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The Use of Nonlinear Programming in Banking Risk Management: A Statistical Study

أستخدام البرمجة اللاخطية في إدارة المخاطر للبنوك: دراسة إحصائية

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المستخلص

يهدف هذا البحث إلى تحديد أهم النماذج غير الخطية (البرمجة التربيعية) التي يمكن استخدامها في النمذجة القياسية، والتي يمكن تطبيقها على دراسة حالة مختارة في مجال إدارة المخاطر في المصارف. حيث يتم تحقيق ذلك من خلال دمج التخطيط الإقليمي مع إدارة مخاطر في المصارف لتشكيل علاقة تنموية مستقبلية. يمكن للمصارف لعب هذا الدور من خلال استخدام المعلومات المتعلقة بالتنمية الإقليمية لتقييم المخاطر بشكل أفضل. على سبيل المثال، يمكن أن يكون للتخطيط الجيد للبنية التحتية تأثير إيجابي على تقليل المخاطر الائتمانية في منطقة معينة، مما يعزز تمويل المشاريع الإقليمية. كما يمكن للمصارف أن تلعب دورًا في تمويل مشاريع التنمية الإقليمية، مما يؤدي إلى تحقيق عوائد اقتصادية وتحسين الوضع المالي.

الكلمات المفتاحية :التخطيط الإقليمي، البرمجة لا خطية، إدارة مخاطر.

Abstract

This research aims to identify the most important non-linear models (quadratic programming) that can be used in standard modelling, which can be applied to a selected case study (in banking risk management). This is achieved by integrating regional planning with banking risk management to form a future development relationship. Through integration, Banks can play this role by using information about regional development to assess risks better. For example, good infrastructure planning can positively impact the reduction of credit risks in a certain area, thus financing regional projects. Banks can play a role in funding regional development projects, thereby achieving economic returns, improving the financial situation, and subsequently, sustainable development. Banks can support projects that promote development, such as environmental projects that reduce environmental and financial risks, etc. Overall, the relationship between regional planning and banking risk management lies in balancing sustainable regional development and effectively

managing financial risks to achieve economic and social stability, taking into account cyclical, incidental, and sudden changes affecting the working system and the objectives set for it. The linkage between regional planning and banking risk management is significant as they intersect in several aspects, such as resource distribution and infrastructure at the regional level, to achieve balanced and sustainable development across all facets and approaches of regional planning. Regional planning cannot be complete and achieve its objectives and investments in all fields without a stable banking and financial system free from risks, which is used in developing analytical models capable of dealing with banking risk management using ready-made statistical programs such as SPSS, Solver, Eviews, etc.

Keywords: Regional Planning, Non-linear Programming, Banking Risk Management

1. Introduction: Banking risk management is one of the most important aspects that financial institutions focus on due to its direct impact on the stability and profitability of the banking sector. With the complexity of financial markets and the emergence of multiple unplanned factors that affect, for example, the performance of assets and portfolios, etc., traditional risk management tools have become insufficient to provide accurate and comprehensive estimates. Hence, it is important to research nonlinear programming as an advanced analytical tool to handle complex patterns and interactions between risk factors efficiently.

2. Research Methodology

2.1 Research problem: The research problem includes (how non-linear programming can contribute to improving the efficiency of banking risk management and providing better estimates of the nonlinear financial challenges facing financial institutions through a study of a group of mixed banks.

2.2 Research objective: - This research aims to explore the role of nonlinear programming in improving the efficiency of banking risk management, through analytical models that help financial institutions estimate risks more accurately and determine appropriate strategies to mitigate them

2.3 Research Hypothesis: The research is based on the hypothesis that the possibility of applying nonlinear programming according to an efficient model for risk management in banks will save banks a lot of losses, capital, and effort by using some techniques for nonlinear programming. (The hypothesis says that there is a direct relationship between return and risk).

2.4 The importance of the research: It is summarized in improving risk management, by providing nonlinear programming models that banks can improve their methods of estimating risks, which helps to predict better and respond quickly to changes that occur as a result of periodic, incidental, and sudden variables of the planned operating system that is expected to accomplish its tasks effectively as planned, and the subsequent financial risks that affect financial institutions (Through financial stability - increased profitability and efficiency - information base).

4. Axis One: The Theoretical Aspect

4.1 The concept of standard modelling and nonlinear programming

Various quantitative methods and approaches fall within the decision-making process, which can be expressed in a series of steps that start with the inputs represented by the raw data, then processing with various quantitative methods, standard modeling, operations research, data analysis, etc. to come up with results and conclusions, which the decision-maker relies on in making the decision, as quantitative methods are a link in the decision-making chain[1].

Standard modeling is among the most important quantitative methods that assist in decision-making, as it allows the analysis of various economic phenomena based on frugal theory and the application of mathematical and statistical methods, and includes a set of steps aimed at building a standard model that allows for the frugal analysis of the relationships between variables and/or predicting the values of a variable or several variables to anticipate the future[2]. All of this is aimed at extracting results that assist in decision-making. Standard modelling goes through a set of steps, the first of which is building the standard model by identifying the study variables and the functional formula that links these variables. This latter functional formula is often assumed by researchers to be linear; However, this assumption is not achieved in many economic phenomena, as many economic relationships are characterized by non-linearity. Therefore, constructing a standard model assuming a linear relationship between variables without verifying this may lead to misspecification of the model, thus negatively affecting the results and analysis**.**

4.2 Standard modelling concept and its stages: Standard modelling is among the most important quantitative methods widely used in analyzing economic phenomena. In this part of the research, we will discuss its concept and stages**.**

4.2.1 The **concept of standard modelling:**

Standard modelling is a quantitative method that allows the analysis of various economic phenomena based on economic theory and the application of a set of appropriate mathematical and statistical methods. It goes through a set of steps to finally reach an acceptable standard model that allows the economic analysis of the relationships between variables and/or the prediction of the values of one or more variables, all of which destination to results that help decision-making**.**

4.3 Standard Modelling Stages

4.3.1 Modelling any phenomenon usually goes through five stages:

The first stage is building the standard model, and we rely on economic theory and previous studies in building the standard model. In this stage, we determine the dependent variable, and determine the variable (independent variable. And determine the functional formula for the relationship between these variables.

4.3.2 The second stage is determining the appropriate standard methodology for the phenomenon under study. Which is the standard method that we will rely on to study the phenomenon determined in this stage? Will we do simple linear regression or multiple linear regression? Wind joint integration models, Engel and Granger methodology, VECM model, (ARDL) model. Panel data models[6]. Nonlinear modelling.... etc. The factors that determine the appropriate model include the purpose, economic theory, data characteristics, data size, stability of the studied time series (degree of integration), presence or absence of joint integration, etc.

4.3.3 The third stage is an estimation based on known standard estimation methods such as ordinary least squares OLS, maximum plausibility MV .... etc.). Ready-made statistical software can be used for this.

4.3.4 Stage Four: Studying the validity of the estimated standard model: This is done by conducting various statistical tests for validity. If the test results are positive and the model is acceptable, we move directly to the fifth stage to analyze and interpret the results[7]. However, if the estimated model suffers from standard problems, they must be addressed before analyzing and interpreting the results.

4.3.5 Stage Five: Analysis and Interpretation of Results and/or Prediction. In this final stage, we interpret and analyze the results reached through the accepted standard model in terms of the presence/absence of an effect of the independent variables on the dependent variable, and the extent of this effect. Linking the results reached with the economic theory and with the reality of the phenomenon studied and the study period. The model can also be used to conduct a predictive study if the goal is[8].

5. Definition of nonlinear models, their sections, and how to estimate them:

Quadratic Programming and Nonlinear Programming are two different areas of mathematical programming, although there are similarities between them in some aspects. However, there are differences in their areas of use and accuracy in obtaining data.

5.1 Nonlinear Programming (NLP): Nonlinear programming refers to any mathematical optimisation problem in which the objective function or constraints (or both) are nonlinear functions. Nonlinear programming includes a wide range of problems, as the functions can be polynomial, exponential, radical, trigonometric, or any other nonlinear type[9]. Nonlinear programming problems are solved using algorithms such as the Gradient Method or Newton's method, and their complexities vary depending on the nature of the functions.

5.2 Quadratic Programming (QP): Quadratic programming is a special case of nonlinear programming where the objective function is quadratic, while all constraints are linear[10]. Quadratic programming is used in applications such as finance, resource allocation, and portfolio analysis. Common algorithms for solving quadratic programming include the Interior-Point Method and the Active Set Method.

5.3 Quadratic programming: A special type of nonlinear programming that focuses on a quadratic objective function and linear constraints only.

5.4 Nonlinear programming: More general, where the functions (either objective or constraints) can be of any nonlinear type.

Therefore, quadratic programming is not synonymous with nonlinear programming, but rather a sub-case.

6. Definition of non-linear models

As we mentioned above, determining the functional formula for the relationship between the dependent variable and the independent variables is one of the most important elements of building the standard model[11]. Non-linear models are mathematical models in which the functional formula for the relationship linking the dependent variable to the independent variable or variables is non-linear, whether for the variables, the parameters, or both of them together.

6.1 Nonlinear Model Divisions

Among the divisions of nonlinear models is their division into nonlinear models that can be converted into linear models and nonlinear models that cannot be converted into linear models.[12]

6.1.1 Non-linear models that can be converted into linear models: These are mostly non-linear models in the variables but linear in the parameters. The most important of these models is:

Exponential function: It is a non-linear function that takes the following form: In which the independent variables are powers of real numbers. And multiplied by another real number[13] :

$B_0X_1^{B_1}X_2^{B_2}\ ....X_K^{B_K}$ But it can be converted to a linear form by entering the logarithm on the function= Y

$$\text{Ln}(Y_t)=\ln(B_0)+B_1\ln(X_{1t})+B_2\ln(X_{2t})+\cdots+B_k\ln(X_{kt})+\ln(\varepsilon_t)$$

$Y_t^*=B_0^*+B_1X_{1t}^*+B_2X_{2t}^*+\cdots+B_kX_{kt}^*+\varepsilon_t^*$

$Y_t^*=\ln(Y)$,$B_0^*=\ln(B_0)$,و =ln (X_{it}) i=1,2,…,k) $X_{it}^*($ $\varepsilon_t^*=\ln(\varepsilon_t)$)

An example of this is the Cobb-Douglas function. It was originally a nonlinear function but it can be converted to a linear function through a logarithmic transformation)Q=$B_0K^{B_1}L^{B_2}$(

(t=1,2,…,n) ln(Q_t)=ln$(B_0)+B_1\ln(K_t)+B_2\ln(L_t)+\ln(\varepsilon_t)$

$$Q_t^*=B_0^*+B_1K_t^*+B_2L_t^*+\varepsilon_t^*$$

6.1.2 Polynomial function: It is a nonlinear function concerning the variables because it contains variables with powers.

Y=$B_0+B_1X+B_2X^2+B_3X^3+\cdots+B_kX^k$(But it can be estimated as if it were a linear function, considering each variable in the power as an independent variable in the model.

$$Y_t=B_0+B_1X_{1t}+B_2X_{2t}+B_3X_{3t}+\cdots+B_kX_{kt}+\varepsilon_t$$

Where: t=1,2,…,n

$X_{1t}=X,X_{2t}=X^2,X_{3t}=X^3,\dots,X_{kt}=X^k$

As an example, the total cost function takes the following form:

$CT_t=B_0+B_1Q_t+B_2Q_t^2+\varepsilon_t$

Where CT is the total cost and Q is the production quantity

Semi-logarithmic function: It is a non-linear function where one of the variables is logarithmic, and we distinguish between two cases:

The dependent variable in logarithms is: ln (Y)=B_0+B_1 X and its origin is Y=$e^{B_0+B_1x}$ Where $Y_t^*=\ln(Y)$ It can be converted to linear form $Y_t^*=B_0+B_1X_T+\varepsilon_t$

The independent variable in logarithm: Y=B_0+B_1ln(X) and its origin is $e^Y=B_0X^{B_1}$ and it can be converted to linear form: Y_t=B_0+ $B_0X_t^*$+ε_t where $X_t^*=\ln(x)$.

Inverse function: It is a function that takes the following non-linear form: Y=B_0+$B_1(\frac{1}{X})$ and can be converted to a linear form:Y_t =B_0+$B_1X_t^*$+ε_t where: X_t^*=$\frac{1}{X}$

An economic example of the reciprocal function is the relationship between the rate of change in wages (W_t) and the unemployment rate (R_t) (Phillips curve), which takes the following form: W_t=B_0+$B_1(\frac{1}{R_t})$+ε_t. This model can be converted to a linear model as follows: R_t^*=$\frac{1}{R_t}$, so the model becomes linear: W_t=B_0+$B_1R_t^*$+ε_t

6.1.3 Non-linear models cannot be converted into linear models: This section of non-linear models is mostly non-linear in parameters. They may be linear or non-linear in variables, unlike the models we discussed above[14]. These models cannot be converted into linear form. Due to the complexity of their mathematical formula or the lack of a suitable transformation that can be performed.

Such models can be written in the following form: Y=f(X, B).

Where: Y is the dependent variable, X is the matrix of independent variables. B is the vector of parameters. € is the error term.

F (.) is the mathematical function that expresses the non-linear relationship between the dependent variable and the independent variables. It is a function that can take any mathematical formula that cannot be converted into a linear formula[15].

7. How to estimate non-linear models

The method of estimating non-linear models differs according to their type, whether they can be converted into any linear model or not.

7.1 Estimating non-linear models that can be converted into linear models:

Since this type of non-linear model can be converted into linear models, to estimate them, we perform the appropriate transformation on the non-linear model to convert it into a linear model, then we estimate it using known estimation methods such as the ordinary least squares method and the maximum likelihood method to provide the linearity hypothesis[16]. They are well-known methods, so there is no need to go into detail about them.

7.2 Estimating nonlinear models that cannot be converted into linear models:

Nonlinear models that cannot be converted into linear models cannot be estimated using the ordinary least squares method because the linearity condition is not met. To estimate such models, we use mathematical methods such as numerical optimisation, which depends on iterative processes in Taylor diffusion. Gauss and Newton developed a method that allows estimating such models based on Taylor diffusion by giving initial values for the parameters (initial value)[17]. Then we repeat the estimation process each time using Taylor diffusion to obtain new parameters, and we stop the iteration process when the estimated parameters become relatively stable (i.e. we obtain almost the same parameters from one estimate to another). These relatively stable parameters are the estimated parameters of the model.

I point out the importance of choosing the initial values of the parameters well for this method to be effective. This can be done by relying on economic theory, previous studies, or the graphical form of the data. In case of poor choice of initial values for the parameters, the estimated optimal model may be locally optimal but not completely optimal[18]. The further the initial values are from the optimal values for the parameters, the more iterations we need. Let the following nonlinear model be: Y=f(X, B) + ε

We have the sum of squared errors (residuals) equal to

RSS=$\hat{\varepsilon}^{'}\hat{\varepsilon} = [Y - f(X,B)]'(Y - f(X,B))$

To find the smallest value of the previous relation, we must calculate the derivative and make it zero, i.e. $\frac{\partial RSS}{\partial B} = 0$

We have:

$$\boldsymbol{\frac{\partial RSS}{\partial B} = -2\frac{\partial f(X,B)}{\partial B}\left(Y - f(X,B)\right) = 0}$$

$.f^{'}(x)f(x)$ =:2)´ [f(X)]^2(From the form)

With:

$$\boldsymbol{\frac{\partial f(X,B)}{\partial B} = Z(B) = \begin{pmatrix} \frac{\partial f(x_1,B)}{\partial B_1} & \cdots & \frac{\partial f(x_1,B)}{\partial B_1} \\ \vdots & \ddots & \vdots \\ \frac{\partial f(x_n,B)}{\partial B_1} & \cdots & \frac{\partial f(x_n,B)}{\partial B_k} \end{pmatrix}}$$

Taylor Diffusion Reminder: Every function f(X) can be written near an initial point X^0using Taylor Diffusion as follows**:**

$$f(X) = f(X^0) + (X - X^0)f'(X^0) + \frac{(X-X^0)^2}{2!} f''\left(X^0\right) + \cdots + R$$

Let $\hat{B}^1$ be the initial values of the parameters at which the iterative processes begin.

Let Z(($\hat{B}^1$)be the matrix Z(B) under the initial values of the parameters (B=($\hat{B}^1$)

Using Taylor diffusion near the initial point ($\hat{B}^1$). The observation t can be approximated to:

$$\mathbf{F}\ (x_t, B) \cong f\left(x_t, \hat{B}^1\right) + (B - \hat{B}^1)\frac{\partial f(x_t, \hat{B}^1)}{\partial B}$$

$$(f(x_t, B) \cong f\left(x_t, \hat{B}^1\right) + (B - \hat{B}^1)(\frac{\partial f(x_t, B)}{\partial B_1}|_{B=\hat{B}^1} \cdots \frac{\partial f(X_T, B)}{\partial B_k}|_{B=\hat{B}^1})$$

The function is:

$$f(X,B) \cong f\left(X, \hat{B}^1\right) + (B-\hat{B}^1)Z(\hat{B}^1)$$

Returning to the first nonlinear model and substituting, we find:

We have:

$$Y=f(X, B) + \varepsilon = f\left(X, \hat{B}^1\right) + \left(B - \hat{B}^1\right)Z\left(\hat{B}^1\right) + \varepsilon$$

$$Y-f(X,\hat{B}^1) = Z\left(\hat{B}^1\right)B - Z\left(\hat{B}^1\right)\hat{B}^1 + \varepsilon$$

$$Y-f(X,\hat{B}^1) + Z\left(\hat{B}^1\right)\hat{B}^1 = Z\left(\hat{B}^1\right)B + \varepsilon$$

$$Y^*\left(\hat{B}^1\right) = Y - f\left(X, \hat{B}^1\right) + Z(\hat{B}^1)\hat{B}^1$$

Through this relationship, the initial nonlinear model (Y=f(X,B)+ε) can be approximated to the following linear model:

$$Y^*\left(\widehat{B^1}\right) = Z\left(\widehat{B^1}\right)B + \varepsilon$$

Since this last model is linear, it can be estimated using the following formula:

$$\hat{B}^2 = [Z(\hat{B}^1)'Z(\hat{B}^1)]^{-1}Z(\hat{B}^1)'Y^*(\hat{B}^1)$$

$$\hat{B}^2 = [Z(\hat{B}^1)'Z(\hat{B}^1)]^{-1}Z(\hat{B}^1)'[Y - f\left(X, \hat{B}^1\right) + Z(\hat{B}^1)\hat{B}^1$$

$$\hat{B}^2 = \hat{B}^1 + [Z(\hat{B}^1)'Z(\hat{B}^1)]^{-1}Z(\hat{B}^1)'[Y - f\left(X, \hat{B}^1\right)]$$

8. The concept of banking risk management:

Risk management has become a matter of interest to many regulatory authorities and monetary authorities, but it has also captured the attention of financial institutions (WB) (IMF) and the Group of Ten, which is considered the main organization for fund globalization and its main supporter[19]. Especially the Basel Committee on Banking Supervision, banking risk management has become one of the basic topics that the stakeholders, from bankers and regulatory authorities, have focused on.

Therefore, the aforementioned committee studied and analyzed the causes of the banking crises that have swept most countries. It became clear that the most important causes of these crises are: -

- The inability of these institutions to manage the banking risks they are exposed to.
- Weak internal and external control (national regulatory authorities).

It focused on addressing the causes that led to these crises to ensure the strength of banks, especially in the wake of the successive financial crises starting from 1994 that hit Mexico and ending with Argentina. All these crises aroused the interest of fiscal and banking institutions, which made them study and analyze the causes of these crises to identify those causes and then develop successful solutions[20]. Through these studies, it became clear that this is due to the high severity of banking risks facing financial institutions and the lack of control over them through weak oversight and management and changes in interest rates. On this basis, those in charge of banking institutions should keep in mind developing special strategies to study this phenomenon, namely the phenomenon of the high severity of banking risks, and perfect appropriate procedures to identify, measure, follow up, and monitor risks and procedures for reducing, reporting and controlling them[21]. Therefore, there is a clear risk that has emerged and its effects have become clear in the balance sheet of banks. To respond to it, banks have seriously tried to focus comprehensively on risk control and management systems and formulate Risk Systems Management and Control strategies to achieve their banking objectives and reduce the negative effects of these risks. Reporting and controlling it.

From this perspective, risk management has become a cornerstone of broad banking practices and applications, and through this emerged the importance of our research in using nonlinear programming to study a selected case that we will discuss later.

Risk management is a pivotal aspect of both finance and computing in banks, as it acts as a safeguard against potential losses and system failure[22]. In finance, risk management involves identifying, analyzing, and mitigating financial risks that could negatively impact investment returns. It includes a variety of strategies, including diversification, asset allocation, and hedging. On the other hand, computing focuses on risks associated with information security, data integrity, and system reliability. Here, risk management strategies may include implementing robust security protocols, regular system updates, and developing disaster recovery plans.

From the researchers' perspective, risk management is protecting assets and ensuring long-term growth. They may employ:

1. Risk assessment tools: to quantify the risks associated with different investment vehicles.

2. Portfolio diversification: to spread risk across different asset classes.

3. Insurance products: such as annuities to manage longevity risk or life insurance for estate planning. However, a computer scientist (CS) will approach risk management with a focus on:

A. Algorithmic solutions: to predict and mitigate cybersecurity threats.

B. Data redundancy: to prevent data loss in the event of hardware failure.

C. Encryption techniques: to secure data transmission and storage.

For example, a financial planner might advise a client to invest in a mix of stocks, bonds, and real estate to mitigate the risks of market volatility. Similarly, a computer scientist might design a database with multiple backups and fail-safe systems to ensure that important data is not lost if it happens a system failure.

In both areas, the goal is to minimize potential losses while maximizing the chances of success. By combining the acumen of financial professionals with the expertise of computer scientists, risk management algorithms can be developed that are more sophisticated and effective than ever before[23]. These algorithms can analyze vast amounts of data to identify patterns and predict outcomes, leading to better decisions and improved risk mitigation strategies. For example, an algorithm might analyze historical market data to predict stock performance or monitor network traffic to detect potential cybersecurity threats.

Risk management in finance and banking computing is an interdisciplinary field that benefits greatly from the integration of knowledge and technologies from both sectors. By leveraging the strengths of each, professionals can develop comprehensive strategies that protect against a wide range of future risks, taking into account the cyclical, episodic, and sudden changes in the planned operating system and its intended objectives[24].

9. Reasons for the high risks in Iraqi banks:

The high risks in Iraqi banks are due to a set of factors as follows:

1. The lack of banking in basic requirements, such as appropriate financial resources and insufficient investment expertise in this field.
2. The modernity of the banking system, which needs a quick return and a liquidity factor, is not achieved by Iraqi banks in general due to their reliance on long-term investments.
3. The influences of the surrounding environment, which work to create obstacles that raise the degree of risk, including legislation and procedures that serve traditional banking, and subjecting banking to monetary policies approved by central banks that are not compatible with the nature of banking work, which is different and not fixed between one bank and another.
4. The prevailing social misconceptions view some banks, including Islamic banks, for example, as charitable institutions that do not aim to achieve profit.
5. Indicators of the self-structure of banks in general and their use of the simulation approach of traditional banks in some areas, such as in attracting and employing resources.
6. The absence of an active financial market that contributes to the development and activation of banking work in general.

10. Development of banking indicators in Iraq

Banks have witnessed important developments during the past two decades, as the year 1993 witnessed the establishment of the first Iraqi Islamic bank, the Iraqi Islamic Bank, followed by the establishment of several Islamic banks and other non-Islamic banks, the number of which reached seven banks by 2014, five of which were listed on the Iraq Stock Exchange, the last of which was the Arab Islamic Bank, which was listed in the first quarter of 2023, and it is one of the branches of the Arab Jordanian Bank.

11. Bank indicators for the banking sector

To know the importance and role of mixed banks in general for the Iraqi banking sector in the Iraqi Stock Exchange, we will review some important indicators such as the trading volume of the shares of these banks, the value of this trading, and the growth of the number of shares and specifying the second quarter of 2023, considering that it is the last quarter of the study period.

11.1 Number of traded shares

The number of traded shares of the four banks under study for the second quarter of 2023 amounted to about 43,187.6 million shares, or 27.1% of the trading volume of the banking sector in the Iraqi market, which amounted to 159,687.2 million shares. This percentage is considered an important and influential percentage in the banking sector, which confirms the role and importance of the Iraqi banking sector in particular and the Iraqi economy in general.

11.2 Trading volume

The trading value of the banks under study for the second quarter of 2023 amounted to approximately 34,514.2 million dinars at a rate of 27.6% of the total trading value of the banking sector in the Iraqi market, which amounted to 124,908.2 million dinars.

11.3 Market value of shares

The nominal value of the shares of the banks under study in the Iraqi market for the banking sector amounted to 1,448,700 million dinars, representing 30.21% of the market value of the banking sector, which amounted to 4,795,468 million dinars. As for the number of shares issued for these banks, it was 1,201,000, representing 22.5% of the number of shares in the banking sector, which amounted to 5,334,359 shares.

11.4 Development of financial indicators (research sample) for the period 2013-2023: The period between the first quarter of 2013 and the second quarter of 2023 witnessed remarkable developments in the most important indicators of these banks, such as the traded shares, the market value of these shares, and the trading value of these shares.

11.5 Traded shares: The period from the third quarter of 2013 to the second quarter of 2023 witnessed fluctuations in the number of shares traded for the banks of the research sample, and this reflects the unstable investment environment in Iraq due to the security situation, the spread of financial and administrative corruption, and the weakness of the administrative apparatus, etc. (As shown in Table No. 1 below:

Risk management in banks under study using the quadratic programming model) A learns of a sample of selected banks in Iraq

Sequence	Year	Number of chapters	Elaph	Tigris and Euphrates	Kurdistan	Iraqi Islamic
1	2013	3	132	104	406.7	17846.7
2	2014	4	229.6	545.1	444.3	516.6
3	2015	1	108.5	537.1	5365.2	2073.6
4	2016	2	80.2	49.3	2968.5	1671.7
5	2017	3	36.1	36226.2	40616.5	29245.5
6	2018	4	70.2	29872	634.2	45670
7	2019	1	72.9	38	461.4	2233.8
8	2020	2	133.2	42.1	1071.8	41940.5
9	2021	2	144.6	45.5	1089.9	52950.6
10	2022	3	177.5	66.8	1288.2	54871.4
11	2023	4	196.5	74.3	13023	56665.3

Table (1) Number of shares traded in Islamic banks (research sample) for the period 2013-2023

11.6 Trading volume: The trading volume of the research sample banks did not differ much from the number of traded shares, as the four banks were moving in the same direction. Table (2) shows the trading volume path.

Sequence	Year	Number of chapters	Elaph	Tigris and Euphrates	Kurdistan	Iraqi Islamic
1	2013	3	119.8	67.3	1028.7	25656.2
2	2014	4	421.6	327.8	971.8	681.2
3	2015	1	85.7	385.8	14911.1	2251.7
4	2016	2	59.3	36.5	7496.7	1810.8
5	2017	3	24.4	24690.5	71787.2	28045.9
6	2018	4	52.5	20225.9	1194.8	43193.1
7	2019	1	45.9	19.5	868.9	1686
8	2020	2	80.9	18.9	1926.7	29359.4
9	2021	3	95.7	385.8	7496.7	1810.8
10	2022	4	69.3	36.5	82787.2	38045.9
11	2023	1	27.4	31690.5	2394.8	53193.1

Table (2) Trading volume in Islamic banks for the period 2013-2023 / Source: Securities Commission, Quarterly Trading Movement Bulletin in the Iraq Stock Exchange for the period 2013-2023

11.7 The development of the number of shares and the market value of shares: The period from the third quarter of 2013 to the second quarter of 2023 did not witness any noticeable developments in the market value of shares, as these values witnessed fluctuations between rise and fall, which confirms the unstable investment environment in Iraq.

Table (3): This fluctuation.

Year	Number of chapters	Elaph	Tigris and Euphrates	Kurdistan	Iraqi Islamic
2013	3	139840	61000	630000	218880
2014	4	117040	59000	675000	260580
2015	1	114000	70000	885000	267500
2016	2	97280	66000	570000	250000
2017	3	98800	70000	860000	237500
2018	4	110960	66000	760000	237500
2019	1	94240	49000	692000	185000
2020	2	120000	45000	800000	182500
2021	3	127560	46000	770000	198890
2022	4	210452	50000	873200	213400
2023	2	223402	51021	860321	199500

Table (3) Market value of the shares of the four banks for the period 2013-2023 in the Iraqi market/ Source: Securities Commission, Quarterly Trading Movement Bulletin in the Iraqi Stock Exchange for the period 2013-2023

12. Axis Two: The Practical Aspect, Nonlinear programming model and analysis of results:

12.1 Nonlinear programming model (quadratic): The quadratic programming problem is a type of nonlinear programming (Non-Linear Programming) in which the optimization problem is linearly constrained by a quadratic objective function, i.e[25]. the problem is nonlinear with a quadratic objective function and linear constraints, or the objective function may be linear or one of the constraints may be nonlinear and forms the basis for some nonlinear programming algorithms, or one of the constraints may be nonlinear and forms the basis for some nonlinear programming algorithms.

The quadratic programming model can be written in the case of maximization as follows:

$$\max f(x) = C^T X - \frac{1}{2} X^T Q^X$$

S.t

AX≤ b

X≥ 0

In the case of minimization, the quadratic programming model can be written as follows:

$$minimze\ f(x) = C^T X + \frac{1}{2} X^T Q^X$$

S.t

AX ≥ b

X ≥ 0

Where:

X: is the decision variable.

Q, C: are the weight vectors of the objective function.

A: is a matrix of dimension **(m*n).**

b: is the constraint values , and the right side of the coefficients represents.

12.2 Determining an optimal investment portfolio using nonlinear programming: Harry Markowitz developed a method to solve the financial portfolio problem in an article in 1952, where he presented an approach called the (rate-variance) approach, for which he won the Nobel Prize in 1990[26]. Portfolio theory is a normative theory concerned with rational financial decisions made by investors to find a balance between the return and risk of investing in certain assets (material or subsidized).

Markowitz was able to use the nonlinear programming model to determine the investment portfolio, as this model is based on several assumptions, including:

1- Perfect competition and the absence of commission expenses.

2- There is no short selling.

3- There is a sufficient number of financial assets in terms of quantity and type, and there are no restrictions on the sale or purchase of financial assets.

Therefore, the objective function of this model is to minimize the risk of the portfolio according to the following formula:

$$\min S = X_1^2 S_1^2 + X_2^2 S_2^2 + \cdots \ldots + X_n^2 S_n^2 \sum_{i=j} x_i x_j r_{ij}$$

Where:

The optimal portfolio model includes three constraints:

The proportion of money invested in stock i,j ,$x_i x_j$.

S_i^2 The variance of stock returns i .

r_{ij} The correlation coefficient between stock returns i,j.

$S_i S_j$ The standard deviation of stock returns i,j.

1-The minimum expected return that the investor wants to achieve, which is calculated using the following formula:

$$r_i X_i + r_2 X_2 + \cdots \ldots + r_n X_n \geq r_m$$

Where:

r_i Expected annual return per share i.

X_i Percentage of money invested in the stock i.

r_m Minimum desired annual return on the portfolio.

2-The condition for investing the entire amount is determined according to the following formula:

$$X_1 + X_2 + \cdots \ldots + X_n = 1.0$$

3- Non-negativity condition $X_i \geq 0$.

12.3 Data used in the non-linear programming model[27]: The Islamic banking sector in Iraq consists of seven Islamic banks, five of which were listed on the Iraq Stock Exchange until the end of the second quarter of 2023, as four of these banks were used and the National Islamic Bank was excluded due to its recent entry into the Iraqi market, as it disclosed the results of its data from the first quarter of 2023 and the entry of a new Islamic bank at the beginning of 2023.

Due to the lack of a sufficient annual time series for the seven banks, a quarterly time series was used for only four banks for the period from the second quarter of 2023 to the first quarter of 2013, and Table 3 shows the quarterly closing of the stock for the four banks in the research sample that was adopted.

Sequence	Years	the chapter	Tigris and Euphrates	Elaph	Kurdistan	Iraqi Islamic
1	2013	1	0.88	0.88	0.25	1.3
2	2014	2	0.79	0.86	0.68	1.44
3	2015	3	0.61	0.92	2.1	1.44

4	**2016**	**4**	**0.59**	**0.77**	**0.25**	**1.29**
5	**2017**	**1**	**0.7**	**0.75**	**0.95**	**1.07**
6	**2018**	**2**	**0.66**	**0.64**	**1.9**	**0.95**
7	**2019**	**3**	**0.7**	**0.65**	**2.15**	**0.91**
8	**2020**	**4**	**0.66**	**0.73**	**1.9**	**0.95**
9	**2021**	**1**	**0.49**	**0.62**	**1.73**	**0.74**
10	**2022**	**2**	**0.45**	**0.67**	**2.32**	**0.73**
11	**2023**	**3**	**0.52**	**0.81**	**2.58**	**0.75**

Table (3) Closing price of the four banks for the period from the first quarter of 2013 to the second quarter of 2023 (dinar) / Source: Securities Commission, Quarterly Trading Movement Bulletin in the Iraq Stock Exchange 2013-2023

Table 4 shows the quarterly return per share for the four banks from the first quarter of 2013 to the second quarter of 2023. The quarterly return per share was obtained through the following equation:

Return per share = (Share price at the end of the period / Share price at the beginning of the period)

Sequence	**years**	**the chapter**	**Tigris and Euphrates**	**Elaph**	**Kurdistan**	**Bank of Iraq**
1	**2013**	**1**	**0.11**	**0.02**	**-0.2**	**-0.1**
2	**2014**	**2**	**0.3**	**-0.1**	**0.3**	**0**
3	**2015**	**3**	**0.03**	**0.2**	**-0.1**	**0.12**
4	**2016**	**4**	**-0.2**	**0.03**	**-0.24**	**0.21**
5	**2017**	**1**	**0.1**	**0.171**	**0.6**	**0.126**
6	**2018**	**2**	**-0.1**	**-0.02**	**-0.12**	**0.044**
7	**2019**	**3**	**0.1**	**-0.11**	**0.131**	**-0.042**
8	**2020**	**4**	**0.35**	**0.2**	**0.1**	**0.3**
9	**2021**	**1**	**0.1**	**0.033**	**-0.14**	**0.014**
10	**2022**	**3**	**0.31**	**0.043**	**0.12**	**0.032**
11	**2023**	**2**	**0.03**	**0.041**	**0.14**	**0.122**

Table (4) Quarterly return on equity for the four banks for the period 2013-2023 (dinars) / Source prepared by the researchers based on Table (3).

One of the requirements for solving the nonlinear (quadratic) programming model is to find both the average and variance of the return for the period under study and for the four banks, as in Table 5.

The bank	**Contrast**	**) r_1(Average annual return)**	**Bank code**
Iraqi Islamic	**0.03**	**0.10**	**X1**
Kurdistan	**0.10**	**0.04**	**X2**
Elaph	**0.01**	**0.05**	**X3**
Tigris and Euphrates	**0.02**	**0.10**	**X4**

Table (5) Average and variance of the return for the four banks for the period 2013-2023 / Source: Prepared by the researchers based on data from Table (4).

Table 6 below shows the matrix of correlation coefficients between banks, which is one of the requirements of the quadratic programming model.

Correlation coefficients	**Iraqi Islamic**	**Kurdistan**	**Elaph**	**Tigris and Euphrates**
Iraqi Islamic	**1.00**	**0.10**	**0.70**	**0.01**
Kurdistan	**0.10**	**1.00**	**0.10**	**0.53**
Elaph	**0.70**	**0.10**	**1.00**	**0.10**
Tigris and Euphrates	**0.01**	**0.53**	**0.10**	**1.00**

.Table (6) Matrix of correlation coefficients between the four banks / Source: SPSS program outputs based on data from Table (4).

Formulating the objective function and constraints of the optimal portfolio model Based on Tables (3) and (4) and using the SPSS and Solver programs to solve the model, the objective function and constraints of the model can be formulated as follows:-

Formulating the objective function and constraints of quadratic programming for the optimal portfolio**:**

$$min\ S = X_1^2(0.10) + X_2^2(0.04) + X_3^2(0.05) + X_4^2(0.10) + X_1X_2(0.10)(0.03)^{\frac{1}{2}}(0.10)^{1/2} + X_1X_3(0.70)(0.03)^{1/2} + (0.01)^{1/2}$$

$$0.03X_1 + 0.10X_2 + 0.01X_3 + 0.02X_4 \geq 0.073$$

$$X_1 + X_2 + X_3 + X_4 = 1.00$$

$$X_1 \geq 0$$

Through the constraints and objective function of the programming model above, and the objective function of the model, where it is the objective function of minimizing portfolio risks, which is measured by variance and standard deviation.

As for the constraints, they represent three constraints. The first represents the lowest possible return that the portfolio can achieve, which is the average of the returns of the four banks, which is (0.073). In other words, the investor will not be satisfied with less than this return in light of the lowest possible risk for the portfolio.

The second constraint represents the distribution of the percentage of invested money among the four banks, provided that the four percentages do not exceed 100% of the size of the invested amount, and the third constraint represents the Non-negativity conditions[29].

13. Results Analysis: Analyzing the Optimal Investment Portfolio Using Two Scenarios Based on the Quadratic Programming Model[30]. SPSS program and solver tool are used to solve the model. The first scene will include the results of the normal solution according to Table (5), and the second scene will analyze the sensitivity of the model in the event of an increase or return by a percentage of a decrease in the return by 20% and prove the direct relationship between the return and the risk.

13.1 The first stage: Appendix (1) shows the results of the optimal investment portfolio according to the quadratic programming model. The results indicate that the portfolio risk was (0.007) and the standard deviation was (0.084), i.e. 8.4%, which is a low risk. In other words, if the investor wants a return of 0.073, he must accept a risk of 10%. As for the invested amount, it was distributed at a rate of 13% in the Iraqi Islamic Bank and 1% in the Kurdistan Bank, which is the lowest invested percentage of the total amount; 54% in Elaf Bank, which is the highest invested percentage of the total amount; and 33% in the Tigris and Euphrates Bank.

13.2 The second stage: In this scene, the model's sensitivity to the increase or decrease in return will be tested, and the direct relationship between return and risk will be proven. Table 8 shows the investment portfolios under the quadratic programming model.

Wallet sequence	Percentage increase or decrease	Return	Risk is measured by standard deviation	Wallet (Banking Group)
1	**%20+**	**0.088**	**0.89**	**X1=0.10 X2=-0.02 X3=0.58 X4=0.30**
2	**%20+**	**0.896**	**0.095**	**X1=0.10 X2=-0.02 X3=0.58 X4=0.30**
3	**%20+**	**0.108**	**0.123**	**X1=0.45 X2=-0.09 X3=-0.05 X4=0.70**
4	**%20-**	**0.0584**	**0.084**	**X1=0.10 X2=-0.02 X3=0.58 X4=0.30**

5	**%20-**	**0.0467**	**0.084**	**X1=0.10** **X2=-0.02** **X3=0.58** **X4=0.30**
6	**%20**	**0.0374**	**0.084**	**X1=0.10** **X2=-0.02** **X3=0.58** **X4=0.30**

Table (8) Sensitivity analysis of the quadratic programming model for change in return/source SPSS outputs for the second stage

Table No. (8) shows the sensitivity of the optimal investment portfolio to changes in return. Therefore, in this section, investment portfolios will be determined in the case of a 20% increase in return and the associated risk.

The first increase was (20%), i.e. a return of (0.088), while the average return in the first scene was (0.073). Therefore, the risk increased from (0.084) to (0.089). This confirms the hypothesis that there is a direct relationship between return and risk. As for the amount invested in banks, the results confirmed that investment is limited to three banks, which are (x1, x2, x3), while bank (x2) was excluded from the portfolio, meaning that no amount was invested in bank (x2), and the same applies to the second portfolio. The third increase in the return was by 20%, i.e. it became an average of (0.108), and the results were an increase in the risk index to (0.123), and the total investment in banks decreased to only two banks, x1, x4, and the second bank, x3, was excluded from the portfolio.

The second axis is through testing the sensitivity of the portfolio to reducing the return, as the first decrease was by (-20%) for the return, so the return became from (0.073) in the first scene to (0.0584), so the risk associated with this return was () which is the same risk as the return in the first scene, meaning that the risk in this portfolio did not decrease, and this indicates that the risk in the portfolio of the first scene is the lowest possible risk for the portfolio through the quadratic programming model and the same was the case when reducing 5 and 6, Table (6), as the risk associated with the return was the same risk.

14. Conclusions and recommendations:

In light of the results obtained from the theoretical framework of Islamic banks and the quadratic programming model, some conclusions and recommendations can be presented to those in charge of banks in general and Islamic banks in particular, as follows:

14.1 Conclusions:

1- The theoretical aspect confirmed that Islamic banks bear higher risk ratios than usurious banks due to the activities practiced by these banks.

2- The results of the quadratic programming model for the first case showed that the risks of the portfolio measured by the standard deviation were 8.4% with a return of 0.73, as the risk of this portfolio is low compared to the average return, which proved that the goal of this model is to reduce the total variance of the portfolio.

3- The results of the model also showed that the investment portfolio in the first case confirmed the necessity of investing in the four banks, but at different rates, as the highest investment rate was in Elaf Bank at 53% of the total amount, which confirms that the risk in this bank is the least, while the Tigris and Euphrates Bank came at 33%, then the Iraqi Islamic Bank at 13%, and finally the Kurdistan Bank at 1%, which confirms that the risks in this bank are the greatest.

4-Sensitivity analysis of the change in return on risk confirmed that increasing the return by 20% for portfolios (1, 2, and 3) Table (8) led to an increase in the risk from 0.084 in the first scene to 0.089 to 0.095, 0.123 respectively in the second case Appendix (2, 3, and 4) while reducing the return by 20% for portfolios (4, 5, and 6) did not lead to a decrease in the risk. The reason is that the risk of the first portfolio in the first case is the lowest risk obtained from the quadratic programming model.

14.2 Recommendations

1- The Central Bank of Iraq must play a major role through the Monetary Authority in encouraging Islamic banking through supporting legislation, such as exempting Islamic banks from the capital ceilings set by the Central Bank or reducing restrictions and controls on them, because these banks are subject to two types of financial supervision, the second of which is Sharia supervision**.**

2-Intensifying studies and research that deal with risk models to avoid these banks from these risks because part of these risks are borne by the customer, and thus this leads to limiting the growth, development, and spread of these banks.

3- The necessity of Islamic banks moving towards banking mergers among themselves to form a strong and large financial bank to face banking competition, whether from government banks or private banks, as well as facing the challenges of financial liberalization.

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