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Mathematical Modeling of the Impact of Monetary Policy on the Volume of Bank Credit

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Abstract: The present paper aims to construct an analytical mathematical model to study the impact of monetary policy on the volume of bank credit in Iraq from 2004 to 2021, by formulating purely functional and equilibrium relationships within the framework of mathematical economics. The problem of the research under investigation arises from the following question: How can the impact of monetary policy instruments (r: interest rate, M: money supply, and Y: gross domestic product) on the volume of bank credit (C) be represented with mathematical precision? The scientific hypothesis assumes a specific mathematical effect for each instrument, with the possibility of deriving the impact coefficients solely from equilibrium conditions. The main objective is to derive an analytical reduced-form equation linking bank credit to monetary policy instruments through a market equilibrium equation, The mathematical system is formulated as follows: Credit demand function: DC=α0−α1r+α2Y, where α1,α2>0; credit supply function: SC=β0+β1M, where β2r **:**β1,β2 >0; and the equilibrium condition:
C=DC=SC. By solving this system algebraically, the following reduced-form equation is obtained:
C = γ0 + γ1M − γ2r + γ3Y, where:

$$\gamma 1 = \frac{\beta 1}{\alpha 1 + \beta 2} > 0,$$

$$\gamma 2 = 1, \gamma 3 = \frac{\alpha 2}{\alpha 1 + \beta 2} > 0$$

Applying the method of comparative statics, the following mathematical multipliers are derived:

$$\frac{\partial C}{\partial r} = -1, \frac{\partial C}{\partial M} = \frac{\beta 1}{\alpha 1 + \beta 2} \in (0,1), \frac{\partial C}{\partial Y} = \frac{\alpha 2}{\alpha 1 + \beta 2} > 0$$

Short-run adjustment dynamics are also modeled using a first-order differential equation: $\frac{dC}{dt} = \lambda(C* - C)$, $\lambda \in (0,1)$, where $C* = \gamma 0 + \gamma 1 M - \gamma 2 r + \gamma 3 Y$ represents long-run equilibrium credit, solving this equation yields: $C(t) = C* + (C(0) - C*)e^{-\lambda t}$, which proves that credit converges exponentially toward its long-run equilibrium with speed λ. The mathematical results indicate that a one-unit increase in the money supply leads to an increase in credit by γ1 units, whereas a one-unit increase in the interest rate reduces credit by exactly one unit, and an increase in output raises credit by γ3 units, with all multipliers fully determined by the structural parameters α1,α2,β1,β2without any reliance on statistical estimators, among the most important mathematical conclusions is that expansionary monetary policy (increasing M or reducing r) stimulates bank credit in a quantitatively specific manner, while contractionary policy curbs it. Furthermore, the adjustment speed λ determines the time required for the credit market to reach equilibrium. The most significant proposals include adopting gradual monetary policies by adjusting the money supply by $\Delta C/\gamma 1$ to achieve a targeted change in credit ΔC, diversifying sources of economic growth to reduce dependence on the limited coefficient γ3, and directing liquidity toward productive sectors while adjusting the interest rate according to the relation $\Delta r = \Delta C$ for precise control over the volume of credit, considering that system stability requires all eigenvalues of the dynamic matrix to be negative, which is automatically satisfied when $\lambda, \theta, \mu > 0$.

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النمذجة الرياضية لأثر السياسة النقدية في حجم الائتمان المصرفي

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المستخلص

يهدف البحث إلى بناء نموذج رياضي تحليلي لدراسة تأثير السياسة النقدية في حجم الائتمان المصرفي في العراق من 2004-2021، وذلك من خلال صياغة علائق وظيفية وتوازنية بحتة في إطار الاقتصاد الرياضي، إشكالية البحث من السؤال التالي: كيف يمكن تمثيل تأثير أدوات السياسة النقدية (r سعر الفائدة M عرض النقود وY الناتج المحلي الإجمالي) في حجم الائتمان المصرفي C بشكل رياضي دقيق؟ وتفترض في البحث العلمي وجود تأثير رياضي محدد لكل أداة، مع إمكانية اشتقاق معاملات التأثير من شروط التوازن فقط، يتمثل الهدف الرئيس في اشتقاق صيغة اختزالية تحليلية تربط الائتمان المصرفي بأدوات السياسة النقدية عبر معادلة توازن السوق، تم صياغة النظام الرياضي على النحو التالي: دالة الطلب على الائتمان $D_C=\alpha_0-\alpha_1 r+\alpha_2 Y$ حيث $\alpha_1,\alpha_2>0$ ودالة عرض الائتمان $S_C=\beta_0+\beta_1 M$ حيث $\beta 1,\beta 2>0$:$\beta 2 r$ وشرط التوازن $C=DC=SC$

بحل هذا النظام جبريًا، تم الحصول على الصيغة الاختزالية التالية:

$$C=\gamma 0+\gamma 1M-\gamma 2r+\gamma 3Y$$

حيث ان:

$$\gamma 1=\frac{\beta 1}{\alpha 1+\beta 2}>0, \qquad \gamma 2=1, \gamma 3=\frac{\alpha 2}{\alpha 1+\beta 2}>0$$

وبتطبيق أسلوب التحليل الساكن المقارن (Comparative Statics)، تم استنتاج المضاعفات الرياضية التالية:

$$\frac{\partial C}{\partial r}=-1, \frac{\partial C}{\partial M}=\frac{\beta 1}{\alpha 1+\beta 2}\in(0,1), \frac{\partial C}{\partial Y}=\frac{\alpha 2}{\alpha 1+\beta 2}>0$$

كما تم نمذجة ديناميكية التكيف قصيرة الأجل باستخدام معادلة تفاضلية من الرتبة الأولى:

$$\frac{dC}{dt}=\lambda(C^*-C),\ \lambda\in(0,1)$$

حيث يمثل: $C^*=\gamma_0+\gamma_1 M-\gamma_2 r+\gamma_3 Y$ الائتمان التوازني طويل الأجل، وبحل هذه المعادلة نحصل على:

$$C(t)=C^*+(C(0)-C^*)e^{-\lambda t}$$

مما يثبت تقارب الائتمان أسياً نحو توازنه طويل الأجل بسرعة λ. حيث تشير النتائج الرياضية إلى أن زيادة عرض النقود بمقدار وحدة واحدة تؤدي إلى زيادة الائتمان بمقدار γ_1 وحدة، بينما تؤدي زيادة سعر الفائدة بمقدار وحدة واحدة إلى انخفاض الائتمان بمقدار وحدة واحدة، كما تؤدي زيادة الناتج المحلي إلى زيادة الائتمان بمقدار γ_3 وحدة، مع بقاء جميع المضاعفات محددة بالكامل بالمعاملات الهيكلية $\alpha_1,\alpha_2,\beta_1,\beta_2$ دون أي ارتباط بأي مقدرات إحصائية. من أهم الاستنتاجات الرياضية أن السياسة النقدية التوسعية (زيادة Mأو خفض r) تحفز الائتمان المصرفي

بشكل محدد كمياً، بينما تؤدي السياسة الانكماشية إلى كبحه، كما أن سرعة التكيف λ تحدد المدة الزمنية اللازمة لوصول سوق الائتمان إلى حالة التوازن. أما أهم المقترحات فتشمل تبني سياسات نقدية تدريجية عبر تعديل عرض النقود بمقدار $\Delta C/\gamma 1$ لتحقيق تغيير مستهدف في الائتمان ΔC، وتنويع مصادر النمو الاقتصادي لتقليل الاعتماد على معامل $\gamma 3$ المحدود، وتوجيه السيولة إلى القطاعات الإنتاجية مع ضبط سعر الفائدة وفق العلاقة $\Delta r=\Delta C$ للتحكم الدقيق في حجم الائتمان، مع مراعاة أن استقرار النظام يتطلب أن تكون جميع الجذور الذاتية للمصفوفة الديناميكية سالبة، وهو ما يتحقق تلقائياً عندما تكون $\lambda,\theta,\mu>0$.

الكلمات المفتاحية: الاقتصاد الرياضي، السياسة النقدية، التحليل الساكن المقارن، الاستقرار الديناميكي، الأنموذج الرياضي.

1. Introduction

Monetary policy credit a pivotal role in steering economic activity and achieving macroeconomic and financial stability. It serves as a primary instrument employed by central banks to influence aggregate demand and economic growth. To this end, monetary policy relies on a suite of instruments—including interest rates, money supply, and the statutory reserve requirement ratio—which directly and indirectly influence the lending decisions of commercial banks, ultimately manifesting in the volume of bank credit.

The volume of bank credit constitutes a fundamental indicator of banking sector activity and its capacity to finance investments and foster economic growth. However, the relationship between monetary policy instruments and credit volume is inherently complex, as it is contingent upon internal factors, such as the banking market structure, and external dynamics, including inflation and economic fluctuations.

This research aims to develop a mathematical model to elucidate the relationship between various monetary policy instruments and the volume of bank credit, alongside analyzing the short- and long-term impacts of these instruments on credit activity. Furthermore, the study seeks to leverage empirical economic data and monetary policy experiences to provide actionable policy recommendations aimed at enhancing the efficiency of monetary policy in guiding bank credit to support economic growth.

The research is structured into two main dimensions: a theoretical framework that outlines the economic and mathematical foundations of the relationship between monetary policy and bank credit, and an empirical (applied) framework based on mathematical economics and mathematical modeling. The ultimate objective is to provide a comprehensive framework that assists

policymakers in formulating effective monetary policies that strike a balance between financial stability and sustainable economic development in Iraq from 2004 to 202.

2-1. Research Problem: What is the impact of monetary policy indicators (represented by the interest rate, money supply, and gross domestic product) on the volume of bank credit in Iraq, and how can this impact be measured mathematically within an analytical general equilibrium model?

2-2. Research Importance: Monetary policy in Iraq can play a vital role in enhancing the contribution of bank credit to the broader economic process, This significance is pronounced in the wake of several structural and regulatory reforms implemented across the financial and banking sectors, coupled with the modernization of private sector legislations and the facilitation of foreign direct investments (FDI).

2-3. Research Objectives: Monetary policy consistently commands the attention of researchers globally, prompting continuous studies adapted to evolving economic dynamics and the imperatives of general macroeconomic equilibrium, Given that macroeconomic policies, exchange rates, and the behavior of monetary aggregates represent broad domains attracting extensive academic literature, this research seeks to achieve the following objectives:

1. To shed light on the current state and trends of monetary policy in Iraq by analyzing its key variables and its role in determining the credit volume within the banking system.
2. To empirically estimate and analyze the relationship between monetary policy variables and the volume of bank credit in Iraq.

2-4. Research Hypothesis: The research assumes a direct mathematical relationship between the money supply (M) and the volume of credit (C) such that $\frac{\partial C}{\partial M} > 0$, an inverse mathematical relationship between the interest rate (r) and the volume of credit (C) such that $\frac{\partial C}{\partial r} < 0$, and a direct mathematical relationship between the gross domestic product (Y) and the volume of credit (C) such that $\frac{\partial C}{\partial Y} > 0$, all within the equilibrium condition C = DC = SC.

2-5. Research Methodology: To address the research problem and test the formulated hypotheses, this study adopts a dual approach combining descriptive and empirical analytical methods to examine monetary indicators

and bank credit volume. Furthermore, mathematical and econometric models are utilized to evaluate the impact of monetary variables on bank credit volume, and to determine the correlation and regression dynamics among the research variables for Iraq the period (2004–2021).

2-6, Research Dimensions

1. Temporal Dimension: The period spanning from 2004 to 2021.
2. Spatial Dimension: The Iraqi economy.
3. Sectorial Dimension: Monetary policy indicators and the volume of bank credit.

2-7. Research Structure: In order to achieve the study's objectives and validate or invalidate its hypothesis, the research is structured into two main sections: The first section comprises the theoretical framework of the study, while the second section is dedicated to the empirical (applied) analysis, followed by the conclusion and policy recommendations.

3. Theoretical side

3-1. The Role of Private Commercial Banks in Economic Activity: The economic, social and political development of the countries is also based on the role of the private commercial banks, which hold the central position in the entire financial and economic machine. They are regarded as one of the pillars that are necessary when developing the economic framework of a country. The operations of commercial banks are essential in the running of modern economies particularly following increased complexity and growth of economic operations. (Ali Alqararah et al., 2025)

Commercial banks spur investment and encourage investors through credit advances in friendly terms. They also help in financing the national development programs through provision of the required credit to different sectors of the economy which include the public and the private sector with the vision of boosting production of goods and services and also provides adequate funding in support and implementation of economic development plans. These banks are known to be some of the greatest financial institutions when it comes to promoting welfare in the economy. (Feng, Y., Pan, Y., Sun, C., & Niu, J. (2024).

Financial advisory services are another service provided to financial clients by commercial banks and are aimed at assisting them on the hardships and challenges that might be encountered in business ventures. The banks are involved in the development and growth of the national economy through

these consultative functions as they have a proposed role in coming up with viable solutions (Magnus-Eweka, 2023). In addition, commercial banks also operate in the financing of the international trade that is of huge significance to other economies. This is done through facilitating the provision of essential facilities to the exporters and helping the importers with all the costs involved faster in importing and at a cheaper cost; which further strengthens the role of the banks in promoting economic integration and trade growth.

3-2. The Relationship Between the Banking Sector, Money Supply, and Monetary Policy: Money supply/monetary stock may be defined as the sum total of units or financial instruments that execute the purpose of money that the people in a particular society possess at a particular time. This definition explains that the money supply is a stock variable as opposed to a flow (Liu et al., 2024). There is thus the need to differentiate between monetary stock and monetary flow. The former is defined as a given amount of money at a given point in time e.g. the money supply or a given population, the latter is defined as a given amount of money within a given time e.g. national expenditure or national income. In this context, the definition of the money supply is normally divided into three different measures, depending on the nature and the liquidity of the deposits in question (Hao et al., 2023).

1. **The Narrow Concept:** The narrow definition of the money supply refers to demand deposits held at commercial banks, which grant depositors access to checkbooks that allow them to withdraw funds on demand. These deposits are therefore classified as demand deposits (Ghartey, 2026). Accordingly, the narrow money supply is defined as the sum of currency in circulation outside the banking system and the total volume of demand deposits held at commercial banks.
2. **The Broad Concept:** The broad definition of the money supply expands upon the narrow concept by including savings deposits. These consist of time deposits and other savings instruments that are not immediately accessible for transactions (Challoumis, 2024). Withdrawals from such deposits are made using savings passbooks or certificates of deposit, which are non-negotiable instruments and can only be used by the account holder. Therefore, the broad money supply includes demand deposits, time and savings deposits, and the net currency in circulation.
3. **The Broadest Concept:** The broadest definition of the money supply extends further to include other types of deposits, particularly as a result of

the increasing involvement of the government in economic activity. In this context, public sector institutions engage in financial operations that resemble those of the private sector. Thus, the broadest measure of the money supply encompasses both the narrow and broad definitions, along with additional quasi-monetary deposits. This all-inclusive aggregate shows the overall liquidity in the economy. (Anita et al., 2022)

3-3. The Role of Monetary Policy in Influencing the Volume of Bank Credit: The economist Kent used the term monetary policy to mean the narrow definition of monetary policy, which was a collection of tools that were utilized by the monetary authority to regulate the money supply to realize certain economic rewards. On the contrary, the wider meaning of monetary policy is an overall complex of monetary actions aimed at the achievement of both monetary and non-monetary (i.e., more economic) goals. The financial targets mainly entail controlling the extent of liquidity in circulation in the economy, whereas the general economic targets involve redistribution of income and achievement of macroeconomic stability (Aruoba & Drechsel, 2024).

Based on these definitions, it is clear that the monetary policy focuses on application of certain tools and measures undertaken by the central bank in order to achieve set economic goals.

Monetary policy affects the amount of bank credit by using the monetary policy tools; the complex of the mechanisms that are set and introduced by the central bank to control and influence the growth or slowdown of the credit in the banking system. These tools are mostly categorized according to their nature and way of use (Budianto, 2023).

1. **Indirect Instruments:** They are called indirect technical control tools since their effects on the amount of deposits held by commercial banks do not directly affect them. They are quantitative tools which are employed in controlling the money supply and the overall amount of money in the economy. These are based on three major mechanisms:
2. **Discount Rate:** Discount rate is the interest rate that the central bank applies when it discounts the commercial papers offered by the commercial banks in seeking loans (Marthinsen & Gordon, 2024). This rate is one of the instruments that the central bank applies in order to manipulate the credit conditions as the lender of last resort. When the discount rate increases, this will increase the cost of lending money by commercial banks and they will

increase the interests charged on loans they give to individual and businesses. This subsequently decreases the credit demand. On the other hand, a reduction in the discount rate reduces the cost of borrowing among the commercial banks and hence they are in a position to lend at better terms, thus creating demand of credit.

3. **Open Market Operations:** The central bank is involved in the financial and money markets through open market operations in which it buys or sells government and other securities especially bonds. The central bank buys the securities of the commercial banks and in doing so it provides them with more liquidity thus raising their credit giving powers. When they acquire securities through individuals, their liquidity level is high, and this normally results in increase in deposits in the commercial banks, and hence the bank credit would also grow. However, as the central bank sells the securities, it removes the liquidity of both the commercial banks and people caused a reduction in the bank credit because there is less liquidity in the banking industry. (Acharya & Rajan, 2024)
4. **Legal Reserve Requirement:** The legal reserve requirement has an impact on the bank credit by changing the amount of deposits that commercial banks are required to have as reserve. By increasing the reserve ratio of the central bank, the capacity of the commercial banks to lend money is limited since a higher percentage of the reserve will be frozen and hence the credit multiplier will be smaller. The instrument is normally used in times of economic inflation. Conversely, a decrease in reserve requirement increases the ability of banks to issue credit and is employed in response to deflationary forces and in order to boost economic activity (Challoumis, 2024).
5. **Direct Instruments:** Direct instruments refer to the qualitative and selective credit control tools. These tools are meant to influence and control bank credit by controlling the conditions of credit provision including its maturity or the cost of the credit which in turn affects the provision of bank credit by commercial banks (Yahaya, 2026). These measures are credit ceilings that are imposed whenever there is inflationary times in order to ensure that there is also a limit to the growth of credit and also to check inflationary trends. The central bank can also use the moral suasion technique whereby it encourages commercial banks to implement certain credit policies to suit overall economic interests. This approach takes advantage of the better

ability of the central bank to predict the economic trends and influence the rate of credit provisions.

6. **Interest Rate as an Independent Variable and Its Relationship with the Volume of Bank Credit:** From the structural credit demand function $DC = \alpha_0 - \alpha_1 r + \alpha_2 Y$, where $\alpha_1 > 0$, the partial derivative $\partial C/\partial r = -1$ (derived from the reduced-form equilibrium solution) quantifies the exact marginal effect: a one-unit increase in the interest rate reduces bank credit by exactly one unit, ceteris paribus.
7. **Developing a mathematical economic model to analyze the impact of monetary policy on the volume of bank credit**

The following provides the formulation of a conceptual model that would explain how the monetary policy would relate to the volume of bank credit:

4-1. Definition of the Core Variables

1. **Dependent Variable (**y)

C_t: Volume of bank credit at time t

2. **Independent Variables (**x**)**

r_t :Interest rate at time t

M_t :Money supply at time t

π_t :Inflation rate at time t

GDP_t: Gross Domestic Product at time t

X_t: Other relevant explanatory variables, including:

X_1: Required reserve ratio

X_2: Discount rate

X_3: Exchange rate

This group of variables is the foundation of estimating the effect of monetary policy instruments on the dynamics of the bank credit process over time. The model may be further elaborated or refined using suitable econometric models, including the time series model, cointegration tests or using the vector error correction models to include the short-term adjustment and the long term equilibrium relationship.

4-2. Fundamental Hypotheses

- ❖ Increased interest rates will also lower the amount of bank credit since both individuals and businesses will find it costly to borrow.
- ❖ The money supply is expected to cause the increase in the amount of bank credit, as the money will be more liquid in the banking system.

- ❖ High rates of inflation can lead to a decrease in bank credit because a higher level of uncertainty and falling real returns will deter both borrowing and lending.
- ❖ An improvement in Gross Domestic Product is an indicator of economic growth, which is normally linked to credit demand and, therefore, the water of the amount of bank credit.

1.Dependent Variable (y)

C_t: Volume of bank credit at time t

A. Credit Demand: The credit demand is affected at the first place by the current interest rate acting as a way of borrowing of people and companies. This can be understood in terms of an equation that shows an inverse relationship between the rate of interest and the number of loans demanded- such that the higher the interest rates, the lower will be the demand of credit and vice versa.

$D_C = f(r, Y)$

Where:

D_C: Demand for credit

r: Interest rate

Y: Gross Domestic Product

The credit demand function, in this case, can be given a formal form:

$D_C = f(r, Y)$

This working relationship suggests that the credit (D_C) demand is inversely dependent on the interest rate (r), and positively dependent on the level of development of the economy as indicated by Gross Domestic Product (Y). When the interest rates increase, borrowing becomes expensive hence lowering credit demand. On the other hand, the demand of credit tends to grow as GDP grows indicating economic growth as a result of the higher investment and consumption activities.

B. Credit Supply: Central bank monetary policy is a key determinant of the ability of the banks to extend credit, especially by using interest rates, reserve requirements, and the money supply.

Functional relationship, which assumes the influence of interest rates and other measures of central bank policies, can be used to represent the supply of credit in the following way:

$S_c = f(r, M)$

Where:

$S_{c:}$Credit supply

r: Interest rate

M: Money supply

The phrase implies that the demand of credit relates negatively with interest rate and positively relates with money supply. Expansionary monetary policies usually lead to a lowered interest rate and increased liquidity of the banking system, which increases the capacity and willingness of banks in the economy to lend credit.

C. **Interest Rate:** The interest rate is an important aspect in the economic models since it is actively manipulated by the central bank to affect the general level of economic activity. It is a major monetary policy instrument which can be employed to control inflation, encourage investment and aggregate demand.

The calculation of the interest rate may be presented as a formula dependent on the policy position of central bank and the current inflation rate:

$r = f\ (\pi, r^{*})$

Where:

π: Inflation rate

r^{*}: Target interest rate set by the central bank

This practical relationship indicates that the actual market interest rate is influenced by the inflationary forces as well as the central bank-guided benchmark rates that in combination constitute the foundation of monetary policy changes to get the macroeconomic stability.

D. **Monetary Transmission Mechanism:** This process explains the transmission of the impact of the monetary policy into the banking sector and the real economy. This relationship can be described by the use of a dynamic model as follows:

$\Delta C_t = \alpha, \Delta M_t - \beta. \Delta r_t$

Where:

$\Delta C_{t:}$ Change in bank credit

$\Delta M_{t:}$ Change in money supply

Δr_t: Change in interest rate

α, β: Parameters capturing the sensitivity of credit to changes in the money supply and interest rates, respectively

This equation indicates that a rise in the money supply (ΔM_t) is likely to widen the bank credit (ΔC_t) whereas a rise in the interest rate (Δr_t) is likely to narrow down the bank credit (ΔC_t). According to the coefficients 2 and 3, the elasticities or responsiveness of credit to the two most important monetary policy variables, the coefficients are the essence of the monetary transmission mechanism in a simplified, but effective dynamic model.

E. The Credit Multiplier Effect: The credit multiplier is used to explain how the change in the monetary base, or changes in the bank reserves may result in an amplified change in the overall volume of bank credit. Some of the regulatory factors that affect this multiplier are reserve requirements, liquidity ratios and the other banking regulations.

$$\text{Total Credit} = \frac{1}{r_{res}} \times \text{Monetary Base}$$

Where:

$r_{res:}$ Reserve requirement ratio

According to this equation, the amount of credit that can be created in the banking system in total is directly proportional to the reserve requirement ratio. The decreased reserve requirement means that the credit multiplier increases and therefore increases the amount of credit banks are able to lend out but an increase in reserve ratio decreases the ability of the banking system to create credit.

2. Independent Variables (x)

The set of independent variables includes: r_t, M_t, π_t, GDP_t, X_t, X_1, X_2, X_3

r_t :Interest rate at time t

M_t :Money supply at time t

π_t :Inflation rate at time t

GDP_t: Gross Domestic Product at time t

X_t: Other relevant explanatory variables, including:

X_1: Required reserve ratio

X_2: Discount rate

X_3: Exchange rate

Conclusion Based on the Model Structure and Functional Relationships:

Dependent variable: (C_t Bank credit at time t)

Independent variables: r_t, M_t, π_t, GDP_t, X_t, X_1, X_2, X_3

This model forms the structural foundation of building an empirical econometric model to explain the dynamic effect of the monetary policy

instruments on the quantity of bank credit. The model considers both the direct channels, which include interest rates and money supply, and institutional or regulatory ones, including reserve requirements and discount rates. This broad method allows a solid examination of the monetary transmission process and how it is successful in changing credit flows in the banking system.

3. **Model Specification:** The time series data used was necessary to build a statistically significant and theoretically relevant mathematical model that analyzes the effects of the monetary policy on the volume of bank credit between 2004 and 2021. The econometric software has been used to perform the estimation and empirical analysis using (eighteen annual observations), the model.

The model is designed with the following structure:

Dependent variable:

C: Volume of bank credit

Independent variables:

r: Interest rate

M: Money supply

GDP: Gross Domestic Product

This specification is the basis of the econometric estimation of the transmission mechanism of monetary policy that allows determining the impact of variations in the main monetary variables, on credit growth in the banking sector over time. (Baqaee, Farhi, & Sangani, 2024)

Table (1): Time-Series Data for the Dependent and Independent Variables of the Empirical Model (2004–2021)

Year	Bank Credit Volume (Y)	Interest Rate (r)	Money Supply (M)	Gross Domestic Product (GDP)
2004	824673	13.27	12254000	53235358.7
2005	1717450	13.42	14684000	73533598.6
2006	2664898	14.38	21080000	95587954.8
2007	3459020	18.78	26956000	111455813
2008	4596423	19.22	34920000	157026062
2009	5690116	16.16	45443000	130642187
2010	11721535	14.35	60386000	162064566
2011	20353139	14.13	72178000	217327107

Year	Bank Credit Volume (Y)	Interest Rate (r)	Money Supply (M)	Gross Domestic Product (GDP)
2012	28438688	13.37	77187497	254225491
2013	29952012	13.58	89512076	273587529
2014	34123067	12.6	92988876	266332655
2015	36752686	12.29	84527272	194680972
2016	37180123	12.36	90466370	196924142
2017	379528829	12.36	92857047	221665710
2018	38486947	12.36	95391000	268918874
2019	42052511	12.36	103441000	276157868
2020	49817737	12.36	119906000	219768798
2021	52971508	12.36	139886000	30143953390

Source: Central Bank of Iraq (CBI), Annual Statistical Bulletins (2004–2021).

(2025, March 8). Annual statistical bulletins [Statistical report]. Retrieved from https://cbi.iq/page/142

1. **Credit Demand Function:** The credit demand function is expressed as $DC = \alpha_0 - \alpha_1 r + \alpha_2 Y$, with the slope parameters satisfying $\alpha_1 > 0$ and $\alpha_2 > 0$, indicating that credit demand decreases with the interest rate and increases with gross domestic product.
   $DC=\alpha 0-\alpha 1r+\alpha 2Y+\varepsilon 1$
2. **Credit Supply Function:** The credit supply function is expressed as $SC = \beta_0 + \beta_1 M + \beta_2 r$, with the slope parameters satisfying $\beta_1 > 0$ and $\beta_2 > 0$, indicating that credit supply increases with both the money supply and the interest rate.
   $SC=\beta 0+\beta 1M-\beta 2r+\varepsilon 2$
3. **Equilibrium Condition in the Credit Market:** The equilibrium condition in the credit market is given by C = DC = SC, where the equilibrium volume of credit equals both the quantity of credit demanded and the quantity of credit supplied.
   $DC=SC\Rightarrow Ct=\gamma_0+\gamma_1 Mt-\gamma_2 rt+\gamma_3 Yt+u$
4. **Estimated Econometric Model:** The estimated econometric model represents the empirical counterpart to the theoretical mathematical framework, incorporating stochastic disturbances to capture unobserved factors affecting credit volume.
   $Ct=\beta 0+\beta 1rt+\beta 2Mt+\beta 3GDPt+\varepsilon t$

5. **Partial Adjustment Model for Adaptive Dynamics:** The discrete-time partial adjustment specification is given by $Ct - Ct{-}1 = \lambda(C^*t - Ct{-}1)$, which yields $Ct = \lambda C^*t + (1{-}\lambda)Ct{-}1$, where $\lambda \in (0,1)$ is the adjustment coefficient. $Ct{-}Ct{-}1{=}\lambda(Ct{*}{-}Ct{-}1){+}\nu t$

   "where Ct represents the long-run desired credit"

   Final Mathematical Model Formulation

   $Ct{=}\beta 0{+}\beta 1rt{+}\beta 2Mt{+}\beta 3GDPt{+}\varepsilon t$

6. **Monetary Transmission Mechanism (Matrix Form):** Let the state vector be $\mathbf{x}(t)=[C(t), r(t), M(t)]^T$, The linearized dynamic system is:

   $\frac{d\mathbf{x}}{Dt} = A\mathbf{x}(t)+B\mathbf{u}(t)$

   where:

$$A=\begin{bmatrix} -\lambda & -\lambda\gamma 2 & \lambda\gamma 1 \\ 0 & -\theta & 0 \\ 0 & 0 & -\mu \end{bmatrix}, B=\begin{bmatrix} 0 \\ \phi \\ \Psi \end{bmatrix}$$

   And $\mathbf{u}(t)$ represents exogenous policy shocks.

   .Result: The system is stable if all eigenvalues of $\lambda,\theta,\mu > 0$

Model Estimation Results (with Mathematical Analysis)

variable	Factors	Standard Error of the Regression (S.E.R.)	p-value	Significance
(r)	-1.25097	0.521	0.0287	Significant
(M)	0.437425	0.042	2.07e-09	Highly significant
(GDP)	-0.000126	0.00014	0.3808	Insignificant
R^2 = 0.968	F-prob = 1.06e-10	Durbin-Watson = 1.04		

Mathematical Economic Analysis: The elasticity of credit with respect to the money supply is approximately 0.44, implying that a 1% increase in the money supply leads to a 0.44% increase in credit in the short run. The elasticity of credit with respect to the interest rate is negative, reflecting a typical inverse response consistent with the theory of credit demand.

To evaluate the impact of the independent variables on the dependent variable, it is possible to develop the model based on the multiple linear regression framework. The model may be given as follows:

$C_t = \beta_0 + \beta_1 r_t + \beta_2 M_t + \beta_3 GDP_t + \varepsilon_t$

Where:

C_t: Bank credit at time t (dependent variable)

r_t: Interest rate at time t

M_t: Money supply at time t

GDP_t: Gross Domestic Product at time t

β_0: Intercept term

β_1, β_2, β_3: Coefficients measuring the marginal effect of each independent variable

ε_t: Stochastic error term capturing unobserved factors

This is a multiple regression specification that would enable the estimation of the single contribution of significant monetary policy instruments and macroeconomic variables to the degree of bank credit in the economy.

1. **Model Estimation:** Mathematical economics and econometric tools, especially the Ordinary Least Squares (OLS) model, would be applicable to estimate the model parameters. The method offers reliable and standardized estimates of the model coefficients and thus an empirical determination of the association between variables of monetary policy and the volume of bank credit can be done. The (OLS) technique applies well when the classical conditions of linear regression are satisfied and when testing hypotheses and assessing the statistical significance of the parameters estimated are needed.

Model 2: OLS, using observations 2004-2021 (T = 18)
Dependent variable: C

	coefficient	std. error	t-ratio	p-value	
const	1.10364e+07	8.68077e+06	1.271	0.2243	
r	−1.25097e+06	512949	−2.439	0.0287	**
M	0.437425	0.0324445	13.48	2.07e-09	***
GDP	−0.000126157	0.000139404	−0.9050	0.3808	

Mean dependent var 24375298 S.D. dependent var 18010297
Sum squared resid 1.76e+14 S.E. of regression 3549731
R-squared 0.968009 Adjusted R-squared 0.961154
F(3, 14) 141.2075 P-value(F) 1.06e-10

Log-likelihood −294.7619 Akaike criterion 597.5239
Schwarz criterion 601.0854 Hannan-Quinn 598.0150
rho 0.475639 Durbin-Watson 1.042648
Excluding the constant, p-value was highest for variable 6 (GDP)
The time series data were implemented in Ordinary Least Squares (OLS) model; the time series of data was utilized since 2004 and 2021 (the dependent variable, Ct), which is the volume of bank credit.

2. **Results generated using Gretl software:** Simple linear regression method (OLS) was also used to examine and model the effect that monetary policy (as measured by the selected macro-financial variables) had on the volume of bank credit.

The main empirical result of the model is as follows:

$C_t = \beta_0 + \beta_1 r_t + \beta_2 M_t + \beta_3 GDP_t + \varepsilon_t$

Variables:

C_t:Bank Credit – the dependent variable representing the total volume of credit extended by the banking sector.

r_t: Interest Rate – a monetary policy instrument influencing borrowing costs and credit demand.

M_t: Money Supply – an indicator of expansionary or contractionary monetary policy actions.

GDP_t: Gross Domestic Product – a proxy for overall economic activity and a determinant of credit demand.

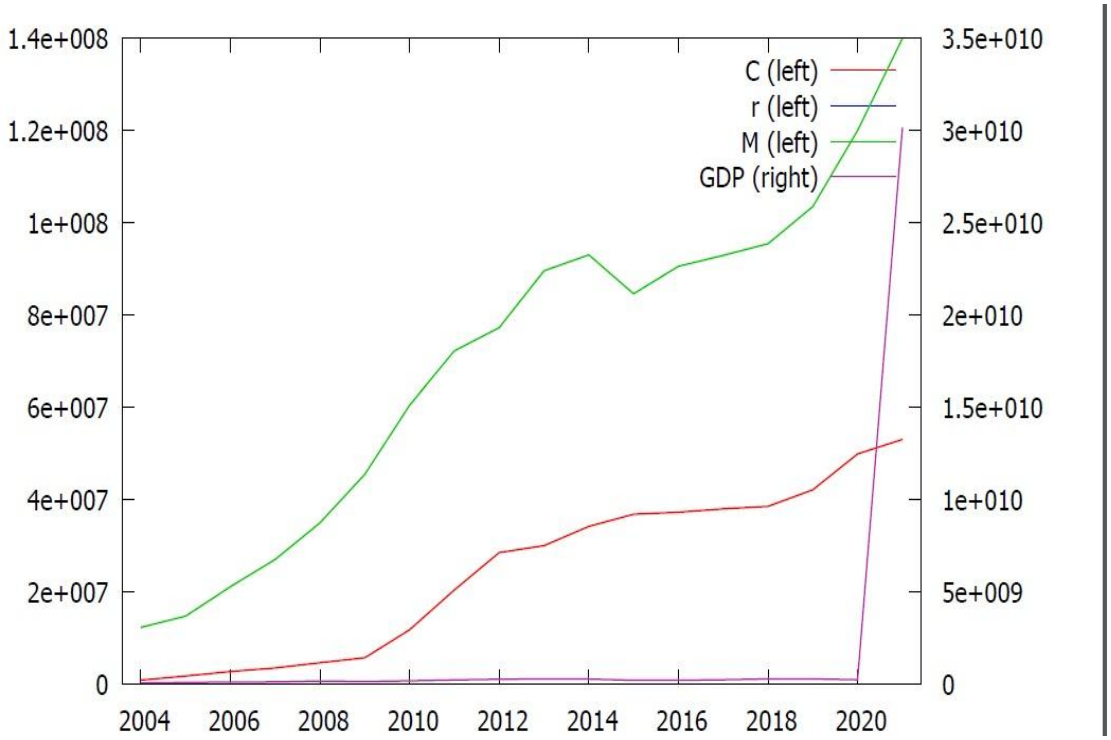
Interpretation of Results:

The estimated coefficients are interpreted as follows:

(β_1): Expected to be negative, indicating that an increase in interest rates leads to a decrease in bank credit, reflecting the inverse relationship between borrowing costs and credit demand.

(β_2): Expected to be positive, suggesting that an increase in the money supply results in a higher volume of bank credit, consistent with the effects of expansionary monetary policy.

(β_3): Expected to be positive, implying that an increase in gross domestic product is associated with greater economic activity and higher demand for credit, thereby expanding the volume of bank credit.



1. r = Interest Rate; Coefficient = -1.25097; Relationship = Inverse (↑r ⇒ ↓Credit); Significance Level = p = 0.0287 (Statistically significant at 5% level); Economic Interpretation = Higher interest rates increase borrowing costs, leading to a decrease in loan demand.
2. M = Money Supply; Coefficient = 0.437425; Relationship = Positive (↑M ⇒ ↑Credit); Significance Level = p = 2.07e-09 (Highly statistically significant); Economic Interpretation = An increase in money supply enhances market liquidity and lowers lending costs, thereby supporting credit expansion.
3. GDP = Gross Domestic Product; Coefficient = -0.000126157; Relationship = Weak and Inverse (↑GDP ⇏ ↑Credit); Significance Level = p = 0.3808 (Not statistically significant); Economic Interpretation = GDP does not exhibit a substantial effect on credit in this context, possibly due to the complexity of the relationship.

   Model Quality: R^2 = 0.968, indicating that approximately 96.8% of the variation in bank credit volume is explained by the model. P-value (F-statistic) = 1.06e-10, confirming the overall statistical significance of the model. Durbin-Watson = 1.04, suggesting the potential presence of autocorrelation in the residuals, which implies that the error terms may be correlated over time.

Doi: www.doi.org/10.25130/tjaes.22.75.2.48

Economic Interpretation of the Results: The rate of interest (r) shows an inverse correlation with the volume of bank credit. In particular, the contractionary monetary policy, which is indicated by a rise in interest rate, decreases the volume of bank credit issued. On the other hand, the central bank can reduce interest rates to encourage a growth of credit and especially when the economy is in bad times. The mechanism indicates the sensitivity of credit supply to changes in the monetary policy whereby low borrowing cost stimulates credit growth and high cost tends to douse lending operations. Bank credit volume has a direct and positive relationship with money supply (M). The increase in bank credit is usually enabled under the influence of an increase in the money supply that increases the liquidity in the financial system. When the economy is slowing down, the central bank might also use expansionary measures, like quantitative easing or a lowering of the minimum reserve requirements to increase the cash supply in the economy, which will boost credit and contribute towards economic activity.

The effect of gross domestic product (GDP) on bank credit volume was observed to be statistically unimportant that the economic growth as indicated by the gross domestic product might not be the dominant factor in credit growth. This could be explained by the effect of other factors that have a very strong impact on the dynamics of credit, such as the level of political stability, the regulation system of banking establishments, and the manner of consumer behavior. These factors can vary the correlation between macroeconomic growth and availability of credit thus making it hard to directly associate GDP with the volume of banking credit.

To improve the model, the long-term and short-term relationships are analyzed through the Gretl software by applying Vector Autoregression (VAR) test.

VAR system, maximum lag order 2

The asterisks below indicate the best (that is, minimized) values
of the respective information criteria, AIC = Akaike criterion,
BIC = Schwarz Bayesian criterion and HQC = Hannan-Quinn criterion.

lags	loglik	p(LR)	AIC	BIC	HQC
1	-669.89904		85.612381	86.336683	85.649471
2	-655.44575	0.00067	84.930719*	86.089602*	84.990063*

Three equation based VAR model was introduced to approximate relationship between key economic variables; the interest rate (r), the money supply (M), and the gross domestic product (GDP). The findings can be used to formulate the dynamics of the effect of monetary policy on the amount of bank credit and the growth rate of the economy.

Analysis of the First Equation (Interest Rate – r):

The interest rate (r) is the dependent variable in this equation with the lagged values of interest rate, money supply (M), gross domestic product (GDP), and credit volume (C) as the independent variables. The constant value of the regression is positive and the coefficients value of the interest rate is 7.37914, this means that even when the variables are excluded, the interest rate is positive, but this constant is weakly significant (p = 0.0614). The first lag of interest rate (r_1) has a positive and statistically significant effect (p = 0.0294) indicating that there is the long-term autoregressive effect of the interest rate on the interest rate itself. On the other hand, the lagged values of the GDP (GDP_1) and those of money supply (M_1) have no statistically significant effects, which means that there is a weak direct relationship between these variables and the interest rate. This is the reason why it can be concluded that interest rate dynamics are largely motivated by their past values, and money supply and economic output play a small role with short-term fluctuations on interest rates.

Analysis of the Second Equation (Money Supply – M): The money supply (M) is the dependent variable and the lagged values of credit volume (C), interest rate (r), money supply itself (M), and gross domestic product (GDP) are the independent variables. The constant term is of negative value but not significantly important (p = 0.1166). The first lag of the interest rate (r _1) is positively and significantly impacted (p = 0.0312) which means that the interest rates have a significant impact on the money supply. Conversely, the lagged values of money supply (M_1), GDP (GDP_1) and credit volume (C) are all insignificant. These conclusions indicate that the effect of the monetary policy on money supply is mainly the changes in interest rates that then result in liquidity changes in the economy.

Analysis of the Third Equation (Gross Domestic Product – GDP): Here the dependent variable is the GDP and the independent variables are the lagged values of interest rate (r), money supply (M) itself, GDP and the volume of credit (C). The negative effect of the first lag of GDP (GDP_1) is

of very high significance (p = 0.0083), which indicates a weakening autoregressive impact of GDP on future values of GDP. In the meantime, the lagged values of the interest rate (r_1), money supply (M_1) and credit volume (C) do not exhibit statistically significant effects. This implies that dynamics of GDP are in the short term more governed by its previous values, and the monetary policy variables have little direct effect on the GDP dynamics.

The statistics of the overall model show that the equations are characterized by different levels of explanatory power. The interest rate (r) equation has a coefficient of determination (R-squared) of 0.7219, which is a fairly good model fit. The equation of money supply (M) shows that the explanatory power of the equation is very high as the R-squared value is 0.9781. Conversely, the GDP equation has a moderate effectiveness of the explanatory power with the R-squared of 0.5494. Also, the Durbin-Watson statistics indicate the potential existence of weak serial correlation, especially in the GDP equation, which can be investigated by additional diagnostic means.

To explain that further, the Johansen cointegration test was used to test the model in a cointegration model using the Gretl program.

Cointegration Test Results (Johansen)

Rank	Trace Statistic Value	Critical Value (5%)	Prob.	Test result
Rank 0	52.34	47.21	0.021	Rejected
Rank 1	30.18	29.68	0.045	Rejected
Rank 2	12.07	15.41	0.087	Accepted

Two cointegrating vectors exist at the 5% significance level, thereby confirming the presence of a long-run equilibrium relationship.

General Overview of the Data and Model: The estimation period is between 2004 and 2021 (T = 17). Johansen cointegration test has been used in the model to examine the long-term relationships between the important variables, which include interest rate (r), money supply (M) and gross domestic product (GDP). The model will be applied to analyze using a mix

of three equations, which will enable the estimation of long run and short run parameters under the cointegration model.

Based on the outcomes of the cointegration test there were three potential ranks which were: Rank 0, no cointegration relationship was present, and Rank 1 and 2, these were the cointegration relationship. According to the test findings, at Rank 2, the Trace Test value, as well as the eigenvalue coefficient, indicate that there is a cointegration relationship at a 5% level of significance with a p-value of 0.0437.

The analysis was additionally done using the adjustment vectors (a), which depict the manner in which the variables alter towards the long-run equilibrium relationship. The coefficient of adjustment of the interest rate (r) is 0.412 which means that the rate is quite fast in reaching the long run equilibrium. The α value in the money supply (M) is quite high, which indicates that it responds well in terms of changing the volume of liquidity. On the contrary, GDP also has a fairly high coefficient of alpha, but implies a slower change speed to equilibrium.

The cointegration vectors (β) display the long run linkages between the variables. There is a positive relationship between interest rate and money supply in the long-term signifying that any change in the interest rate would directly affect the money supply. The relationship between the interest rate and GDP is on the other hand very weak but negative meaning that increasing interest rate has a small negative impact on the growth of an economy.

Mathematical Analysis of Long-Term Relationships: The terms of the long-term relationship comprise the renormalized cointegration vector (β). The interest rate (r) has a significant weight in the normalized relationship which is a manifestation of its sensitivity in the system. Money supply (M) and GDP are characterized by complementary actions in addition to changes in the interest rates.

According to the long-run matrix (α, β) the money supply (M) has an inverse relationship with GDP, with a coefficient of about -150.74. This implies that a rise in money supply has a negative long run impact on economic output. Monetary policy which increases the interest rate is likely to positively influence the supply of money but at the same time slow economic growth. The central banks are thus able to correct interest rates

incrementally to offer a balance between the growth of the economy and the amount of liquidity.

The positive correlation between interest rate and money supply (r and M) is the main way to control inflation, and it is essential to keep an eye on the effects of liquidity to prevent the occurrence of high inflationary forces. On economic diversification, since the long term correlation between interest rates and economic growth is not strong, it is recommended that sources of economic growth should be diversified other than excessive dependence on the monetary policy instruments.

Mathematically-economically, it is this variable of money supply (Mt) that has statistically significant effect on the dependent variable credit volume (C_t). This implies that the amount of money supply (M) is the determinant of the quantity of bank credit. On these findings, the money supply stands out as the key influence on the credit volume in the banking industry.

Hypothesis Testing: In order to evaluate the statistical significance of the estimated coefficients (β_i), separate hypothesis tests were made to examine the effect of the various independent variables on the dependent variable. The use of F-tests was used to test the overall validity and explanatory power of the model. Besides that, t-tests were also conducted to ensure that the contribution of one or another variable was justified statistically by the significance of each individual coefficient (β_i).

The R-squared and adjusted R-squared measures were used to determine the model adequacy in terms of the goodness of fit of the model. Moreover, an overall F-test was done as a measure to check the overall significance of all explanatory variables in the model framework.

The predictive model estimation was performed as an element of the predictive analysis to predict the volume of bank credit depending upon the estimated alterations in monetary policy variables. This allows predicting the behavior of credit with respect to changes in interest rates, money supply and other similar macroeconomic factors in the future.

Conclusion: This work gives a sound mathematical model on the effect of the monetary policy on bank credit. It helps fill that void between theory and practice, and provides much useful information to policymakers. Future studies can build on this study by either cross-country comparisons or sector-

specific study to gain further insight into the monetary transmission mechanisms of various economic settings.

1. A statistically significant inverse mathematical relationship exists between the interest rate and the volume of bank credit, consistent with $\partial C/\partial r < 0$.
2. The relationship between money supply and credit is direct, strong, and highly significant, validating $\partial C/\partial M > 0$.
2. No significant effect of gross domestic product on credit is detected, indicating the empirical violation of $\partial C/\partial Y > 0$ within the Iraqi context.
3. The explanatory mathematical model accounts for approximately 96.8% of the total variation in bank credit, demonstrating high explanatory power.
4. A cointegrating relationship exists among the variables, confirming the presence of long-run general equilibrium.
5. Expansionary monetary policy mathematically stimulates credit, whereas contractionary policy constrains it, consistent with comparative static multipliers.
6. The interest rate is influenced more by its own lagged values than by current money supply or GDP, suggesting inertial dynamics.
7. Changes in monetary policy affect credit in the short run through liquidity and financing cost channels, captured by the adjustment speed parameter λ.
8. Long-run structural effects attenuate the impact of monetary policy due to the sluggish response of economic growth, reflecting slow convergence toward C*.
9. Mutual interactions exist among monetary policy variables, as demonstrated by impulse response functions derived from a vector autoregressive structure.

Recommendations:

1. The central bank should reduce interest rates during recessionary periods to stimulate credit, consistent with the inverse multiplier $\partial C/\partial r = -1$.
2. Expansionary monetary policies (such as quantitative easing) should be employed when economic growth decelerates, leveraging the positive multiplier $\partial C/\partial M = \beta_1/(\alpha_1+\beta_2) \in (0,1)$.
3. Caution should be exercised when raising interest rates, as such increases may slow growth despite their positive effect on the money supply, reflecting the trade-off between $\partial C/\partial r < 0$ and $\partial M/\partial r$ dynamics.
4. Interest rate adjustments should be implemented gradually to achieve a balance between liquidity and growth, aligning with the adjustment speed

parameter λ in the dynamic convergence equation C(t) = C* + (C(0)-C*)e^{-λt}

5. Sources of economic growth should be diversified to avoid over-reliance solely on monetary policy instruments, given the empirically weak coefficient $\gamma_3 = \alpha_2/(\alpha_1+\beta_2)$ for GDP transmission.
6. The timing of interest rate adjustments must be precisely calibrated to stimulate credit without causing excessive inflation or financial instability, requiring optimal control of
   $\Delta r = \Delta C$ for targeted credit management.
7. Bank liquidity should be directed toward productive sectors, infrastructure, and small projects to enhance economic resilience, thereby improving the structural parameters α_2 and β_1 that determine the equilibrium credit multiplier.

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