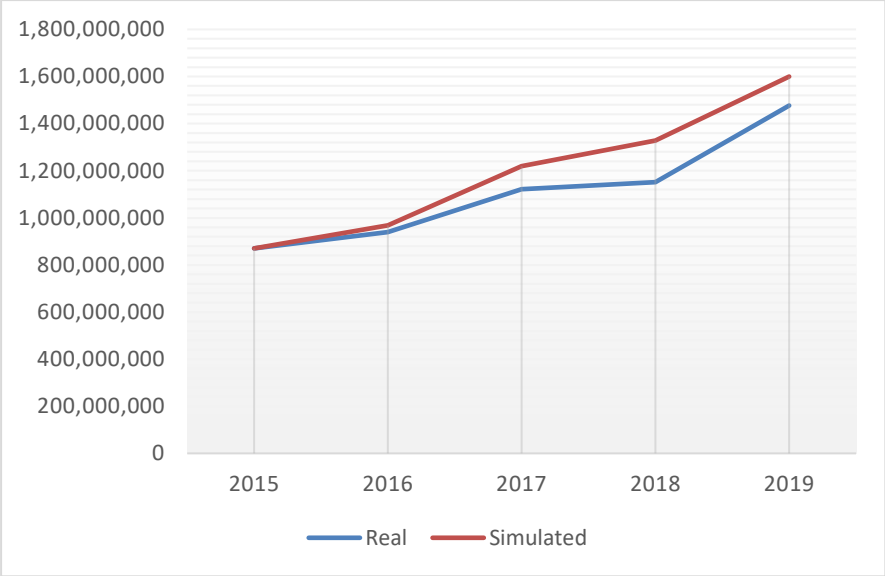


**Fig. 4:** Historical Behavior Reproduction Test for Equity Investment Deposits of the Given Bank

In this equation, $S$ donates results of simulating the pattern variable, $A_t$ indicates real data and $n$ is the number of observations. Using the squared root of mean squared error (RMSE), a new index called root mean square percentage error is made which is useful for the proximity of the simulated results to the real values of the variables. The numerical quantity of RMSPE is compared with the mean of the given variable within the range under study so that the value of prediction becomes clearer. In this study, a relative error index known as RMSPE was used instead of mean square error:

$$RMSPE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{S_t - A_t}{A_t}\right)^2} \quad (2)$$

According to equation (2), the less difference between real and simulated data, the more reliable the simulated results are. That is the closer the index is to zero, the lower the error is. However, the closer it is to 1, the higher the error is [44].

B) Error analysis: In addition to computing the value of the error, identifying the source of the error is also essential since knowing where the error originates and reducing them can influence the reliability of the results to a great degree. Therefore, U-Theil`s test was used for analyzing the mean squared test in this study.

$$U_t = \sqrt{\frac{\sum(S_t - A_t)^2}{\sum A_t^2}} \quad (3)$$

The value of this index is always between zero and one. When the results of the simulation are exactly equal to real data ($S_t$=$A_t$), the value of this coefficient is zero. In other words, the closer this value is to zero, the lower the standard deviation of the simulated results and real results would be [42]. Conversely, the higher the difference between the results of the simulation and the real ones so that the results of the simulation approximate zero ($S_t$=0), the closer this coefficient gets to zero. In order to calculate the error roots, MSE can be used as follows:

$$\frac{1}{n}\sum_{t=1}^{n}(S_t - A_t)^2 = (\bar{S} - \bar{A})^2 + (S_S - A_A)^2 + 2(1-r)S_S S_A \quad (4)$$

Where

$\bar{S}$: the mean of simulated values which is computed as $\frac{1}{n}\sum S_t$.

$\bar{A}$: the mean of real values computed as $\frac{1}{n}\sum A_t$.

$S_S$: SD of the simulated values calculated using $\sqrt{\frac{1}{n}\sum(S_t - \bar{S})^2}$.

$S_A$: SD of real values calculated through $\sqrt{\frac{1}{n}\sum(A_t - \bar{A})^2}$.

($\bar{S}$-$\bar{A}$): measures the bias between simulated and real series.

($S_S$-$A_A$): a part of MSE which is created due to differences in variance of simulated and real series and it also measures unequal changes between these two series.

$2(1-r)S_S S_A$: part of the error caused by incomplete covariance between the two series and it measures the degree of mismatch of changes in the simulated series with changes in the real series at one point.

Eventually, the correlation coefficient between the simulated and real values is computed as:

$$r = \frac{\frac{1}{n}\sum(S_t - \bar{S})\,(A_t - \bar{A})}{S_S S_A} \quad (5)$$

By dividing each element of the error into MSE, unequal ratios are:

$$U^M = \frac{(\bar{S} - \bar{A})^2}{\left[\frac{1}{N}\sum_{i=1}^{n}(S_t - A_t)^2\right]} \quad (6)$$

$$U^S = \frac{(S_S - S_A)^2}{\left[\frac{1}{N}\sum_{i=1}^{n}(S_t - A_t)^2\right]} \quad (7)$$

$$U^C = \frac{[2(1-r)S_S S_A]}{\left[\frac{1}{N}\sum_{i=1}^{n}(S_t - A_t)^2\right]} \quad (8)$$

Where $U^M$ is the inequality of the mean of the outputs of the model with real data, $U^S$ indicates inequality between the variance of real data and the simulated ones, and finally, $U^C$ donates inequality between the covariance of the results of the model and real data. The point is that the following equation should be observed for these inequality ratios:

$$U^M + U^S + U^C = 1 \quad (9)$$

In equation 9, a decrease in $U^S$ and $U^M$ implies the proper performance of the simulation model. In an idealistic state, $U^S = U^S = 0$ , $U^C = 1$. The results from error calculation tests for the key variables of the

model are indicated in Table 2. As can be seen, the degree of error in all of these variables is at a desirable level.

**Table 2:** Results of Model Validation Tests

| Key variables | RMSPE | UT | $U^M$ | $U^S$ | $U^C$ |
|---|---|---|---|---|---|
| Equity Investment Deposits | 0.0886 | 0.0944 | 0.12844 | 0.04248 | 0.82608 |
| Term Loans | 0.0912 | 0.0845 | 0.17608 | 0.00244 | 0.82148 |
| Credit Assets | 0.0759 | 0.0754 | 0.13309 | 0.00602 | 0.86089 |
| Net Income | 0.0863 | 0.0613 | 0.18297 | 0.00610 | 0.81093 |

In general, conducting these tests contributes to the calibration of the model and the results of applying the selected scenarios to the model can be analyzed, afterward.

### 4.6.2 Model Sensitivity Analysis

In system dynamics, like other approaches based on a model, uncertainty about the parameters of the model results in increasing the importance of the sensitivity analysis. Since systems dynamics is a behaviorist simulation approach, the sensitivity analysis of models based on it basically analyzes the sensitivity of output behavioral patterns compared to inputs of the model [23]. In other words, the sensitivity analysis answers this question that how much the model is sensitive to changes in the values of the parameters as well as the slight changes in the structure of the model [48]. As a result, this analysis can increase the reliability of the results of the simulation. To examine the effects of uncertainty of parameters on behavioral patterns, the sensitivity of the criterion of the behavioral pattern such as equilibrium level or Oscillation amplitude of model parameters should be examined [22]. The researcher can conduct further data analysis to decrease the uncertainty of the values of parameters to which the model output is sensitive.

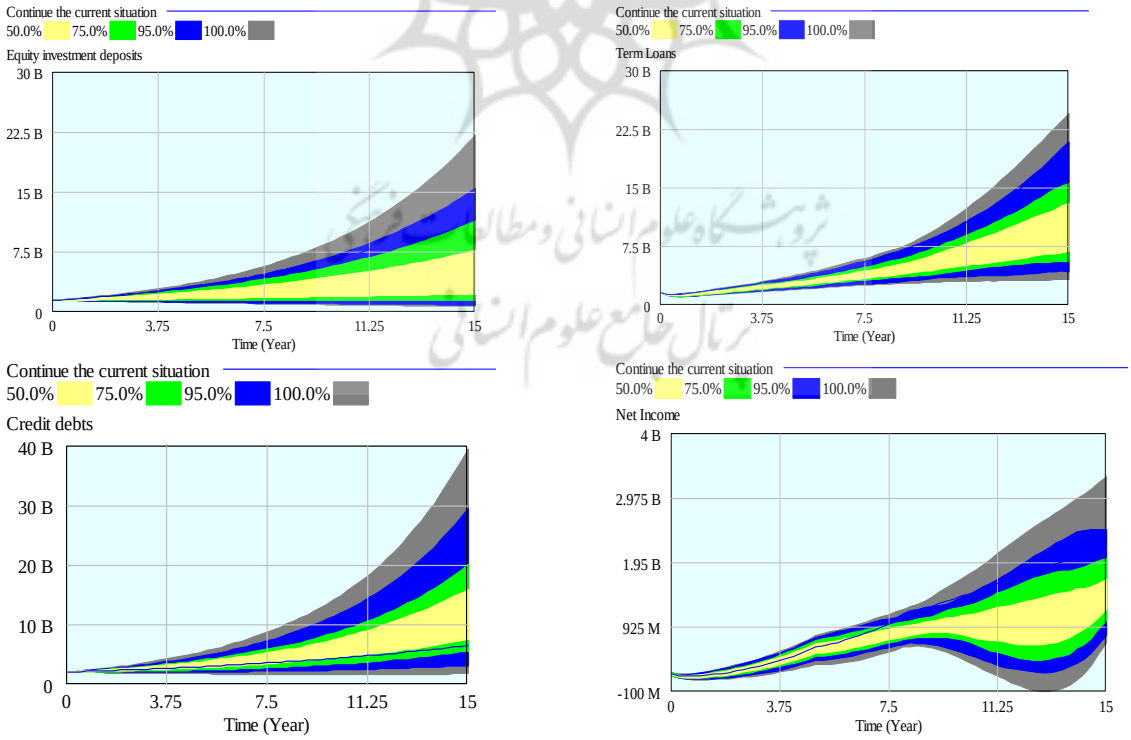


**Fig. 5: S**ensitivity Analysis of the Key Variables of the Model Against Variation of Parameters

In this section, to examine how reliable are the results of the simulation, the sensitivity of variables such as equity investment deposits, term loans, credit debts, and net income was studied against parameters of the average growth of investment deposits, the average withdrawal of depositors, and delay rate. Thus, after determining the domain of changes in these parameters, the extent to which the behavior of the model was changed was investigated and there was an attempt to gain a more comprehensive insight into the banking assets and liabilities management system. The results of this analysis are shown in Fig. 4 indicating that the model is sensitive to changes in the values of the selected parameters.

## 4.7 Scenario Design, Simulation, and Model Optimization

After validating the model and carrying out sensitivity analysis, a valid model with optimized policy structures is designed which can be used to simulate different kinds of related scenarios. Thus, considering different policy and system parameters, various management solutions and their effects on the results of the model under study can be taken into consideration and they can be used in future policy-making [48]. In this regard, after interviewing bank managers and obtaining their opinions and according to the literature in the field of bank assets and liabilities management as well as the results of the related studies and considering the existing variables in the structure of the system, three scenarios are devised. To manage assets and liabilities optimally and obtain the best performance indices, these scenarios were simulated using the designed model. The results of the simulations can aid managers in understanding, learning, and making reasonable and proper decisions. The results of the simulation are presented in the following and in order to ensure that the model fits the time series data, an attempt was made to achieve a separate improvement for the model using optimization while simulating each scenario.

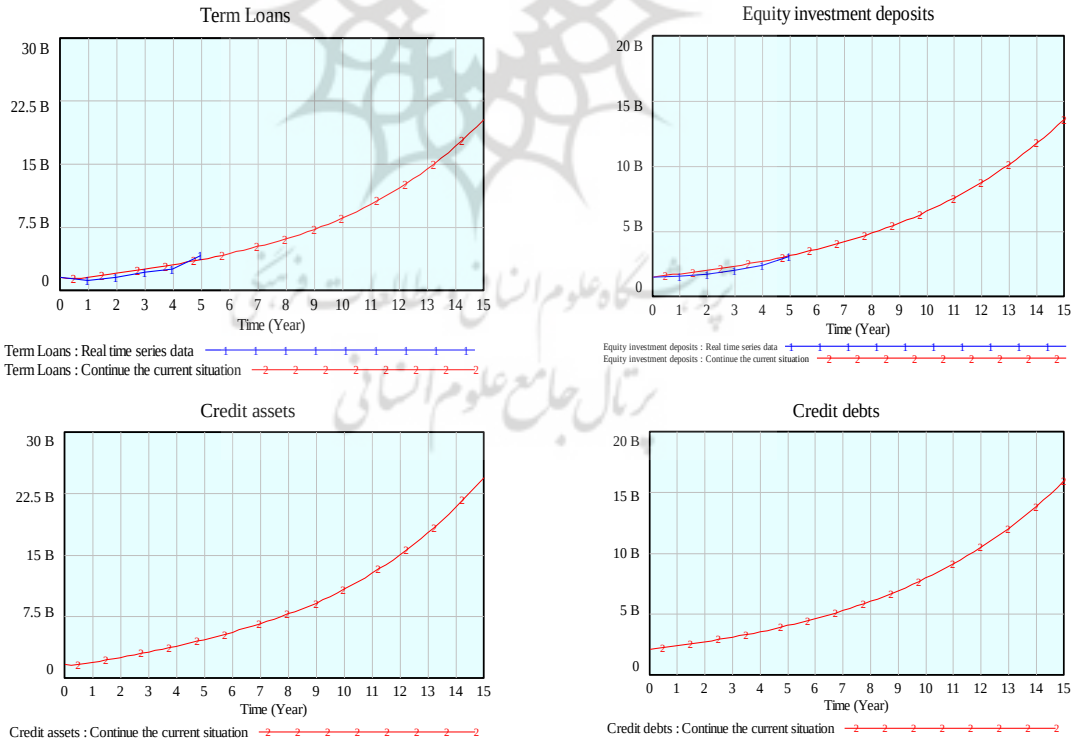


**Fig. 6 :**Behavior of Some Key Variables of the Model if the Current Situation Continues (Research Findings)

### 4.7.1 First Scenario: Continuation of the Current Situations

In the first step, assuming the continuation of the current situation, the simulation was conducted and the dynamic behavior of the main variables of the model was examined. To guarantee the precision of the results of the simulation and to fit the model with time-series data, the information on equity investment deposits and term loans from financial statements during the last five years was extracted and entered into the model. The results of the simulation (Fig. 6) show that in the case of continuing the current situation and considering the current parameters, the process of attracting long-term resources has sufficiently steep. If these resources are allocated optimally and reasonable credit policies are made, banks can increase their credit assets proportionally.

### 4.7.2 Second Scenario: Increasing the Rate of Attracting Deposits

One of the most important resources in the economy is deposits in banks which can play a key role in accelerating regular economic flow. Therefore, the ability of a bank to attract deposits can have a major effect on financing investment projects and creating opportunities for economic growth. In the banking industry, deposits are divided into two groups demand deposits (interest-free savings and current deposits) and time deposits (equity investment deposits). Time deposits are more stable and managers pay more attention to them for providing capital for banks. Hence, using different innovative mechanisms, banks compete with one another to obtain more deposits, especially time deposits and increase their Profitability by allocating them optimally. In the second scenario, the effect of increasing the attraction of term deposits by 3% on some key variables such as term loans, equity investment deposits, credit assets, and net profit of the bank under study, were examined and the results are shown in Fig. 7.

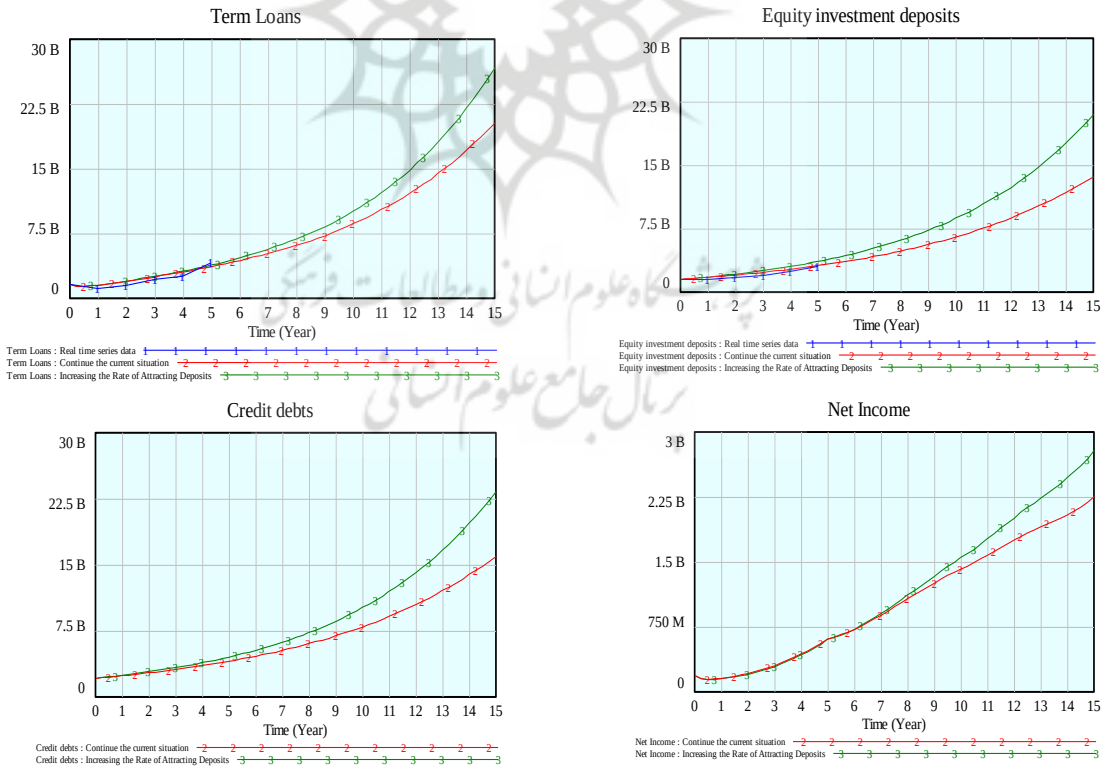


**Fig. 7:** Behavior of Some Key Model Variables in case of Increasing Deposits Attraction Rate

Results of simulating the second scenario (Fig. 7) indicate that increasing the resources from time deposits, if allocated optimally, contributes to an increase in the proportional lending power of a bank as well as a relative increase in net profit. Since the optimal allocation of these resources increases profitability, managers need to use a dynamic process for planning, organizing, coordinating, and controlling assets and liabilities, and their combination, volume, due date, productivity as well as costs to earn maximum profit. Optimization was conducted to achieve optimal equity investment deposits. The following results were obtained based on data on equity investment deposits and the selected domain for searching the related parameters:

**Table 3:** Optimisation Results for Equity Investment Deposits

| | **Initial Point of Search** | **Maximum Payoff Found at** |
|---|---|---|
| Average growth of investment deposits | 0.1 | 0.2 |
| Average withdrawal of depositors | 0.03 | 0.02 |
| Simulations | 1 | 31 |
| Pass | 0 | 3 |
| Payoff | 4.62427e+011 | 9.926e+011 |

As Table 3 shows, after 31 simulations, optimal values for two selected parameters were 0.2 and 0.02, respectively and the Payoff was increased more than double.

### 4.7.3 Third Scenario: Increasing the Quality of Credit Assets

Nowadays, banks play an important role in the financial and monetary growth of countries by attracting resources, giving loans, and participating in financing commercial activities so that loans form the major part of the portfolio of assets in banks. As a result, delay in receiving the installments of these loans poses a tremendous challenge to banks and removes a part of their financial resources from the loan-giving cycle. This reduces the quality of assets and disrupts assets and liabilities management. An increase in nonperforming loans shows a weakness in management and inefficient allocation of financial resources and not forming the optimal portfolio of assets which, in turn, decreases the quality of assets and, in addition to a negative effect on bank risks, it can reduce the profitability of a bank and, finally, influences the stability of the financial system. Therefore, in the third scenario, the effect of a 25% reduction in nonperforming loans on some key variables of the model was examined. The banking system in Iran categorizes nonperforming loans into three separate classes:

1. Past due loans whose payments are delayed for 2 to 6 months.
2. Deferred loans whose payments are delayed for 6 to 18 months.
3. Doubtful loans in which their payments are delayed for over 18 months.

Since the behavior of these variables can be different, each is included separately in the model and their behavior is studied.

Results from the simulation of the third scenario in Fig. 8 indicate that using different methods to reduce nonperforming loans can increase the quality of assets as well as the availability of cash resources. Hence, banks can manage their input and output resources by managing assets and liabilities efficiently and balancing their resources and their expenditures. They can take effective steps to give more loans, invest in new activities, or accept more financial obligations and while maintaining competitiveness, increase their long-term profitability by improving their liquidity situation.

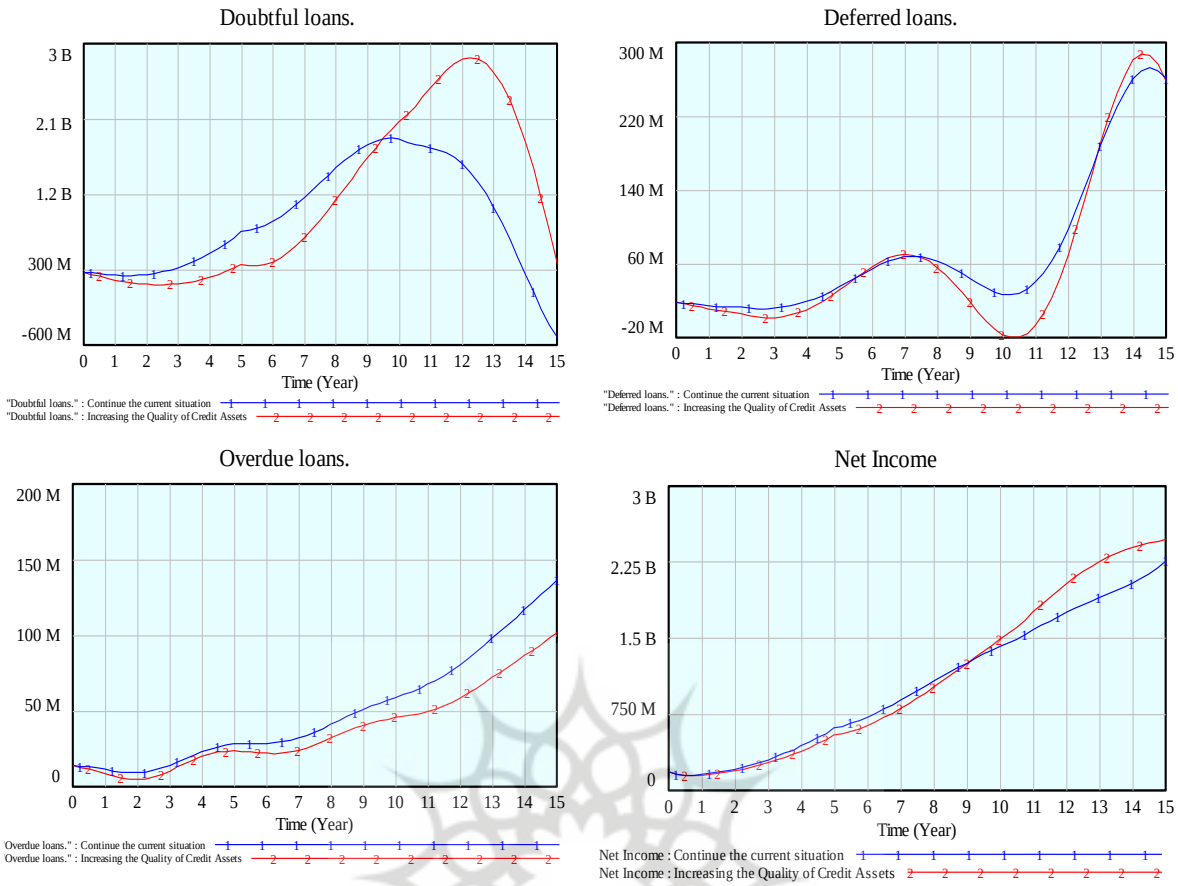


**Fig. 8:** Behavior of Some Key Variables of the Model in case of Increasing the Quality of Credit Assets

Finally, to achieve the optimal value of different categories of nonperforming loans, optimization was carried out. Based on the data of these categories and the selected domain for searching the related parameters, the following results were obtained:

**Table 4:** Optimisation Results for Nonperforming Loans

| | **Initial Point of Search** | **Maximum Payoff Found at** |
|---|---|---|
| Delay rate 4 | 0.01 | 0.008 |
| Delay rate 5 | 0.02 | 0.01 |
| Delay rate 6 | 0. 08 | 0.1 |
| Simulations | 1 | 50 |
| Pass | 1 | 3 |
| Payoff | 6.02079e+010 | 5.12761e+010 |

The results in Table 4 show the optimized values for three chosen parameters after 50 simulations. These results indicate that the Payoff decreased nearly 15%. The components of the Payoff are as follows after optimization:

**Table 5:** The Components of the Payoff

| **Type** | **Component** | **Contribution** | **Percent** | **Values** | **Params** | **Used** | **Skipped** |
|---|---|---|---|---|---|---|---|
| *P | Doubtful loans | 5.04625e+010 | 98.4133 | 5.04625e+010 | 0 | 61 | 0 |
| *P | Deferred loans | 5.67017e+008 | 1.10581 | 5.67017e+008 | 0 | 61 | 0 |
| *P | Past due loans | 2.46568e+008 | 0.480864 | 2.46568e+008 | | | |
| payoff = 5.12761e+010 | | | | | | | |

## 5 Conclusion and Discussion

Banks, as the biggest and the most important active sectors in the money market, not only facilitate commercial transactions by organizing receipts and payments but they provide opportunities for economic growth by collecting savings and directing them toward manufacturing units. Thus, providing and allocating resources properly or in other words, optimal management of assets and liabilities is of great importance and banks can gain a competitive advantage in this way. They use some mechanisms for managing assets and liabilities as an analytical tool for decision-making and try to maximize the value of their shareholders. Successful application of assets and liabilities management in Iran requires designing and utilizing new tools and increasing the autonomy of banks. To this end, using Systems thinking instead of traditional thinking and identifying the factors influencing assets and liabilities management and making a model, and analyzing the existing dynamics could be beneficial. System dynamics as a tool for systems thinking can facilitate building such models by focusing on improving current processes. Therefore, this study aims to identify the dynamic behavior of factors influencing assets and liabilities management as well as the structure causing these behaviors. In fact, the main purpose of this study is to identify systematic and causal structures of a model of banking assets and liabilities management. Hence, a dynamic model is presented that is capable of simulating different scenarios. In this study, in the first step, the continuation of the current situation of asset and debt management as a scenario was examined. In this step, the simulation results were compared with real-time-series data extracted from financial statements, which indicates the fitness of their behavior. Then, according to the offered suggestion by managers, two scenarios of "an increase in the number of deposits" and "increasing the quality of credit assets" were studied.

In the second scenario, the effect of increasing the Rate of Attracting deposits on the related variables was examined. Attracting deposits is not only the most important aim of banks, but it greatly influences the proper regulation of cash flow and the establishment of a monetary and credit system that is appropriate for the long-term and short-term goals of a country. Therefore, banks compete with each other intensely. The results of the simulation indicate that increasing deposits, in case of optimal allocation, rises the lending power of a bank and its profitability. Today, developing e-banking and notable innovations, such as e-money, and Electronic funds transfer terminals, have improved performance and productivity, have speeded up communication, and have reduced operational costs for banks. In modern banking, numerous factors influence the process of collecting the monetary resources of banks and financial institutions. Identifying and determining the extent of effect and type of relationship among these factors with the success of banks in collecting monetary resources is really crucial. As a result, it is recommended that banks, in addition to identifying these factors, can meet the reasonable needs and expectations of customers by promoting a customer-oriented culture in a properly and scientifically. Moreover, using advanced and up-to-date systems of providing electronic services and developing them can greatly influence the attraction of deposits and gain a competitive advantage for banks.

In the third scenario, the effect of increasing the quality of granted loans on some variables of the model was investigated. Inadequate quality of loans poses a serious challenge to banks such as blockage of a large number of their resources, reducing the frequency of debt collection, increasing collection period, not being able to serve customers appropriately, increasing numerous risks, wasting time and resources of different sectors of banks to receive payments and increasing costs of banks. Therefore, in the third scenario, the effect of taking necessary actions to reduce nonperforming loans on the model was simulated. The results showed that increasing the quality of assets reduces nonperforming loans

and improves the liquidity of banks and, in the case of proper management of assets and liabilities and optimal allocation of resources to enhance productive activities, banks can not only maintain their competitive power but also increase their profitability. Thus, with an emphasis on conducting the validation process precisely and following regulatory guidelines of the Central Bank, banks are recommended not to agree with the extension of nonperforming loans as long as the current risk of customers is reevaluated through validation methods. Additionally, regarding the effectiveness of major economic variables on increasing nonperforming loans, given commercial cycles and government revenue, it is proposed that banks use a dynamic flexible lending system that is suitable for macroeconomic conditions.

Overall, the findings of the study reveal that the system dynamics approach was successful in providing a comprehensive and optimal model for managing assets and liabilities. Therefore, it is recommended that the Central bank requires banks to know the structure of their assets and liabilities with a systematic attitude and use a system dynamics approach which is proportional to the size and type of ownership to design an optimal model for managing their assets and liabilities. It is worth mentioning that this model needs to be updated constantly due to changes in the banking environment.

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