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Optimizing Banking Network Resilience to Exchange Rate Shocks

Hadi Adib, Akbar Mirzapour Babajan ✉, Beitollah Akbari Moghaddam, Roozbeh Balounejad Nouri

Department of Economics, Qazvin Branch, Islamic Azad University, Qazvin, Iran.

✉ **Correspondence:**
Akbar Mirzapour Babajan
E-mail:
akbar.mirzapour@gmail.com

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Abstract. This paper explores the resilience optimization of Iran's banking sector in the face of exchange rate shocks—critical macroeconomic disturbances with extensive consequences. We develop a multi-sector macro-dynamic stochastic general equilibrium model encompassing essential economic components, including firms, government, central bank, and the banking sector. This framework facilitates the simulation of the macroeconomic environment and allows for a thorough analysis of the banking sector's adaptive responses to exchange rate fluctuations. Our findings reveal optimization strategies that effectively mitigate the adverse effects of these shocks while maintaining equilibrium in the broader economy. Specifically, we discover that while an initial positive exchange rate shock can enhance banking sector performance, it ultimately triggers inflationary pressures that threaten profitability and operational stability in the medium to long term.

Keywords. Exchange rate shocks, Banking network resilience, Optimization strategies, Dynamic stochastic general equilibrium model, Economic efficiency.

MSC. 91B07.

1 Introduction

The continuity of economic growth and the foundation for sustainable development in developing countries fundamentally rely on a robust and efficient financial system that fosters an environment conducive to investment, production, and overall economic prosperity [7]. Within Iran's economic landscape, various institutions—including banks, insurance markets, capital markets, and pension funds—play vital roles in the intermediation, mobilization, and allocation of financial resources. However, several challenges, such as inadequate infrastructure, the limited development and attractiveness of alternative financial markets, regulatory shortcomings, a lack of diversity in financial instruments, and the overwhelming dominance of the banking sector, reveal significant gaps in the financial depth of Iran's financial markets [7]. Empirical evidence underscores that the banking network bears primary responsibility for mobilizing resources and financing project implementation, providing working capital to production units, issuing mortgage loans, and fulfilling the fundamental needs of economic agents. Furthermore, the banking sector is crucial in counteracting declines in economic activity, investment, and employment, thereby stimulating economic growth and enhancing societal welfare [1, 4, 7, 12, 17]. Hence, the enhancement of this financial sector should be prioritized by policymakers, researchers, planners, and economic agents in achieving long-term economic objectives.

In all economies, irrespective of their level of development, the banking system fulfills essential functions such as providing financial resources, facilitating trade and transactions, delivery of financial services to individuals and businesses, oversight of the financial ecosystem, and ultimately promoting economic development [10]. The banking system operates as an economic entity that seeks to maximize profitability while also serving as a foundation for monetary and financial stability, under the supervision of the central bank. It carries out essential objectives, including the implementation of monetary policies directed by the central bank and the management of critical macroeconomic variables, thereby playing a key role in maintaining equilibrium amidst external economic and non-economic shocks [17].

These shocks can alter community expectations and influence the dynamics between depositing and investing across various sectors -whether productive or speculative- significantly affecting multiple macroeconomic variables [2]. Meanwhile, the responses of central bank officials and the enactment of monetary policies aimed at mitigating the effects of these external shocks further emphasize the banking system's critical role in alleviating adverse impacts across different segments of the economy [6, 20]. Given the banking sector's significance in maintaining general equilibrium in Iran's economy and its role in transmitting economic shocks throughout society, this study aims to investigate how the banking network responds to exchange rate shocks.

Given that a key challenge facing Iran's economy has been the multitude of issues within its banking system, analyzing how this system responds to the country's major macroeconomic shocks can provide valuable insights for addressing current shortcomings. This understanding could facilitate the development of a modern banking system, moving towards a more desirable and ideal state.

The current paper is structured into five sections. Following the introduction, the second section explores the theoretical foundations and background of the research. The third part outlines the data collection methods and research methodology. The fourth section introduces linearization techniques for mathematical models, discusses the estimation using the generalized method of moments, and presents the Bayesian approach. The fifth section analyzes the research findings, while the final section concludes with suggestions.

2 Literature Review

A significant challenge facing the banking sector in Iran is the pervasive intervention of the government and the central bank. This interference manifests in various ways, including the imposition of restrictions on loan ceilings, determination of liquidity requirements that banks must hold in reserve, establishment of the legal deposit rate, provision of depositors' insurance, setting investment ceilings, and regulating asset purchases. Such regulatory measures have substantial implications for bank profitability [14].

Like other industries, the banking sector is susceptible to various risks, including credit risk (the likelihood of default on loan repayments), liquidity risk (the potential inability to meet the demands of loan applicants or depositors), operational risk (including risks such as embezzlement), as well as exchange rate risk, inflation risk, fiscal risk, and supply-side constraints affecting the economy.

Iran's economy, characterized as a transitioning economy that heavily relies on foreign exchange revenues from oil exports, is particularly vulnerable to external shocks and systemic pressures. Empirical evidence suggests that recent external shocks impacting Iran's macroeconomic stability—especially exchange rate shocks—are primarily attributable to the adverse effects of economic and financial sanctions imposed by Western nations (commonly referred to as comprehensive sanctions).

Exchange rate fluctuations significantly influence overall demand in the economy through their effects on imports, exports, and money demand, as well as on the total supply via the costs of imported intermediate goods. Typically, in the goods market, rapid increases in exchange rates resulting from currency shocks lead to higher prices for imported goods while making exported goods cheaper. This dynamic tends to increase the demand for domestically produced goods. Conversely, with regard to supply, exchange rate shocks in developing countries usually result in the depreciation of the national currency, which in turn raises production costs and contributes to a general increase in the price level within the economy [15]. Banks serve as one of the largest and most dynamic players in the foreign exchange market, employing a range of methods to facilitate transactions involving foreign currencies. Their substantial involvement in this market is critical for various operations, including the buying and selling of foreign currency notes and coins, processing different types of foreign remittances, issuing and cashing foreign checks, providing letters of credit for travel purposes, opening letters of credit, accepting and paying foreign drafts, and issuing various forms of foreign guarantees. These activities underscore the indispensable role banks play in the foreign exchange landscape.

Additionally, some banks in Iran—both private and public—engage in speculative activities within the foreign exchange market to boost their profitability, which can contribute to increased market volatility. Given their significant liquidity in the Iranian economy, these banks wield considerable financial power, enabling them either to stabilize or amplify fluctuations in the market. Furthermore, banks engage in currency treasury operations, both in cash and forward markets, which are vital components of their activities in the foreign exchange sphere [19, 22].

In an open economy linked to the global market, the liquidity available in the market impacts real output through the exchange rate mechanism, particularly when nominal wages and prices are inflexible.

Consequently, variations in the money supply and fiscal policies can also affect the foreign exchange market, production levels, and, the overall real sector of the economy.

The influence process unfolds as follows: any macroeconomic policy that leads to a contraction in the money supply will typically result in higher interest rates, which represent the cost and value of money. This increase in interest rates enhances the appeal of domestic deposits compared to foreign investments, thereby boosting the demand for domestic currency.

As a consequence, the domestic currency appreciates due to a reduction in the exchange rate. This appreciation, or decrease in the exchange rate, makes domestically produced goods more expensive for foreign consumers. Consequently, the nation's net exports decline, which subsequently restricts real production. This reduction in supply relative to demand ultimately leads to a decrease in the purchasing power of the domestic currency amid rising inflation. With inflation rates climbing and the purchasing power of the domestic currency diminishing, the exchange rate of the domestic currency relative to foreign currencies increases, reflecting a rise in the exchange rate [12].

From another perspective, an increase in interest rates or a decrease in government expenditure can result in a decline in investments within the economy, which subsequently indicates a reduction in Gross Domestic Product (GDP). As a result, it follows that a decrease in exports coupled with an increase in imports may lead to a diminished demand for currency in the market, ultimately causing a decrease in the exchange rate. However, it is important to note that variations in interest rates or government spending can also influence the exchange rate by affecting inflation. For example, a decline in inflation can lead to a lower exchange rate by changing the purchasing power of the domestic currency relative to foreign currencies [3].

Additionally, to analyze the impacts of liquidity fluctuations induced by macroeconomic monetary and fiscal policies on the volatility of the foreign exchange market in Iran, it is crucial to recognize that the recent surge in exchange rates is primarily attributable to the excessive accumulation of liquidity within the economy. This situation is exacerbated by persistent government budget deficits and the significant influence exerted by the banking sector, particularly financial institutions and banks. A notable consequence of the increased liquidity resulting from these policies is the escalation of inflation rates, which carries severe ramifications for the economy. Elevated inflation rates tend to correlate positively with exchange rate increases, reflecting a direct relationship under typical economic conditions. Furthermore, governments frequently attempt to mitigate this intrinsic dynamic by injecting foreign currency procured from oil revenues into the market. Such interventions, aimed at artificially maintaining lower exchange rates, inadvertently create an accumulation of inflationary pressures, analogous to a compressed spring. Consequently, one may anticipate a subsequent release of this built-up pressure, leading to a currency shock in the future [22].

In the context of economic analysis, Zamarripa employed a Dynamic Stochastic General Equilibrium (DSGE) model to examine the impact of the Central Bank of Mexico's monetary policies on the economy from 1995 to 2019 [26]. The findings suggest that the Mexican Central Bank has maintained a consistent response to inflation since 1995; however, its responsiveness to output and exchange rates has experienced a decline and reached a relative stabilization since 2002. Similarly, Kabzhalyalova analyzed Kazakhstan's pivotal economic decision to transition to a floating exchange rate regime aimed at managing nominal exchange rate fluctuations and their subsequent effects on macroeconomic variables and public welfare [13]. This study seeks to establish a framework for optimizing monetary policy within Kazakhstan's small economy. The analysis indicates that maintaining the exchange rate stability within a 5% band would result in the minimal loss of welfare.

Nakhli et al. in [16] conducted an analysis of the Iranian economy, which is significantly dependent on oil and affected by sanctions, by employing a DSGE model grounded in a new Keynesian framework. The study focused on the implications of oil sanctions, including restrictions on crude oil exports, extraction technology, and external financing in the oil sector. The findings revealed that such sanctions considerably impede foreign and government investments, diminish the levels of extraction technology, and curtail oil exports, thereby adversely affecting overall production. In the monetary and exchange rate domains, these sanctions led to a reduction in the ratio of foreign exchange reserves to the Central Bank's monetary base, resulting in an increase in the nominal exchange rate. This escalation, in turn, facilitated a rise in non-oil exports while simultaneously reducing imports. In another domestic study, Hosseini and Asgharpur investigated the application of the Taylor rule within the Iranian economy, specifically analyzing the effects of monetary shocks on macroeconomic variables under varying degrees of exchange rate pass-through across different inflationary contexts [11]. The results corroborated Taylor's hypothesis, demonstrating a direct relationship between the degree of exchange rate pass-through on import price indices and prevailing inflation levels. Moreover, the impulse response functions related to macroeconomic variables in response to monetary shocks indicated that fluctuations were more pronounced in a high-inflation environment compared to a low-inflation environment.

Rajaee et al. examined the influence of exchange rate shocks on output gaps and inflation within the Iranian economy using a DSGE model framework based on New Keynesian principles, which is suitable for small open economies [18]. This model incorporated factors such as price stickiness through Calvo price adjustment and adherence to the law of one price, while treating the interest rate as exogenous and utilizing the growth rate of the monetary base as a monetary policy instrument. The study's results indicated that total output and the output gap initially respond positively to exchange rate shocks; however, this effect diminishes and ultimately dissipates after twenty periods. Furthermore, in the short term, both inflation and the inflation gap exhibited significant positive responses to exchange rate shocks, although their sensitivity to such shocks decreased in the long term.

3 Research Methods and Data Sources

This paper adopts a library-based methodology for data collection, utilizing existing information obtained from official data publication databases that encompass various economic variables. This approach allows researchers to gather readily available data without the need to replicate earlier research processes. Consequently, the data collection methodology primarily involves systematic note-taking. The study's modeling objectives will rely on historical time-series data (seasonal) covering from the beginning of 1999 to the end of 2021.

One of the essential preliminary steps in constructing general equilibrium models is the organization of data. Specifically, the required data can be structured within a matrix referred to as the Social Accounting Matrix (SAM), along with the Financial-Social Accounting Matrix (FSAM) derived from it. These matrices capture the flow of goods and services, payments between different economic sectors, and additional accounts.

In the context of data analysis within the DSGE model framework, it is common practice to initially create a straightforward core model. This model serves as the foundation for the study, to which further details are gradually incorporated based on the research's predetermined objectives and specific areas of interest. Ultimately, this core model can transform into a comprehensive representation of either a closed or open economy, including various agents, such as firms, government, monetary authorities, and the external sector.

To address the system of equations outlined in this study, we will utilize *Dynare* software within the MATLAB environment. Parameter values will be determined through Bayesian parameterization to facilitate the resolution of the equations and establish initial variable settings along a stable economic trajectory. Subsequently, the study analyzes the effects of the identified random shocks on the target variables and calculates the response functions of the system of equations concerning variable fluctuations. Finally, the impulse response functions will be plotted, and the time required for the variables to return to a stable equilibrium will be assessed.

In this research, the neoclassical approach is utilized due to its specific characteristics in analyzing financial crises and responding to exchange rate fluctuations. Neoclassical theory clearly addresses the role of information asymmetry, price and wage rigidity, and the importance of aggregate demand in the economy. These features help us better understand the impact of exchange rate fluctuations on the banking network.

3.1 Mathematical model linearization

In the context of the equations governing the DSGE model, it is evident that most of the relationships that need to be resolved are nonlinear. This nonlinearity poses significant challenges in solving the equations. Consequently, to facilitate the solution process and mitigate the complexities inherent in the DSGE framework, it is essential to linearize these relationships.

Relative approximation methods utilize information about the value of a function and its derivatives at a specific point (denoted as X_0). This approach employs not only the function itself but also the values of its derivatives for approximation. The most effective technique for linearizing DSGE models through relative approximation is the Taylor expansion, which has distinct formulations for both univariate and multivariate functions. As the relationships in DSGE models are typically multivariate, the relevant theorem for multivariate Taylor expansion will be discussed here.

For a multivariate function represented as $f : \mathbb{R}^n \to \mathbb{R}$ where $X = (X_1^0, \cdots, X_n^0)$, the Taylor expansion can be expressed as follows:

$$\begin{aligned} f(X) = f(X^0) &+ \sum_{i=1}^{n} \frac{\partial f(X^0)}{\partial X_i}(X_i - X_i^0) \\ &+ \frac{1}{2!}\sum_{i=1}^{n}\sum_{j=1}^{n} \frac{\partial^2 f(X^0)}{\partial X_i \partial X_j}(X_i - X_i^0)(X_j - X_j^0) + \cdots \\ &+ \frac{1}{k!}\sum_{i_1=1}^{n}\sum_{i_k=1}^{n} \frac{\partial^k f(X^0)}{\partial X_{i_1}\cdots\partial X_{i_k}}(X_{i_1} - X_{i_1}^0)\cdots(X_{i_k} - X_{i_k}^0) + \nu(\| X - X_0 \|^{k+1}), \end{aligned} \tag{1}$$

where, the term $\nu(\| X - X_0 \|^{k+1})$ represents the remainder (comprising higher-order derivatives), which is asymptotically smaller than the other components of the series, allowing it to be neglected. The order of approximation in the Taylor expansion corresponds to the highest order on the right side of the equation. The accuracy of the approximation is maximized when the expansion is conducted around the steady state point, X_0; deviations from X_0 result in diminished accuracy and precision.

In the context of linearizing DSGE models, the first-order Taylor expansion is typically utilized. Accordingly, the first-order Taylor expansion around X_0 can be articulated as follows:

$$f(X) = f\left(\overline{X}\right) + \sum_{i=1}^{n} \frac{\partial f}{\partial X_i}\left(\overline{X}\right)\left(X_i - \overline{X}_i\right). \tag{2}$$

An alternative representation of this relationship can be expressed as follows:

$$\frac{f(X) - f(\overline{X})}{f(\overline{X})} = + \sum_{i=1}^{n} \left[\frac{\frac{\partial f}{\partial X_i}\left(\overline{X}\right)\overline{X}_i}{f(\overline{X})}\right]\left(\frac{X_i - \overline{X}_i}{\overline{X}_i}\right). \tag{3}$$

By denoting $a_i = \frac{\frac{\partial f}{\partial X_i}(\overline{X})\overline{X}_i}{f(\overline{X})}$ and defining $\widehat{x}_t = \frac{X_t - \overline{X}}{\overline{X}}$, Equation (3) simplifies to:

$$\widehat{y} = \sum_{i=1}^{n} a_i \widehat{x}_i. \tag{4}$$

It is evident that the nonlinear function (1) has been transformed into the linear function (4) through the application of the Taylor expansion at the steady state [24].

3.2 Parameter estimation in economic simulation

In the field of economic simulation, specifying relationships—expressed as simultaneous system equations—is a critical first step. Subsequently, both endogenous and exogenous variables, alongside the parameters governing these equations, must be clearly defined. Endogenous variables are defined as functions within the framework of the DSGE model, while exogenous variables are integrated into the model through time series data. The accurate determination of relationship parameters is especially important, as precise specification of these parameters allows the endogenous variables to more faithfully reflect real-world dynamics.

Achieving appropriate parameter values requires a synthesis of theoretical insights and empirical economic realities. This complexity highlights the challenges involved in estimating parameters in system equations. Various methodologies are available for determining the values of relationship parameters; this study specifically utilizes the calibration method. In this approach, parameters are derived from theoretical frameworks or prior empirical research conducted within the relevant field.

Given that DSGE models involve numerous simultaneous relationships that constitute an economic system, and that these relationships intertwine microeconomic and macroeconomic variables, the estimation of parameters becomes inherently complex. Researchers frequently rely on theoretical discussions to guide their parameter selections, aligning theoretical expectations with estimates obtained from prior studies. In the process of parameter determination for DSGE or Computable General Equilibrium

(CGE) models, researchers typically adopt a dual approach: they may estimate all parameters using various methods or opt to calibrate some parameters while simultaneously estimating others. This flexibility allows for a more nuanced understanding of the underlying economic relationships within the model.

3.3 Estimating with the generalized method of moments

The Generalized Method of Moments (GMM) is a widely used technique for analyzing time series data, particularly in estimating relationships embedded within a complex set of simultaneous equations in economic systems. The GMM framework comprises two essential phases of estimation.

The first phase focuses on estimating the independent variables, which are treated as instruments to address potential endogeneity issues that may arise from correlations between independent variables and the residuals encountered in the second phase. This initial estimation is critical, as it lays the foundation for the subsequent phase. In the second phase, the dependent variable is estimated using the independent variables obtained from the first phase. The results of this phase yield observable outcomes that constitute the principal equation, referred to as the second-phase equation within the GMM methodology. This relationship typically includes lagged values of the dependent variable along with a vector of the independent variables estimated in the first phase. The overall structure of the GMM model can be summarized as follows.

$$\begin{aligned} Y_t &= C_0 + \beta_1 \hat{X}_t + \beta_2 Y_{t-1} + \mu_i, \\ \hat{X}_i &= C_1 + \alpha_1 IV_t + \alpha_2 X_{t-1}. \end{aligned} \tag{5}$$

In system (5), the primary equation, referred to as the second phase, is represented Y_t which is a function of its first lagged value, Y_{t-1}, and a vector of independent $\hat{X}_t$ that are estimated in the first phase. The first phase articulates the relationship where the independent variables $\hat{X}_t$ of the second phase are treated as the dependent variable. This relationship also incorporates instrumental variables IV_t, which serve as explanatory variables in the first phase or are indirectly related through established channels, alongside the first lag of the dependent variable X_{t-1} in this phase.

The GMM estimation method encompasses both ordinary and generalized method of moments' estimators. It is noteworthy that ordinary least squares (OLS) estimators, instrumental variable estimators, generalized least squares, two-phase ordinary least squares (2SLS), and maximum likelihood estimators represent specific instances of this broader estimation paradigm. This comprehensive approach to estimation allows for greater flexibility and robustness in modeling economic relationships.

To gain insight into this model, let us consider a set of observations from a random variable Z characterized by a probability distribution that depends on an unknown parameter θ. The maximum likelihood estimation technique aims to maximize the probability of observing the data Z, while the OLS method concentrates on minimizing the total sum of squared errors, or residuals, associated with the estimated model.

The method of moments is implemented such that if a vector $m(x_t)$ of dimensions $K \times 1$ exhibits a continuous distribution that converges to $\gamma(0)$, has a zero mean probability $m(0)$, and can be expressed as a function of a parameter vector $\beta_{K\times 1}$. Specifically, this can be represented by:

$$\frac{1}{T}\sum_{t=1}^{T} m(x_t) - \gamma(\beta) = 0_{k\times 1}, \tag{6}$$

where the sample mean $\frac{1}{T}\sum_{t=1}^{T} m(x_t)$ is a consistent estimator for $\gamma(0)$, and according to Slutsky's theorem, as long as $\gamma(0)$ is a continuous function, then

$$p\lim \gamma(\hat{\beta}) = p\,\gamma\lim\ \hat{\beta}.$$

Under these conditions, the vector with a zero mean must satisfy the following moment conditions for variance and covariance:

$$\begin{aligned}
&\frac{1}{T}\sum_{t=1}^{T} x_t^2 - \sigma_{xx} = 0,\\
&\frac{1}{T}\sum_{t=1}^{T} y_t^2 - \sigma_{yy} = 0,\\
&\frac{1}{T}\sum_{t=1}^{T} y_t x_t - \sigma_{xy} = 0, \quad \text{or} \quad \frac{1}{T}\sum_{t=1}^{T} y_t x_t - \rho_{xy}\sqrt{\sigma_{xy}}\sqrt{\sigma_{yy}} = 0.
\end{aligned} \tag{7}$$

For instance, in the context of a moving average process denoted as MA(1) where $y_t = \varepsilon_t + \theta\varepsilon_{t-1}$ is defined, the variance and covariance of this process can be expressed as follows:

$$\begin{aligned}
E(y_t) &= 0,\\
E(y_t^2) &= E[\varepsilon_t + \theta\varepsilon_{t-1}]^2 = \sigma_\varepsilon^2(1+\theta^2),\\
E(y_t y_{t-1}) &= E(\varepsilon_t + \theta\varepsilon_{t-1}) \times (\varepsilon_t + \theta\varepsilon_{t-2}) = \sigma_\varepsilon^2\theta.
\end{aligned} \tag{8}$$

Consequently, the moment conditions may be presented simultaneously in the following manner:

$$\begin{pmatrix} \frac{1}{T}\sum_{t=1}^{T} y_t^2 - \sigma_\varepsilon^2(1+\theta^2) \\ \frac{1}{T}\sum_{t=1}^{T} y_t y_{t-1} - \sigma_\varepsilon \cdot \theta \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}. \tag{9}$$

In the GMM model, let us assume that there are q moment conditions, and that the parameter vector $\beta_{K\times 1}$ has an initial value represented by β_0. The moment conditions can then be articulated as follows:

$$E(m(w_t,\beta_0)) = \begin{pmatrix} E(m_1(w_t,\beta_0)) \\ E(m_2(w_t,\beta_0)) \\ \vdots \\ E(m_q(w_t,\beta_0)) \end{pmatrix} = 0_{q\times 1}, \tag{10}$$

where, it is assumed that W_t is stationary and that the weights are estimable. For a system described by the MA(1) process, the sample mean can be derived from (11):

$$\bar{m}(\beta) = \frac{1}{T}\sum_{t=1}^{T} m_1(w_t,\beta_0). \tag{11}$$

When expressed in matrix or vector notation, the mean of $MA(q)$ is represented as follows:

$$J = \begin{pmatrix} \tilde{m}_1(\beta) \\ \tilde{m}_2(\beta) \\ \vdots \\ \tilde{m}_q(\beta) \end{pmatrix} \cdot \begin{pmatrix} w_{11} \cdots w_{1q} \\ w_{21} \cdots w_{2q} \\ \vdots \\ w_{q1} \cdots w_{qq} \end{pmatrix} \cdot \begin{pmatrix} \tilde{m}_1(\beta) \\ \tilde{m}_2(\beta) \\ \vdots \\ \tilde{m}_q(\beta) \end{pmatrix} = \tilde{m}(\beta)' \cdot W \cdot \tilde{m}(\beta). \tag{12}$$

In (12), the matrix W represents the weighted matrix estimated through the GMM model. This matrix is essential for incorporating the actual variance and covariance of the data while estimating the parameter vector $\beta_{K\times 1}$. To elucidate further, in the two-phase model, when K instrumental variables Z are included, the mean of $\beta_{K\times 1}$ is expressed as follows:

$$\bar{m}(\beta) = \frac{1}{T}\sum_{t=1}^{T} Z_t u_t(\beta) = \frac{1}{T} Z' u(\beta) = 0, \tag{13}$$

where $u_t(\beta) = u_t(y_t, x_t, \beta)$, and accordingly the mean matrix calculated as follows:

$$J(\beta, \hat{W}_t) = T m_t(\beta)' \cdot \hat{W}_T^{-1} \cdot m_T(\beta) = (1/T) u(\beta)' Z \hat{W}_T^{-1} Z' u(\beta). \tag{14}$$

3.4 Variance analysis in two-phase GMM

In the context of the two-phase GMM model, which is asymptotically normal, the population variance and covariance, represented as V, can be expressed as follows:

$$\begin{aligned} &\sqrt{T}(\beta - \beta_0) \to N(0, V), \\ &V = (\Sigma' W^{-1} \Sigma)^{-1} \cdot (\Sigma' W^{-1} S W^{-1} \Sigma) \cdot (\Sigma' W^{-1} \Sigma)', \end{aligned} \tag{15}$$

where,

$$\begin{aligned} W &= p \lim (\hat{W}_T), \\ \Sigma &= p \lim \frac{1}{T} Z' \nabla u(\beta), \\ S &= p \lim \frac{1}{T} Z' \nabla u(\beta) u(\beta)' Z. \end{aligned} \tag{16}$$

In system (16), S encompasses not only the variance of $\sqrt{T} m_T(\beta)$ but also the long-term covariance $Z_t u_t(\beta)$. Consequently, within the linear relationship arising from the residuals $u_t(\beta)$ derived from $u_t(\beta) = y_t - X_t' \beta$, the weights estimated within the GMM framework can be delineated as follows:

$$J(\beta, \hat{W}_t) = (\frac{1}{T})(y - X\beta)' Z \hat{W}_T^{-1} Z' (y - X\beta). \tag{17}$$

The probability distribution of the random variable Z, when adhering to the GMM specification, can be expressed as:

$$\theta' = (X' Z \hat{W}_T^{-1} Z' X) X' Z \hat{W}_T^{-1} Z' y. \tag{18}$$

In summary, the fundamental difference between single-phase models—such as OLS and Maximum Likelihood Estimation (MLE)—and simultaneous two-phase models like Two-phase Least Squares (TSLS) and Limited Information Maximum Likelihood (LIML) lies in the weights employed within the GMM approach. These weights are essential for accurately estimating the variance and covariance of the coefficients. Under certain specific conditions, the results obtained from the GMM framework align with those of the aforementioned models. For instance, when the variances of the parameters remain constant over time, the outcomes from the TSLS correspond with those from the two-phase GMM model. This correspondence arises because, in such scenarios, the weights applied across different moments are uniform and equal to $\hat{W}_T = (\frac{1}{T})\hat{\sigma}^2 Z' Z$ (see [25] for more details).

4 Bayesian Approach

The Bayesian approach prioritizes the assessment of beliefs about unknown parameters within a model, rather than focusing on repeated sampling to estimate these parameters. It fundamentally asks the question: "Given the information contained in the data, what beliefs should we hold regarding the random variable θ?". The estimated value $\widehat{\theta}(Y)$ does not assume a particularly significant role. Unlike the classical perspective where θ is viewed as a fixed parameter and $\widehat{\theta}$ as a random variable, Bayesian methodology considers θ to be inherently random, while treating $\widehat{\theta}$ as a fixed estimate. This is due to the information provided by the data that serves to stabilize $\widehat{\theta}$. Specifically, if the data generation process is modeled as $y_t = \mu + \varepsilon_t$ $(t = 1, 2, \ldots, T)$ where $\varepsilon_t \sim N(0, 1)$ represents Gaussian white noise, the likelihood function can be expressed as:

$$P(Y|\mu) = (2\pi)^{-\frac{T}{2}} \exp\left(-\frac{1}{2}\sum_{t=1}^{T}(y_t-\mu)^2\right). \tag{19}$$

Given $\hat{\mu}_{ML,T} = \frac{1}{T}\sum_{t=1}^{T} y_t = \bar{y}$, $Var(\hat{\mu}_{ML,T}) = \frac{1}{T}$ and assuming a prior distribution is Gaussian with mean (μ_0) and variance σ_μ^2, the resulting posterior distribution is given by:

$$P(Y|\mu) \propto (2\pi)^{-\frac{1}{2}} \exp\left(-\frac{1}{2}\frac{(\mu-\mu_0)^2}{\sigma_\mu^2}\right) \times (2\pi)^{-\frac{T}{2}} \exp\left(-\frac{1}{2}\sum_{t=1}^{T}(y_t-\mu)^2\right). \tag{20}$$

To clarify, let $P(Y|\mu) \propto \exp\left(-\frac{(\mu-E[\mu])^2}{Var[\mu]}\right)$, where its variance is

$$Var[\mu] = \frac{1}{(\frac{1}{T})^{-1} + \sigma_\mu^{-2}},$$

and the mean is

$$E[\mu] = \frac{(\frac{1}{T})^{-1}\hat{\mu}_{ML,T} + \sigma_\mu^{-2}}{(\frac{1}{T})^{-1} + \sigma_\mu^{-2}}.$$

Under these conditions, the posterior mean can be interpreted as a convex combination of the prior mean and the maximum likelihood estimate. As the variance $\sigma_m u^2 \to \infty$ or in the absence of prior information, the posterior mean $E[\mu] = \hat{\mu}_{ML,T}$. This implies that in scenarios lacking ancillary information, reliance solely on the data leads the Bayesian expected value to converge with the expected value derived from maximum likelihood estimation. Conversely, when $\sigma_m u^2 \to 0$, it signifies that the prior information is perfectly accurate, reflecting total confidence in its correctness, which results in $E[\mu] = \hat{\mu}_0$. Thus, if the prior information is entirely reliable, the Bayesian expected value aligns closely with the prior expected value, causing the Bayesian estimator to function as a calibration. Overall, the Bayesian estimator represents a synthesis between the maximum likelihood estimator and calibration, contingent on the available information [24].

5 Findings Analysis

This study employs the new Keynesian approach to simulate the Iranian economy, as its underlying assumptions and relationships are more aligned with the realities of the Iranian macroeconomy than those of the Neoclassical or Real Business Cycle (RBC) theories. A significant distinction between Neoclassical assumptions and the characteristics of the Iranian economy—often criticized by economic policymakers—is the belief that business cycles and economic fluctuations stem from the optimal behavior of economic agents. Under this perspective, economic shocks are deemed optimal, which undermines the necessity for intervention by policymakers, rendering both monetary and fiscal policies inconsequential in achieving economic equilibrium.

In this context, the research delineates the New Keynesian approach through eight fundamental characteristics:

1. **Sources of Business Cycles:** Economic fluctuations arise from both real and nominal shocks, acknowledging the roles of price stickiness and inflation. Consequently, supply-side and demand-side shocks are integral to stimulating production and instigating economic variability.

2. **Market Structure:** The labor and product markets are characterized by imperfect competition, evidenced by monopolistic tendencies. The New Keynesian framework posits that the product market operates under monopolistic competition, showcasing heterogeneity among goods and enabling producers to exert influence over prices due to varying quality.

3. **Price and Wage Rigidity:** Prices and wages exhibit rigidity, representing a crucial assumption that sets the New Keynesian model apart from the RBC model. This rigidity implies that price levels are sticky, particularly in the short run, which delays their full adjustment to economic changes and causes real impacts from nominal shocks.

4. **Inefficiencies in Equilibrium:**The presence of monopolistic power in goods and factor markets indicates that existing equilibria are not Pareto optimal.

5. **Real Effects of Policies:** Monetary and fiscal policies are capable of producing real effects, at least in the short term.

6. **Impact of Stabilization Policies:** Policies aimed at stabilizing economic conditions can influence real macroeconomic variables.

7. **Rational Expectations:** Expectations are formed rationally, and any economic equilibrium that exists adheres to the rational expectations framework.

8. **Absence of Asymmetric Information:** The markets operate without asymmetric information, ensuring that all participants have equal access to relevant information.

The equations utilized in this analysis have been derived using a logarithmic algorithm and Taylor expansion, ensuring they are linear and compatible with Dynare software. Within this framework, the central bank operates independently from the government sector and employs discretionary monetary policies that incorporate both inflation targeting and considerations of the output gap. Furthermore, the central bank employs a combination of monetary tools, such as directly adjusting the money supply and modifying interest rates as necessary, to implement its discretionary policies. Meanwhile, the government finances its fiscal policies through direct monetary issuance from the central bank, leveraging oil revenue (specifically excess oil income after setting aside a portion in the National Development Fund), alongside various tax revenues.

To effectively establish the theoretical foundations of the defined economic system, it is essential to calibrate the model parameters prior to addressing the system of equations within the DSGE framework. The calibration of these model parameters has been conducted using a combination of Bayesian methods and expert analysis, with the resulting parameters summarized in Table 1.

Table 1: Model parameters

Parameter	Description	Value	Source
Sigma	CRRA for Household Preferences	1.1739	Study Findings
Betta1	Discount Factor for Patient Household	0.9518	Study Findings
Betta2	Discount factor for Impatient Households	0.9305	Study Findings
Betta3	Discount factor for the Central Bank (CB)	0.93	Arbab Afzali et al. [1]
eta	Elasticity of Labor Supply	2.2304	Study Findings
Phi	Elasticity of Money Demand	0.7415	Study Findings
Tau_T	Tax rate on Labor Income	0.234	Fardhariri et al. [5]
Tau_c	Tax rate on Consumption	0.09	Fardhariri et al. [5]
alfa	Share of Capital in Production Function	0.3114	Study Findings
Roh1	Proportion of Firms Able to Adjust Prices (Calvo Approach)	0.5	Tavakolian & Komijani [23]
delta_b	Bank Capital Management Cost Ratio	0.1	Heydari & Molabhrahmi [9]
teta_b	Undistributed Bank Profit Retained as Capital	0.25	Heydari & Molabhrahmi [9]
Lambda_Adj	Costs Associated with Loan Transactions	0.1	Heydari & Molabhrahmi [9]
r_l	Loan Interest Rate	0.13	Heydari & Molabhrahmi [9]
rr	Foreign Exchange Deposit Interest Rate	0.1	Heydari & Molabhrahmi [9]
kappa	Depreciation Rate of Bank Capital Stock	0.09	Heydari & Molabhrahmi [8]
Lambda_b	Risk Weight Assigned to Loans	0.6	Heydari & Molabhrahmi [8]
nu_b	Bank Capital to Risk-Adjusted Asset Ratio	0.02	Heydari & Molabhrahmi [8]
k_k	Optimal Bank Capital Rate	0.02	Heydari & Molabhrahmi [8]
alfa2	Coefficient of Output Gap in the Phillips Curve	0.874	Study Findings
pibar	Long-Run Inflation Rate	0.097	Tavakolian [21]
omega	Proportion of Oil Revenue Allocated to Foreign Exchange Reserves	0.2621	Study Findings
Lambda_CB	Weight of the Output Gap in the Central Bank's Loss Function	0.2486	Study Findings
K_yn	Additional Output Gap	0.01	Tavakolian [21]
yn	Target Output	0.05	Tavakolian [21]
Sigma_eps_CB	Variance of Output Gap Noise		Arbab Afzali et al. [1]
Sigma_nu	Variance of Inflation Bias Noise		Arbab Afzali et al. [1]
Rho_a	Autoregressive Coefficient of Technology	0.7829	Study Findings
stderr_a	Standard Deviation of Technology Coefficient	0.01	General Rules
Rho_er	Autoregressive Coefficient of Exchange Rate	0.8826	Study Findings
stderr_er	Standard Deviation of Exchange Rate Coefficient	0.01	General Rules
Rho_r	Autoregressive Coefficient of Interest Rate	0.7206	Study Findings
stderr_r	Standard Deviation of Interest Rate Coefficient	0.01	General Rules
Rho_oil	Autoregressive Coefficient of Oil Prices	0.8813	Study Findings
stderr_oil	Standard Deviation of Oil Price Coefficient	0.01	General Rules
cbar_ybar	Partial Derivative of National Income with Respect to Consumption	0.51	Tavakolian & Komijani [23]
ibar_ybar	Partial Derivative of National Income with Respect to Investment	0.321	Tavakolian & Komijani [23]
gdbar_ybar	Partial Derivative of National Income with Respect to Government Expenditures	0.123	Tavakolian & Komijani [23]

Based on the results obtained, a one standard deviation shock in the exchange rate was observed. Figure 1 illustrates that, over the long term, both the profits of the banking sector and GDP have displayed a declining trend in response to the increase in the exchange rate. Conversely, government spending, consumption, inflation, and bank deposit interest rates have exhibited an upward trend during the same period.

Initially, the banking sector's profit response to the exchange rate shock was positive during periods of declining deposit interest rates. However, it subsequently shifted to a negative trajectory. Therefore, analyzing the fluctuations in deposit interest rates concerning the exchange rate shock is essential. The interest rate examined in this study encompass real return rates on various capital assets, including bank deposits, business investments, household wealth, and other forms of capital investment, such as stock market and foreign currency investments. In the long run, achieving equilibrium requires that all these real return rates converge.

Furthermore, since the interest rate in question is a real rate, it decreases as inflation rises. Initially, following the shock of the increased exchange rate, the rapid inflation surge resulted in a decline in the real interest rate on deposits. However, after approximately ten periods post-shock, the nominal return on capital assets began to increase more rapidly than inflation, leading to a subsequent rise in the real interest rate from the tenth period onward. This trend indicates that currency is regarded as a capital asset within the Iranian economy, as its appreciation has also contributed to an increase in its real return.

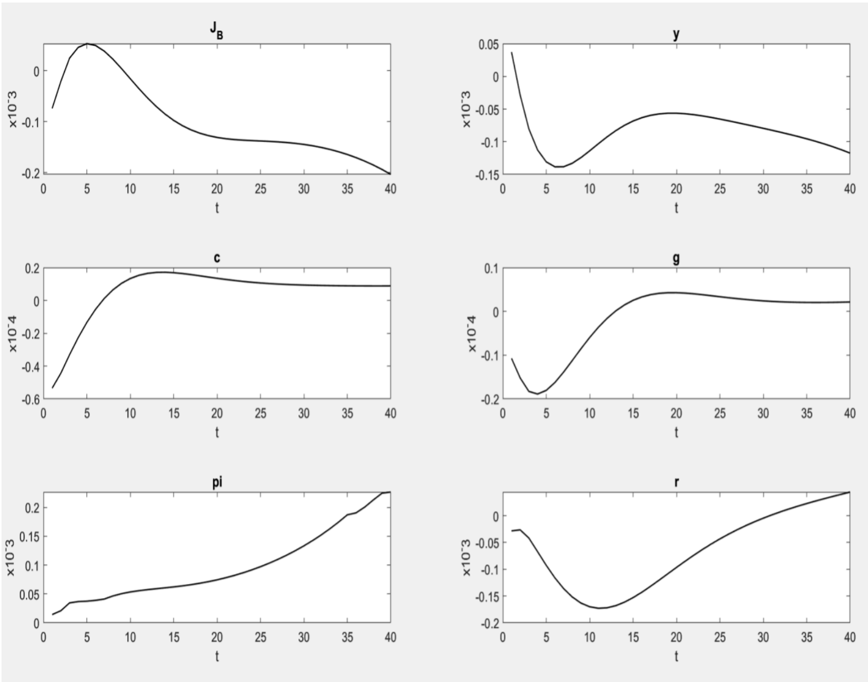

Figure 1: Dynamic analysis of the exchange rate shock responses.

Additionally, the increasing trend in inflation and government expenditures can be justified, as a rise in the exchange rate typically leads to higher inflation levels. On one hand, the government eventually gains access to foreign currency resources from oil sales after a certain period. This delayed access contributes to an increase in government expenditures, which is further intensified by the prior rise in the exchange rate.

The primary drivers of this phenomenon include increased speculative demand for goods at previous prices, changes in consumption patterns, and a rise in demand for domestic or lower-quality products. Furthermore, it is evident that a positive exchange rate shock in the Iranian economy will have significant inflationary effects. Regarding how deposit interest rates respond under these conditions, it is theoretically feasible for the central bank to implement interest rate stabilization policies to mitigate the impact of inflation on deposits and investments. Consequently, deposit interest rates may be adjusted to counteract inflationary effects. However, evidence from the Iranian economy indicates that commercial banks have responded to the positive exchange rate shock by reducing deposit interest rates. This behavior reflects the ineffectiveness of the monetary sector in managing the consequences of the exchange rate shock, contributing to heightened inflation, excess liquidity in the currency market, and an increase in speculative activities in both the currency market and other parallel markets. Although the average deposit interest rate has generally trended upward in response to the exchange rate shock, the misalignment in the timing of interest rate adjustments highlights significant inefficiencies within the banking system and monetary policies in Iran.

Additionally, the active involvement of the banking sector in the currency market and other parallel markets, aimed at achieving returns and improving financial performance, may result in short-term profit gains for commercial banks. However, over time, the effects of inflation and the monetary sector's inefficacy in managing its impact will become evident, leading to a decrease in the long-term (real) profitability of this sector.

These findings highlight a lack of coordination between banks and the central bank, the primary institution responsible for monetary policy in the country. This disconnection explains the persistent upward response of the inflation rate to positive exchange rate shocks. The results indicate that banks benefit from these shocks in the short term, suggesting that banks in the Iranian economy have deviated from their traditional roles. Moreover, the involvement of banks and other sectors in speculative activities has intensified the structural inflation phenomenon in the country. While banks may initially benefit from continuous access to liquidity and financial resources due to the positive exchange rate shock, this growth in profitability is unlikely to be maintained in the medium to long term, ultimately leading to losses.

6 Conclusion and Recommendations

The findings from the simulation of the Iranian macroeconomic structure and the analysis of the dynamic effects of a positive exchange rate shock indicate that real GDP initially displayed a downward trend. Although this trend may evolve over time, economic activities and domestic production levels generally respond unfavorably to the positive exchange rate shock. Theoretically, such a shock could improve the trade balance, enhance the utilization of domestic products, and reduce inflation. However, in the context of the Iranian economy, several factors obstruct these results. These include inefficient financial markets, rent-seeking behavior, widespread speculative tendencies, heavy reliance on imports, a fragile production infrastructure, and the production sector's inability to quickly exploit export opportunities arising from currency appreciation. Collectively, these factors have led to detrimental effects on the production sector, accompanied by rising prices for goods and services and increased inflation.

Regarding government expenditure and fiscal policy responses, it is essential to recognize the government's active and critical role in providing foreign currency. Consequently, the government significantly benefits from the currency supply following a positive exchange rate shock. However, this scenario leads to a decrease in real government expenditures due to inflationary pressures stemming from the shock. This downward trend is unsustainable; the combined effects of declining real GDP and rising inflation will eventually necessitate an increase in government expenditures to cover the associated costs. Furthermore, evidence from this study indicates that while a positive exchange rate shock tends to enhance household consumption, it does not necessarily lead to an increase in household purchasing power, as real GDP reacts negatively to this shock. Therefore, a crucial policy recommendation is to establish a framework that confines banks to their core functions, primarily aimed at supporting and facilitating economic activities while effectively managing financial risks. Implementing such measures can significantly reduce volatility in financial markets. Achieving sustainability requires policies focused on revising and strengthening laws and regulations governing banking activities, minimizing government and external interference in financial markets, and promoting the development of dynamic and efficient financial markets. These initiatives can enhance the stability of the banking sector's performance and improve its coordination with other economic sectors, particularly the central bank in executing monetary policies.

Furthermore, it is essential to recognize that government intervention in the currency market, the existence of multiple exchange rates, and the prevalence of corruption and rent-seeking behaviors have encouraged banks and other sectors to engage in speculative activities. By eliminating such interventions that distort equilibrium prices in the currency market, the motivation for banks, other sectors, and investors to pursue opportunistic practices can be significantly diminished.

Our study on optimizing the resilience of Iran's banking network in response to exchange rate shocks both aligns with and diverges from findings in the related literature.

1. **Impact of Exchange Rate Shocks:** Our findings that initial positive exchange rate shocks can enhance banking sector performance align with the results of Rajaee et al. [18], which indicate that total output and output gaps initially respond positively to exchange rate shocks. Both studies demonstrate that while short-term positive effects may exist, these diminish over time.

2. **Response to Inflationary Pressures:** Our results regarding the inflationary pressures triggered by exchange rate shocks are consistent with findings from Zamarripa [26] and Nakhli et al. [16]. Both studies emphasize the negative impact of economic shocks on production and prices, indicating that unstable monetary policies and sanctions can lead to increased inflation and exchange rate volatility.

3. **Role of Banks in the Foreign Exchange Market:** Our research highlights the role of banks in exchange rate fluctuations and their speculative activities, which overlaps with studies by Sharif et al. [19] and Tavakolian and Afzali Abarquyi [22]. These studies also examine the influence of banks on the foreign exchange market and the resulting volatility from their activities.

4. **Impact of Macroeconomic Policies:** Our findings about the influence of monetary and fiscal policies on exchange rate volatility and economic resilience align with the results of Chen[3]. This study underscores that changes in money supply and fiscal policies can directly affect exchange rates and economic conditions.

5. **Potential Differences:** However, there are some differences. While our study specifically focuses on banking sector resilience, many similar studies analyze broader economic impacts and macroeconomic variables. Additionally, while most studies mention the impact of sanctions, our research emphasizes operational and strategic aspects of banking network resilience.

Limitations of the research:
While this study provides valuable insights into optimizing banking network resilience to exchange rate shocks, several limitations must be acknowledged:

1. **Model Assumptions:** The MDSGE model relies on certain assumptions about market behavior, such as rational expectations and perfect competition. These assumptions may not fully capture the complexities and irrationalities present in real-world economic conditions, potentially limiting the applicability of the findings.

2. **Data Constraints:** The research is dependent on the availability and accuracy of data from Iran's banking sector and macroeconomic indicators. Any inaccuracies or gaps in data can affect the robustness of the model and the validity of the results.

3. **Simplification of Economic Dynamics:** While the MDSGE framework incorporates multiple economic sectors, it may still oversimplify certain dynamics, such as the interaction between different economic agents and the effects of external shocks beyond exchange rate fluctuations.

4. **Focus on Short-to-Medium Term Effects:** The study emphasizes the medium to long-term consequences of exchange rate shocks on the banking sector. However, the immediate impacts may also play a crucial role in the banking sector's resilience, which is not thoroughly explored in this research.

5. **Geographical and Contextual Limitations:** The findings are specific to Iran's banking sector and macroeconomic environment. The results may not be directly applicable to other countries with different economic structures or regulatory frameworks.

6. **Potential for Model Calibration Issues:** The parameters used in the MDSGE model are subject to calibration choices that can influence outcomes. Variations in these parameters could lead to different results, highlighting the sensitivity of the model to initial conditions.

7. **Lack of Consideration for Behavioral Factors:** The research primarily focuses on quantitative aspects of the banking sector's resilience. However, qualitative factors, such as managerial decision-making and consumer behavior in response to exchange rate changes, are not deeply examined.

Declarations

Availability of Supporting Data
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The authors declare that they have no competing interests relevant to the content of this paper.

Authors' Contributions

The main text of manuscript is collectively written by the authors.

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