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Analyzing the effects of interest rate shocks in Iran's economy considering shadow banking, using stochastic dynamic general equilibrium model

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Abstract

In recent years, the expansion of financial institutions such as investment funds, non-bank financial and credit institutions, and financing funds has led to the emergence of a sector in Iran's economy known as shadow banking. This sector operates in parallel with the standard banking sector. The formation of such a structure can be considered part of the monetary transmission mechanism and macroeconomic variables. The present study elucidates two key findings: first, the extent of shadow banking in Iran's economy is increasing rapidly, second, this expansion diminishes the effectiveness of monetary policies.

To model the shadow banking sector, this study employs a Dynamic Stochastic General Equilibrium (*DSGE*) model,

A monetary DSGE model is able to replicate the empirical facts when augmented with intermediaries that allow for regulatory arbitrage on the one hand, and household portfolio rebalancing on the other. incorporating various sectors of the economy 2010 to 2019. The simulation results demonstrate that the impact of the shadow banking sector on macroeconomic variables is analogous to that of the standard banking sector, underscoring its influence on the Iranian economy. Furthermore, simulations of interest rate shocks reveal that developments in interest rates within the shadow banking sector mirror the conventional monetary transmission mechanism in the standard banking sector. Consequently, advancements in this sector can significantly influence the future trajectory of economic variables.

Highlights

- Introducing shadow banking in Iran's economy
- Investigating the monetary policy transmission mechanism in Iran's economy considering shadow banking
- Designing a dynamic stochastic general equilibrium model with the presence of shadow banking in Iran's economy and examining the interest rate channel on macroeconomic variables

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1. Introduction

The granting of facilities and credits is one of the primary functions of the banking sector. However, due to the limited resources available within the traditional banking sector various institutions and intermediaries have emerged to supplement these resources. Unlike the traditional sector, these entities operate without adequate and strict oversight by regulatory bodies. This sector, known as shadow banking, engages in banking operations without being subject to the same regulatory supervision and restrictions as the traditional banking sector. Consequently, the shadow banking sector has evolved, reaching a level of maturity and development now significantly influences macroeconomic variables (Funke, Mihaylovski and Zhu,2015).

The shadow banking system comprises financial institutions that generate credit and liquidity outside the traditional banking system and operate without central bank Oversight Shadow banking describes banking activities not typically performed by traditional banks. In global economic literature, shadow banking is referred to as non-bank financial intermediation and market-based financing, while lending in the shadow banking sector is akin to that in the traditional banking sector, the regulatory frameworks differ. Shadow banks convert long-term non-cash assets into short-term cash claims with greater discretion (Bernanke and Gertler, 1995).

To understand the components of shadow banking in Iran, we examine its elements briefly. Non-banking credit institutions. In Iran are part of this shadow mediation activity. These institutions, as non-banking financial entities, function as funds intermediaries in financial markets, offering services similar to those of banks.

Investment funds, another component, collect funds from, individuals to invest according to their mandate, allowing each investor to share in the fund's profits and. losses proportional to their investment. Depending on their type, investment funds allocate resources to fixed income securities, stocks, commodities, etc. Many of these funds operate as subsidiaries of banks, aiming to attract resources beyond the Central Bank's regulations and the rates approved by the Supreme Council of Money and Credit, thus addressing banks' resource deficits. Insurance and leasing companies also play significant roles as shadow factors influencing economic policies. A notable development in the insurance industry, is the blurring of the lines between traditional banking and insurance, with insurance companies accepting investments and providing facilities, similar to banks. Consequently, their activities are considered part of shadow banking.

Leasing companies are another type of non-banking financial institution. These companies finance the purchase of various goods by securing credit from investment banks, financial institutions, or international banks, utilizing both domestic and foreign credit sources. They employ two methods: leasing with the option of ownership and sales under specified conditions.

The purpose of this research is to investigate the effects of shadow banking on Iran's macroeconomic variables through the interest rate. A stochastic dynamic general equilibrium (*SDGE*) model, incorporating both shadow banking and traditional banking sectors, has been designed and implemented, modeling these sectors separately and specifying interest rate dynamics independently. This structure enables the examination of the impact of shadow banking decision-making on macroeconomic variables. The results of this model demonstrate that interest rates set within the shadow banking sector, significantly affect macroeconomic variables through the monetary transmission mechanism, similar to the traditional banking sector[1].

This article is organized into five part, the second part, reviews previous studies, the third par, discusses the theoretical foundations and the fourth and fifth parts focus on model estimation and conclusions, respectively.

2. A Review of the Related Literature

According to the description of shadow banking, this financial sector, like the traditional sector, can influence the economy's performance and its ultimate goals through the monetary transmission mechanism. Therefore, analyzing this sector requires examination of the monetary transmission channel.

The study of shadow banking is essential for two primary reasons Firstly, the increase in, the assets and transactions resulting from shadow banking activities has raised concerns about its impact on monetary policies. Secondly, because a portion of deposits is held within shadow banks, monetary policy does not fully influence these funds, thereby reducing its effectiveness. This policy not only affects the total amount of bank deposits, but also influences the relative share of shadow and traditional banking. Since deposits in the shadow banking sector lack sufficient guarantees, they also affect financial stability.

The first and most significant channel through which shadow banking influences the monetary transmission mechanism is lending and credit provision. In a traditional banking structure, the volume of bank lending depends on the volume of deposits and what can be borrowed in the interbank market. Shadow banking operates on a similar principle. For example, an investment fund collects money from investors and issues shares representing the investors' deposits in the fund. To generate investment returns, the fund uses this money to purchase securities, such as bonds issued by countries or companies.

The second critical element of shadow banking is the interest rate on facilities and credits, which is influenced by the effectiveness of the money supply managed by these institutions. In shadow banking, the money supply includes funds created by both the traditional banking network and shadow banking entities. The shadow banking money supply mainly consists of cash claims created by money market funds (*MMFs*). A critical factor in creating an effective shadow banking channel is the difference between customers of traditional and shadow banks, as these groups differ in their sensitivity to interest rates and risk tolerance.

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[1]Other studies find that monetary policy also affects shadow banking. Nelson et al. (2018) find a contractionary monetary policy reduces commercial bank assets' but increases shadow banks' assets. Several studies, including Mazelis (2016) and Chen et al. (2018a , 2018b), confirm this finding. Chen et al. (2018a, 2018b) find that contractionary monetary policy encourages banks to increase investments in entrusted assets to circumvent the loan-to-deposit ratio (LDR) and safe-loan regulations.

While shadow banking reduces the economy's reliance on traditional banking by diversifying financial markets, it also carries the risk of contributing to banking crises and economic stagnation due to its potential for rapid expansion.

2. B Domestic and Foreign Studies

Gang et al. (2021) utilized a Dynamic Stochastic General Equilibrium (*DSGE*) model to analyze the effects of shadow banking on monetary policy and to evaluate the characteristics of shadow banking cycles. Numerical simulations demonstrated that positive interest rate impulses are associated with the expansion of shadow banking. Simultaneously, these impulses have reduced the credit leverage of commercial banks.

Yang, Liu et al. (2019) investigated shadow banking in China, focusing on financial regulations and the effectiveness of monetary policies, using data from 2009 to 2016 and employing a *DSGE* model. The study considered two types of banks, traditional banks, and shadow banks, while also accounting for the requirement of traditional banks to adhere to the deposit-to-loan ratio law. The results indicated that monetary shocks have been a crucial factor in expanding the volume of shadow banking. Furthermore, due to the lack of restrictions on shadow banking, this sector can negatively impact the effectiveness of monetary policies.

Zarei et al. (2020) examined the impact of shadow banking on the effectiveness of monetary policy in several G20 countries by analyzing data from 16 member countries and applying two methods, Generalized Method of Moments (*GMM*) and quantile regression, over the period from 2002 to 2018. The study concluded that the effectiveness of monetary policies has diminished due to the presence of shadow banking.

Azimi (2019) explored the effects of the shadow banking system on Iran's monetary policy using seasonal data from 2015 to 2018 and employing the Structural Vector Autoregression (*SVAR*) method. The results of the shock response functions during the period under review confirmed the existence of a negative relationship between economic growth and the expansion of shadow banking.

3. The DSGE Structure of Monetary Mechanism with Shadow Banking

A first attempt to introduce a financial sector in a New Keynesian DSGE framework has been made by Bernanke et al. (1999). In their model, the financial sector is limited to a banking sector that amplifies the effects of the shocks via the financial accelerator effect. More recently, some authors have enhanced the structure and role of the financial sector in DSGE models. Iacoviello (2005) extends the Bernanke et al. (1999) model by introducing collateral constraints for firms, as in Kiyotaki and Moore (1997). Christiano et al. (2003, 2008) and Goodfriend & McCallum (2007) consider a perfectly competitive banking sector that offers agents a variety of financial assets with different returns, while Kobayashi (2008) and Gerali et al. (2010) consider imperfect competition in the banking sector so as to model the setting of interest rates by banks. Cúrdia & Woodford (2003) also allow for a time-varying spread between deposits and lending rates. Finally, a number of papers (see, for instance, Van den Heuvel, 2008, Gertler and Karadi, 2010, de Walque et al., 2010 and Meh and Moran, 2010) study the role of bank capital in the transmission of macroeconomic shocks.

To develop an analytical model for evaluating the shadow banking sector, a stochastic dynamic general equilibrium (SDGE) model has been designed. This model includes the household, business, banking (both standard and shadow), and policymaking (government and central bank) sectors. In this section, each of these components is modeled, and based on his system of equations, the model's summarized form is extracted. Finally, the shadow banking sector is evaluated based on this linear system.

3.1. Households

Based on the study of Woodford (2003), it is assumed that households are homogeneous and have unlimited life. Considering the homogeneity of households, the form of the utility function for a household can be assumed as follows, and it can be generalized for all households:

$$Max_{C,i,b,k,z} \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t - hC_{t-1})^{1-\sigma_C}}{1-\sigma_C} + \frac{\left(\frac{M_t}{P_t}\right)^{1-\sigma_m}}{1-\sigma_m} - \frac{L_t^{1+\sigma_L}}{1+\sigma_L} \right] \quad (1)$$

In relation (1), C_t is actual household consumption, M_t is the nominal balance of money, P_t is the general level of prices and L_t is the amount of labor supply. Also, β is the subjective discount factor, σ_C is the inverse of inter-period consumption substitution elasticity, $0<h<1$ is the consumption habit parameter, σ_m is the elasticity of the money demand function, and σ_L is the inverse of the labor supply elasticity. In this structure, the household is faced with two conditions: the first condition is that household expenses cannot exceed its income (budget condition), and the second condition is that the net fixed capital (net of depreciation) is limited to the amount of investment in each period and Net capital is left over from the previous period.

The budget constraint against the household is specified in such a way that household expenses (including consumption of goods and services, purchase of government bonds, holding cash, and investment expenses) must be less than or equal to its income (including wages, cash from the previous period, interest on bonds purchased in the last period and the rate of return on capital) whose secondary form is as follows:

$$C_t + b_t + m_t + i_t \leq w_t L_t + (M_{t-1}/(1+\pi_t)) + (1 + r_{t-1}^{w})(b_{t-1}/(1+\pi_t)) + r_t^k z_t \bar{K}_{t-1} - a(z_t)\bar{K}_{t-1} \quad (2)$$

Also, the condition of capital formation is assumed as follows:

$$K_t = (1-\delta)K_{t-1} + i_t \left(1 - S\left(\frac{i_t}{i_{t-1}}\right)\right) \quad (3)$$

In relations (2) and (3), the variables of the model are such that b_t is the amount of household savings, which can be in the form of buying government bonds, depositing in banks, or depositing in shadow banking. m_t the natural balance of money, i_t real investment expenditures, w_t real wage rate, π_t inflation rate, r_{t-1}^{w} weighted interest rate paid to household savings, r_t^k rate of capital return, z_t capital utilization rate, $\overline{K}_t$ capital volume (z_t) is a function of capital usage cost and S(.) capital adjustment cost. Also, δ is the capital depreciation rate.

According to the variables in the decision-making function of the household, the objective function of the household is maximized. Based on this, the household follows a path of consumption level, capital volume, adequate capital volume, capital utilization rate, investment, Tobin's q function, and money demand function in such a way that its maximum utility is achieved according to budget constraints and capital accumulation; Finding these paths requires the formation of the Lagrange function and optimization with respect to the mentioned variables, which results in the formation of a nonlinear system of first-order optimal conditions for the household. However, due to the nonlinearity of this device, it is difficult to find a unique equilibrium solution for it, and therefore, by using the first-order Taylor expansion, the system of nonlinear equations becomes a linear device, whose summarized form is the system of equations below.

$$\hat{C}_t = \frac{h}{1+h}\hat{C}_{t-1} + \frac{1}{1+h}E_t\hat{C}_{t+1} - \frac{1-h}{\sigma_c(1+h)}\left(\hat{r}_t^p - E_t\hat{\pi}_{t+1}\right) \quad (4)$$

$$\hat{\bar{k}}_t = -\left(1-\frac{\bar{\iota}}{\bar{k}}\right)\hat{z}_t + \left(1-\frac{\bar{\iota}}{\bar{k}}\right)\hat{\bar{k}}_{t-1} + \frac{\bar{\iota}}{\bar{k}}\hat{\mu}_t + \frac{\bar{\iota}}{\bar{k}}\hat{\iota}_t \quad (5)$$

$$\hat{k}_t = \hat{u}_t - \hat{z}_t + \hat{\bar{k}}_{t-1} \quad (6)$$

$$\bar{r}^k\hat{r}_t^k = a''(u)\hat{u}_t \quad (7)$$

$$\hat{\iota}_t = \frac{1}{1+\beta}(\hat{\iota}_{t-1} - \hat{z}_t) + \frac{\beta}{1+\beta}E_t(\hat{\iota}_{t+1} + \hat{z}_{t+1}) + \frac{1}{1+\beta}\hat{q}_t^k + \frac{1}{1+\beta}\hat{\mu}_t^k \quad (8)$$

$$\hat{q}_t^k = \left(\frac{\bar{r}^k}{\bar{r}^k+(1-\delta)}\right)\hat{r}_t^k + \left(\frac{(1-\delta)}{\bar{r}^k+(1-\delta)}\right)E_t\hat{q}_{t+1}^k - \left(\hat{r}_t^p - E_t\hat{\pi}_{t+1}\right) \quad (9)$$

$$\widehat{m}_t = \frac{\sigma_C}{(1-h)\sigma_m}\left(\hat{C}_t - h\hat{C}_{t-1}\right) - \frac{1}{\sigma_m}\hat{r}_t^p \quad (10)$$

In the above relationships, the variables with the ^ sign mean the linearized variables of the primary nonlinear system around its long-term equilibrium point. Also, $\hat{k}_t$ is the volume of adequate capital, $\hat{u}_t$ is the capital utilization rate, $\hat{z}_t$ is the productivity growth rate, $a''(u)$ is the second derivative of the utility cost function, $\hat{q}_t^k$ is Tobin's q variable, and $\hat{\mu}_t^k$ k is the capital efficiency effect value.

3.2 Banks

The second unit of the economic structure of the model is the banks, whose balance sheet is assumed as follows:

$$\mathrm{Nt+1 = Rkt+1QtSt - Rt+1Dt+1 = (Rkt+1 - Rt+1)QtSt + Rt+1Nt} \quad (11)$$

In this relation, $Dt + 1 = QtSt - NtSt$. Also, S is the volume of granted facilities, Q is the portfolio price (capital), N is the bank's net worth, D is the deposit received from the household, R is the interest rate paid to the household, and Rk is the interest rate of the facility. Banks seek to maximize their net worth during the period of their activity under the assumption that the probability of their presence in the banking industry in the next period is equal to θ. A condition that can be placed in front of the bank in order to attract more resources is that the banker can default on a part λ of the volume of the facility, and the depositor will not be able to compensate it. However, depositors keep their money in the bank as long as the value of the bank's franchise (Vt) is greater than the default amount (νtQtSt t) (Vt ≥ λtQtSt). The definition of Vt is as follows:

$$Vt = \nu tQtSt + \eta tNt \quad (12)$$

$$\nu t = Et[(1 - \theta)\beta\Lambda t + 1(Rkt + 1 - Rt + 1 + \beta\Lambda t + 1\theta xt + 1\nu t + 1] \quad (13)$$

$$\eta t = Et[(1 - \theta) + \beta\Lambda t + 1zt + 1\theta\eta t + 1] \quad (14)$$

In these relations, z is the growth rate of net worth, and x is the growth rate of assets.

The size of the bank's facility portfolio depends on the size of its net worth:

$$Vt = \lambda tQtSt \quad (15)$$

$$\nu tQtSt + \eta tNt = \lambda tQtSt \quad (16)$$

$$QtSt(\lambda t - \nu t) = \eta tNt \quad (17)$$

$$Q_t S_t = \frac{\eta_t}{\lambda_t - \nu_t} N_t \quad (18)$$

The financial index of capital in the form of debt and capital, which is called the debt ratio, can be defined as follows:

$$\phi_t = \frac{\eta_t}{\lambda_t - \nu_t} \quad (19)$$

The debt ratio endogenously reacts to the productivity level of the economy and depends on the borrowing rate and monetary policy (Gertler & KiyotakiT, 2010). Using this ratio, the growth rate of the variables z and x can be defined:

$$z_{t+1} = \frac{N_{t+1}}{N_t} = (R_{kt+1} - R_{t+1})\phi_t + R_{t+1} \quad (20)$$

$$x_{t+1} = \frac{Q_{t+1}S_{t+1}}{Q_t S_t} = \frac{\phi_{t+1}}{\phi_t} z_{t+1} \quad (21)$$

The third economic unit of the current structure is the shadow banks, which sell their fund shares (FS_t) to the household and grant their facilities (S_t^{SB}) in the following way:

$$Q_t S_t^{SB} = FS_t \quad (22)$$

Shadow banks advertise their fund shares (Vt) and assume with probability J_t that they can collect people's resources. This search and coordination of fund stocks for deposits can be expressed using the separation probability (χ^{SB}). Shadow banks choose the volume of advertising and granting facilities (to households and companies) in such a way that their future discounted profits are maximized:

$$Max_{v_t, S_t^{SB}} E_t \sum_{i=0}^{\infty} \beta^i \Lambda_{t,t+i} \Pi_{t+i}^{SB} \quad (23)$$

$$\Pi_t^{SB} = (R_{kt} - R_t^{SB}) Q_{t-1} S_{t-1}^{SB} - v_t \quad (24)$$

For the sake of simplicity in deriving relations, it is assumed that SB $(v_t, \hat{S}_t^{SB})$ is the profit-maximizing function. The restriction of resources against shadow banks is assumed as follows:

$$FS_t = (1 - \chi^{SB}) FS_{t-1} + J_t v_t \quad (25)$$

Based on this, the optimal conditions of the first order of the shadow bank are:

$$\frac{dSB}{dv_t} = 0 \Rightarrow \lambda_t^{SB} = \frac{1}{J_t} \quad (26)$$

$$\frac{dSB}{dS_t^{SB}} = E_t\beta\Lambda_{t+1}(R_{kt+1} - R_{t+1})Q_t - \lambda_t^{SB}Q_t + E_t\beta\Lambda_{t+1}\lambda_{t+1}^{SB}(1-\chi^{SB})Q_t = 0$$

By inserting the first-order optimal conditions, we will have:

$$\lambda_t^{SB} = E_t\beta\Lambda_{t+1}\{(R_{kt+1} - R_{t+1}) + \lambda_{t+1}^{SB}(1-\chi^{SB})\} \tag{27}$$

$$\frac{1}{J_t} = E_t\beta\Lambda_{t+1}\left\{(R_{kt+1} - R_{t+1}^{SB}) + \frac{1}{J_{t+1}}(1-\chi^{SB})\right\} \tag{28}$$

Based on this, the system of linearized equations of the banking part of the model can be expressed as follows: The first equation related to the banking network is the optimal debt ratio, which is linearized in the form of equation (30):

$$\hat{\eta}_t = \frac{\bar{\phi}\bar{\lambda}}{\eta}\hat{\phi}_t + \frac{\bar{\phi}\bar{\lambda}}{\eta}\hat{\lambda}_t - \frac{\bar{\phi}\bar{v}}{\eta}\hat{v}_t - \frac{\bar{\phi}\bar{v}}{\eta}\hat{\phi}_t \tag{30}$$

The net worth of all banks in the banking network is defined as relation (31):

$$\widehat{N}_t = \frac{\overline{N_e}}{\bar{N}}\widehat{N}_{et} + \frac{\overline{N_n}}{\bar{N}}\widehat{N}_{nt} \tag{31}$$

that the net value of newly established banks was as (32):

$$\widehat{N}_{nt} = \widehat{Q}_t + \widehat{K}_{t-1} \tag{32}$$

Moreover, the net value of existing banks is in the form of relation (33):

$$\widehat{N}_{et} = \hat{z}_t + \widehat{N}_{t-1} \tag{33}$$

The growth rate of the bank's capital is also defined as follows:

$$\hat{z}_t = \frac{\bar{R}_k\bar{\phi}}{\bar{z}}\widehat{R}_{kt} + \frac{\bar{R}_k\bar{\phi}}{\bar{z}}\hat{\phi}_{t-1} - \frac{\bar{R}\bar{\phi}}{\bar{z}}\hat{\phi}_{t-1} - \frac{\bar{R}\bar{\phi}}{\bar{z}}\widehat{R}_t + \frac{\bar{R}}{\bar{z}}\widehat{R}_t \tag{34}$$

The growth rate of the bank's net worth is as follows:

$$\hat{x}_t = \hat{\phi}_t - \hat{\phi}_{t-1} + \hat{z}_t \tag{35}$$

The linear relationship of banks' net wealth is also defined as (36):

$$\hat{\eta}_t = \beta\bar{\Lambda}\theta\bar{Z}\left(\widehat{\Lambda}_{t+1} + \hat{Z}_{t+1} + \hat{\eta}_{t+1}\right) \tag{36}$$

Also, according to the definition, the amount of bank capital is equal to:

$$\hat{v}_t = \frac{\beta\bar{\Lambda}(1-\theta)\bar{R}}{\bar{v}}\left(\widehat{\Lambda}_{t+1} + \widehat{R}_{kt+1} - \widehat{R}_t\right) + \beta\bar{\Lambda}\theta\bar{x}\left(\widehat{\Lambda}_{t+1} + \hat{x}_{t+1} + \hat{v}_{t+1}\right) \tag{37}$$

The linearization of the portfolio of facilities granted by banks is as follows:

$$\hat{S}_t = \hat{\phi}_t + \widehat{N}_t - \widehat{Q}_t \tag{38}$$

The linearized balance sheet of the banking network is defined as follows:

$$\widehat{D}_t = \frac{\bar{Q}\bar{S}}{\bar{D}}\left(\widehat{Q}_{t-1} + \hat{S}_{t-1}\right) - \frac{\bar{N}}{\bar{D}}\widehat{N}_{t-1} \tag{39}$$

Also, the linearized weighted interest rate due to standard banks and shadow banks is as follows:

$$\widehat{R}_t^w = -\widehat{B}_t + \frac{\bar{R}\bar{D}}{\bar{R}^w}\left(\widehat{R}_t + \widehat{D}_t\right) + \frac{\bar{R}^{SB}\overline{FS}}{\bar{R}^w}\left(\widehat{R}_t^{SB} + \widehat{FS}_t\right) \tag{40}$$

The dynamics of shadow banking shares are as follows:

$$\widehat{FS}_t = (1-\chi^{SB})\widehat{FS}_{t-1} + \frac{\bar{q}\bar{v}}{\overline{FS}}(\hat{q}_t + \hat{v}_t) \tag{41}$$

The linearization of the Euler equation related to the promotion of shares of the shadow sector is as follows:

$$\hat{J}_{t+1} = \beta\bar{\Lambda}\bar{R}\left(\widehat{R}_{kt+1} + \hat{J}_t\right) - \beta\bar{\Lambda}\bar{R}^{SB}\left(\hat{J}_t + \widehat{R}_{t+1}^{SB}\right) + (1-\chi^{SB})\hat{J}_t \tag{42}$$

The profit of financial intermediaries to creditors is defined as follows:

$$\widehat{K}_{t+1} = \frac{\bar{S}}{\bar{K}}\hat{S}_{t+1} + \frac{\bar{S}^{SB}}{\bar{K}}\hat{S}_t^{SB} \tag{43}$$

The shadow banking interest rate is as follows:

$$\widehat{R}_t^{SB} = (1-\omega^{HH})\frac{\bar{R}}{\bar{R}^{SB}}\widehat{R}_{t+1} + \omega^{HH}\frac{\bar{R}_k}{\bar{R}^{SB}}\widehat{R}_{kt} + \omega^{HH}\frac{\bar{\theta}}{\bar{R}^{SB}}\hat{\theta}_t \tag{44}$$

Also, the probability that shadow banking attracts resources is defined as follows:

$$\hat{q}_t = -\xi\hat{\theta}_t \tag{45}$$

The shadow banking search function is as follows:

$$\hat{\theta}_t = -\frac{\bar{D}}{\bar{D}+\overline{FS}}\hat{D}_{t+1} + \frac{\overline{FS}}{\bar{D}+\overline{FS}}\widehat{FS}_t + \frac{\bar{v}}{\bar{D}+\overline{FS}}\hat{v}_t \tag{46}$$

Moreover, finally, the amount of savings is defined as follows:

$$\hat{B}_t = \frac{\overline{FS}}{\bar{B}}\widehat{FS}_t + \frac{\bar{D}}{\bar{B}}\hat{D}_t \tag{47}$$

3.3. Firms

The final producer company is actually an entity that gathers all the produced goods and sells them in a market structure. The main feature of the mentioned company, which plays the role of an intermediary in the supply of goods and services, is that it is a perfect competition; that is, it does not make a profit from the supply and sale of goods and services.

The final company acts in such a way that it absorbs the goods produced by the companies $Y_t(i)$, Furthermore, from their combination and supply to the market it determines the gross domestic product:

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{1}{1+\lambda_{f,t}}} di\right]^{1+\lambda_{f,t}} \tag{48}$$

where Y_t is the gross domestic product, and λ_t is the markup of intermediary companies. The general level of prices for this producer is such that the profit of its buying and selling operations is equal to zero:

$$P_t = \left[\int_0^1 P_t(i)^{-\frac{1}{\lambda_t}} di\right]^{-\lambda_t} \tag{49}$$

where P_t is the index of the total price of domestically produced goods and $P_t(i)$ is the price of the i-th product.

On the other side, there are intermediate production companies that are characterized by index i; This category of companies has a technology function to combine labor and capital production factors, through which the level of gross domestic product is determined (Smet & Waters, 2007):

$$Y_t(i) = K_t(i)^{\alpha}(Z_t L_t(i))^{1-\alpha} \tag{50}$$

In this regard, parameter α is the share of capital in production and Z_t is the labor productivity process. In order to determine the company's demand for labor and capital, the intermediate company hires a level of agents that has the minimum cost for the company, which results in extracting the first-order optimal condition as follows:

$$\frac{w_t L_t(i)}{r_t^k K_t(i)} = \frac{1-\alpha}{\alpha} \tag{51}$$

In the second stage, the intermediary company chooses a path of the price level that maximizes its expected profit during a period:

$$E_t \sum_{i=0}^{\infty} \beta^i \psi_p^i \lambda_{t+i}\, y_{t+i} \left[\frac{\tilde{P}_t(i)}{P_t} \left(\frac{\left(\frac{P_{t-1+i}}{P_{t-1}}\right)^{\gamma_p}}{\frac{P_{t+i}}{P_t}} \right) - \left(1 + \lambda_{p,t+i}\right) mc_{t+i} \right] = 0 \qquad (52)$$

In the above-maximized profit function, ψ_p^i is the degree of flexibility of companies in determining prices and γ_p is the price adjustment compared to the inflation of the previous period and mc_t is the actual final cost of the company. Based on this, the company's first-order optimal conditions are obtained as follows:

$$\hat{\pi}_t = \frac{\beta}{1+\beta\gamma_p} E_t \hat{\pi}_{t+1} + \frac{\gamma_p}{1+\beta\gamma_p} \hat{\pi}_{t-1} + \frac{1}{1+\beta\gamma_p} \frac{(1-\psi_p\beta)(1-\psi_p)}{\psi_p} \qquad (53)$$

$$\widehat{mc}_t = (1-\alpha)\widehat{w}_t + \alpha \hat{r}_t^k \qquad (54)$$

$$\hat{y}_t = \alpha \hat{k}_t + (1-\alpha)\hat{L}_t \qquad (55)$$

$$\hat{r}_t^k = (1-\alpha)\left(\hat{L}_t - \hat{k}_t\right) \qquad (56)$$

$$\hat{L}_t = -\widehat{w}_t + \hat{r}_t^k + \hat{k}_t \qquad (57)$$

where π^_t is the country's inflation rate.

Based on the study of Gertler, Sala, and Trigari (2007), it is assumed that companies act in two ways to determine wages: one proportion of them determines the new wage through negotiation, and the other group determines the new wage through wage adjustment compared to the inflation of the previous period. Specify According to the nature of the labor market in Iran, almost all economic enterprises determine the new wage through wage adjustment based on a ratio of the previous period's inflation. Accordingly, in this model, the wage determination relationship is assumed as follows:

$$W_t = W_{t-1}(1 + \alpha_\pi \pi_{t-1}) \qquad (58)$$

where α_π is the percentage of inflation in determining the new salary. Based on this, the linearization of this expression is as follows:

$$\widehat{w}_t = \widehat{w}_{t-1} + \alpha_\pi \hat{\pi}_{t-1} - \hat{\pi}_t \qquad (59)$$

3.4. Central bank

Over the past years, the investigation of the central bank's behavior shows that the monetary policymaker has never used a specific monetary rule in order to react to economic fluctuations. In contrast, the behavior of the financial policymaker has been defeated. Therefore, in this study, no policy rule is defined for the central bank, and in the modeling, attention is paid to the fact that the country's money supply is not based on a specific policy rule, which is based on the net amount of the central bank's foreign reserves (the conversion of government currencies into Rials) and government debt. (in other words, the amount of budget deficit) is determined. Accordingly, instead of explaining a monetary rule for the central bank, the definition of the monetary base is used:

$$M_t = NFA_t + GDB_t + NOT_t \qquad (60)$$

In this NOT_t is the net of other items, GDB_t is the government debt to the central bank and NFA_t is the net of foreign reserves of the central bank, which is defined as follows:

$$NFA_t = NFA_{t-1} + NX_t \qquad (61)$$

which is net export NX_t.

The state budget can be expressed as follows:

$$b_t^g = g_t + (1 + r_{t-1})\frac{b_{t-1}^g}{1+\pi_t} - t_t - \left(gdb_t - \frac{gdb_{t-1}}{1+\pi_t}\right) - \alpha_{oil} oil_t \quad (62)$$

where b_t^g is the level of the government's real debt, g_t is the government's actual expenses, r_(t-1) the interest rate of the government's debt in the previous period, t_t is the actual level of taxes, gdb_t is the government's real debt to the central bank and oil_t is the actual income. The export is oil, of which the government's share is equal to α_{oil}. In this structure, it is assumed that the tax revenue of the government is determined as follows:

$$t_t = \rho_{tr} t_{t-1} + \rho_y y_t \quad (63)$$

To describe the dynamics of other model variables, autocorrelation equations are used as follows:

$$\hat{\mu}_t^k = \rho_\mu \hat{\mu}_{t-1}^k + \varepsilon_t^\mu \quad (64)$$

$$\widehat{gdb}_t = \rho_{gdb} \widehat{gdb}_{t-1} + \varepsilon_t^{gdb} \quad (65)$$

$$\widehat{Yoil}_t = \rho_{yoil} \widehat{Yoil}_{t-1} + \varepsilon_t^{yoil} \quad (66)$$

$$\widehat{Ynonoil}_t = \rho_{ynonoil} \widehat{Ynonoil}_{t-1} + \varepsilon_t^{ynonoil} \quad (67)$$

$$\hat{\pi}_{s,t} = \rho_{\pi s} \hat{\pi}_{s,t-1} + \varepsilon_t^{\pi s} \quad (68)$$

$$\widehat{NOT}_t = \rho_{NOT} \widehat{NOT}_{t-1} + \varepsilon_t^{NOT} \quad (69)$$

$$\hat{g}_t = \rho_g \hat{g}_{t-1} + \varepsilon_t^g \quad (70)$$

At the end, the market settlement condition is stated as follows:

$$\hat{y}_t = \frac{\bar{C}}{\bar{Y}}\hat{C}_t + \frac{\bar{G}}{\bar{Y}}\hat{G}_t + \frac{\bar{I}}{\bar{Y}}\hat{\imath}_t + \frac{\overline{NX}}{\bar{Y}}\widehat{NX}_t \quad (71)$$

4. Empirical Results

The data used in this study include the monetary base, policy interest rate, gross domestic product (GDP), total exports, investment expenditures, oil exports, inflation rate, private sector consumption, nominal exchange rate, import volumes, taxes, and the net foreign assets of the central bank. Additionally, the ratios of steady-state values and the variance of shocks have been calculated and calibrated, respectively. The model's structural parameters have been estimated using seasonal data from 2019 to 2020, employing the Bayesian method, with the results presented in Table (1).

To verify the accuracy of the estimated results, diagnostic tests related to the Bayesian method are employed, as outlined below.

Table 1. The result of the estimation of the parameters

Parameter	Prior Mean	Posterior Mean	Prior PDF	Standard Deviation
h	0.7	0.9	Beta	0.12
σ_c	1.5	2.05	Gamma	0.2
a"	0.2	0.3	Beta	0.05
δ	0.02	0.02	Beta	0.005
σ_m	1.5	0.67	Gamma	0.2
γ_p	0.6	0.63	Beta	0.1

Parameter	Prior Mean	Posterior Mean	Prior PDF	Standard Deviation
α	0.3	0.42	Beta	0.03
ρ_2	0.83	0.85	Beta	0.1
ρ_{yoil}	0.23	0.23	Beta	0.03
ρ_{gdb}	0.42	0.41	Beta	0.07
ρ_{tr}	0.78	0.82	Beta	0.09
ρ_{y}	0.14	0.13	Beta	0.02
ρ_{g}	0.67	0.82	Beta	0.12

Source: *Research finding*

4.1. MCMC Statistic

The Monte Carlo Markov Chain (*MCMC*) algorithm is used to estimate the model's parameters by generating samples from a probability distribution function. For the algorithm to be effective, the variance between each chain must tend to zero, indicating no difference between the characteristics of the samples from each chain. Based on this, criterion, the output related to these statistics, produces two graphs: the blue graph represents the weighted average of the variance within each chain and the variance between the chainswhile the red graph depicts the variance within each chain.

The parameters of the model are considered optimally fitted if, firstly, the variance between the chains tends to zero, and secondly, as the sample size increases, the variance within each chain stabilizes to a constant value. These two characteristics can be observed in Chart (1).

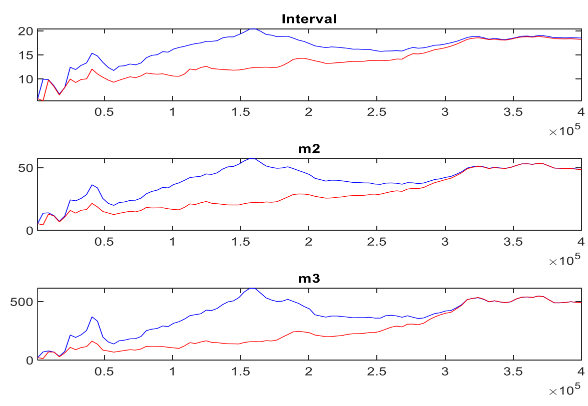


Diagram 1. MCMC of Model
Source: *Research finding*

4.2. Smoothed Shocks

The smoothed shocks are calculated using all available sample information to reproduce the values of the unobserved shocks during the sample period. These calculations are performed using the Kalman smoother. Unlike ordinary least squares regression, the Bayesian method does not inherently require that the sum of the shocks equals zero, although the model assumes their average is zero. Therefore, if the output related to the smoothed shocks systematically deviates from zero, the model may have issues. Diagram (2) illustrates the output of the smoothed shocks, indicating that they are centered around zero Thus, the does not suffer from model

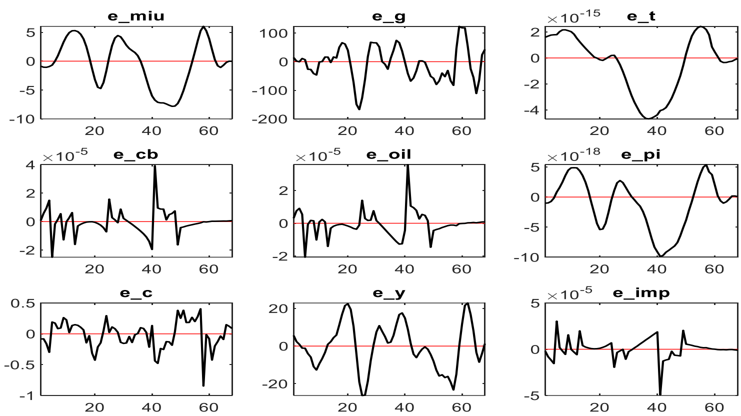
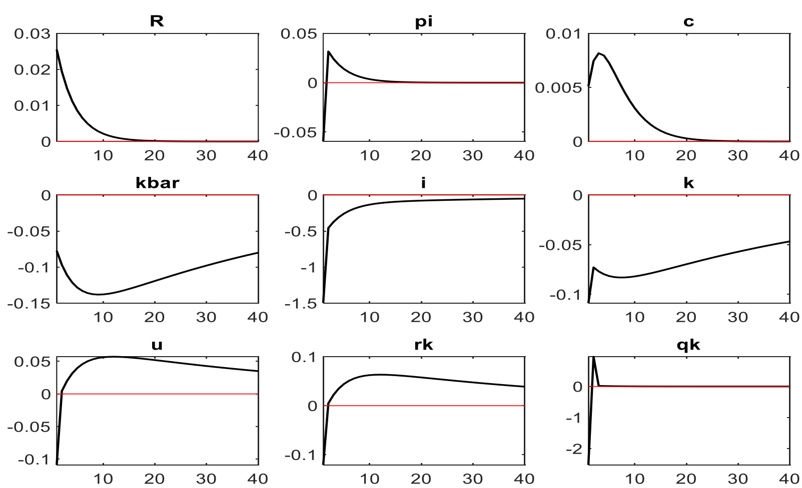


Diagram 2. Smoothed shocks
Source:*Research finding*

In order to investigate the mechanism of monetary transmission in this structure, firstly, the effect of a unit increase in the deposit interest rate in the shadow banking sector on macroeconomic variables is investigated, the results of which are shown in graph (3):



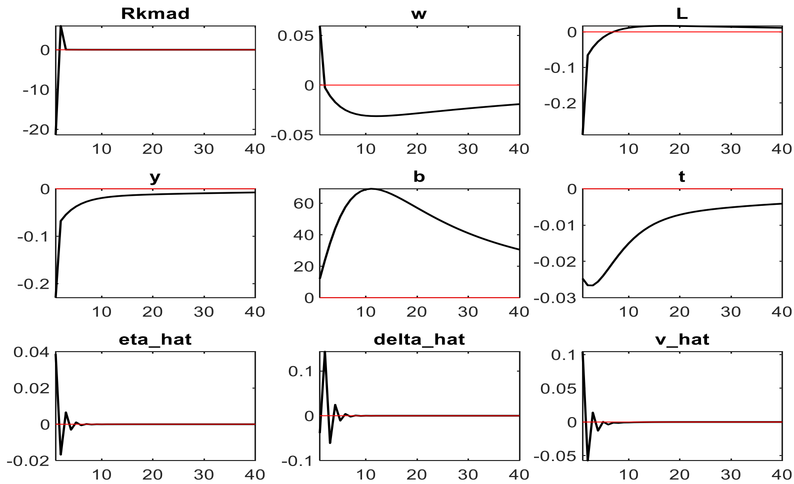


Diagram 3. Reaction of model variables to shadow banking interest rate shock
Source: *Research finding*

Based on the simulation results, an increase in the interest rate in the shadow banking sector leads to an increase in the interest rate in the standard banking sector (R) (as described in Equation 21). When the interest rate rises in one sector of the economy, resources are drawn to that sector. To maintain competitiveness, other sectors are compelled to raise their rates, either officially (within the framework of regulations set by the supervisory body) or unofficially (without adhering to laws and directives). As interest ates rise, investment costs in the economy increase, leading to a decrease in investment levels andconsequently, a reduction in the economy's capital stock.

With reduced investment levels, a portion of the economy's total demand diminishes, resulting in a decrease inflation relative to its long-term level. However, because the reduction in inflation surpasses the increase in the economy's interest rate, the changes in the real interest rate are adverse, leading to an increase in private-sector consumption.

Ultimately, despite the rise in private sector consumption, the economy's production level decreases relative to its long-term. This decrease indicates lower production alongside a reduced level of aggregate demand for goods and services. As production declines, the demand for labor decreases, and the government's tax revenues diminish.

(Graph 4), illustrates the effects of a unit increase in the facility interest rate

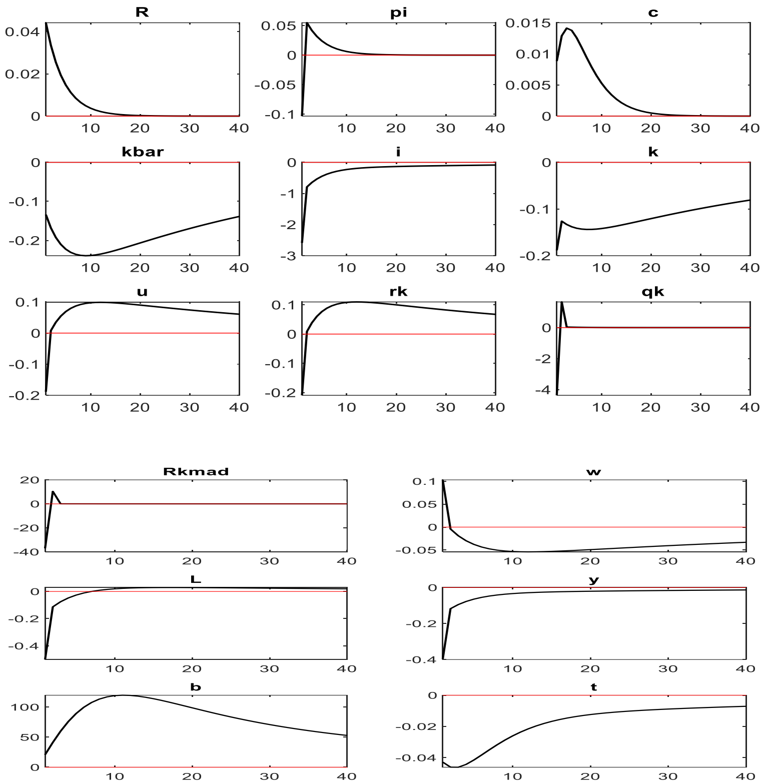


Diagram 4. Reaction of model variables to standard banking interest rate shock
Source: *Research finding*

According to (Graph 4), an increase in the interest rate in the economy, coupled with rising investment costs, leads to a decrease in the level of investment. This, in turn, causes a reduction in the inflation rate compared to its long-term level and an increase in the consumption costs of the private sector relative to its long-term level. Developments in the investment sector cause the equilibrium production level of the economy to decline compared to its long-term level, resulting in a decreased demand for production factors.

5. Concluding Remarks

This study aimed to investigate the role and significance of the shadow banking sector in Iran's economy. To analyze this structure, a stochastic dynamic general equilibrium (SDGE) model incorporating the shadow banking sector was developed. The structural parameters of this model were estimated using the Bayesian method. Simulation results, based on the estimated parameters, indicate that the monetary transmission mechanism specifically interest rate changes within the shadow banking sector functions similarly to the conventional monetary transmission mechanism in the standard banking sector. Consequently, developments within the shadow banking sector can significantly influence the trajectory of key economic variables.

Author Contributions

In all stages of writing the article, including conceptualization, methodology, validation, formal analysis, preparation of the primary draft, review and editing, and supervision, all authors of the published version have read and agreed with the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

Data Availability Statement

The data used in the study were taken from:
https://www.cbi.ir/BanksInstitutions/BankInstitute.aspx
https://www.fipiran.com
https://www.cbi.ir/BanksInstitutions/BankInstitute.aspx
https://www.cbi.ir/category/2692.aspx

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