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Effect of Sentiments on Macroeconomic Variables in Iran: A Dynamic Stochastic General Equilibrium Approach

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This study aims to evaluate the effect of sentiments on Iran's economy through a New Keynesian Dynamic Stochastic General Equilibrium model in a closed economy. In this study, the coefficients of the proposed model are calibrated and estimated using the quarterly data of Iran's economy from 2004 to 2015. It shows that in the presence of sentiment, how stochastic impulses affect the main macroeconomic variables. Also, for more adaptation of the model to the real world, and considering the importance and role of stickiness the effect of nominal variables on production (price stickiness) is introduced to the model. In this model, the response of macroeconomic variables to exogenous shocks of idiosyncratic demand, idiosyncratic noise, monetary policy, oil revenues, government expenditures, target inflation, and technology has been evaluated. The results obtained from the review of the impulse response functions indicate that with the occurrence of idiosyncratic demand shocks and idiosyncratic noise shocks, fluctuations in the level of macro variables do not differ in terms of the sign of the initial effect. Idiosyncratic demand and noise shocks impact on output, investment, employment, and consumption has a primary positive effect; it just has negative effects on inflation; they are different in the amount of variations; so that in the case of idiosyncratic noise shock, the initial change after the shock is much higher.

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JEL Classification*:* D81, D83, E2, E3

1 Introduction

All of economics is meant to be about people's behavior, and for this reason, economists have incorporated an increasing number of results from behavioral economics into macroeconomic models. Indeed, psychological factors play an important role in economic fluctuations, but they are typically omitted from

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modern macroeconomic models. Economists such as John Maynard Keynes and Hyman Minsky recognized the existence of sentiments and emphasized the sudden changes in expectations to explain the fluctuations of business cycles in their writings, but their ideas were not entirely considered by the mainstream economics (Van Aarle & Kappler, 2012). However, the concept of economic sentiment and its changes have recently been addressed in the macroeconomic literature.

There are three competing views or conceptual frameworks in the recent literature on the role of sentiment in the economic fluctuation: 1) Irrational animal spirits, 2) Self-fulfilling animal spirits, and 3) News.

Irrational animal spirits advocates (dating back to Keynes (1936), but more recently Akerlof and Shiller (2010) and De Grauwe and Ji (2016)) see the cause of macroeconomic fluctuations in purely psychological waves of optimism and pessimism, implying that any expansion driven by animal spirits must eventually lead to a bust as fundamentals remain unaffected.

Self-fulfilling animal spirits advocates (e.g. Farmer (1999), Farmer (2012b), Farmer (2013), Acharya et al. (2017), Benhabib et al. (2016), Benhabib et al. (2015)) also see the root of macroeconomic fluctuations in purely psychological, sunspot-driven waves, but believe that precisely the actions following these waves lead to changes in fundamentals making the initial boom or bust in confidence rational as expectations eventually materialize.

News advocates (e.g. Beaudry and Portier (2014), Beaudry and Portier (2006), Barsky and Sims (2012), Blanchard et al. (2013)) on the other hand, believe that agents have access to a non-measurable source of imperfect information about future developments of the economy; a signal, which makes them act as to cater to the economy's future demand today. In this framework, the economy is subject to recurrent booms (if the signal was correct) and occasional busts (if the signal was false).

In modern dynamic stochastic general equilibrium (DSGE) models, the main source of fluctuations is usually the shocks to demand, such as exogenous shifts in preferences, risk-premia, and monetary and fiscal policies, shocks related to technology, such as Hicks-neutral or investment-specific technology shocks, or to market power, such as price and wage markup shocks. While the empirical DSGE in macro literature disagrees on the relative contributions of each shock, most of it implicitly agree on assigning a nil role to explanations based on non-fundamental expectational shifts, such as swings in sentiment that are not necessarily motivated by fundamentals (Milani, 2017).

Recently, models in this form have been investigated, in which fluctuations can be extracted by waves of optimism or pessimism that are distinct from fundamental principles. Shifts in market sentiment and aggregate demand often appear to obtain without obvious innovations in people's tastes and abilities, firms' know-how, and the like. Sentiment-driven equilibria exist because firms must make production decisions before the realization of demand, and households must make labor supply decisions and consumption plans before the realization of production. When firm decisions are based on expected demand, and household decisions are based on expected income, equilibrium output can be affected by consumer sentiments (Benhabib et al., 2015).

The recent crisis in Iran brings these ideas back onto the agenda, as it appears to be fraught with aspects that can be related to sentiment. Consider, for example, the recent exchange rate crisis and subsequent inflation. The earlier boom in exchange rate markets has been attributed to exuberant beliefs about future prices; the subsequent bust came with a fast reversal in these beliefs, and the ongoing recovery is said to hinge on how quickly firms and households regain their confidence in the economy. The reason for this change in expectations cannot be explained by conventional economic reasons. These waves of optimism or pessimism can explain some of these changes, which we call it by the term "sentiments".

To demonstrate our basic insights, we build on the signal structure originally explored by Benhabib et al. (2015). In this paper, we want to show how extrinsic variation in market expectations and forces akin to sentiment can be accommodated in the modern DSGE paradigm without abandoning the discipline of either rational expectations or equilibrium uniqueness. Indeed, this paper applied an approach to introduce psychology at the center of macroeconomic analysis, by modeling 'sentiment' in a micro-founded DSGE model of the Iranian economy. The paper's main objective was to investigate whether the typically omitted sentiment matters for aggregate fluctuations.

In this regard, we tried to formalize the effect of sentiment by designing a New Keynesian DSGE model using the second approach introduced above. So then, in the second part, we will review the literature. The third part of this article is devoted to the research methodology. In the fourth section, the model is estimated, and the results are presented in the final section.

2 Literature Review

Angeletos and Lao (2013), in his article "Sentiment", developed a new theory of volatility that helps to adapt the concepts of "animal spirit" and "market sentiment" in a unique equilibrium, rational expectations, and macroeconomics models. For this purpose, they restricted communication. Subsequently, they showed that the business cycle might be extracted by a specific type of external shock that we call sentiments. These shocks shape changes in expectations of economic activity without changing the preferences and basic technologies; they are similar to sunspots but are used in unique-equilibrium models. Besides, they showed how communication might help propagate these shocks in a way that resembles the spread of fads and rumors, and that gives rise to boom-and-bust phenomena. They finally illustrate the quantitative potential of their insights within a variant of the RBC model.

Arias (2014), in his research entitled "Sentiment Shocks as Drivers of Business Cycles," addresses the role of sentiment shock as a source of business cycle fluctuations. Taking into account the New Keynesian standard of the business cycle, this paper introduces agents who update beliefs about the parameters of their forecasting models using newly observed data and exogenous sentiment shocks. The resulting learning model fits U.S. data better than its non-sentiment version and then its rational expectations counterpart. The sentiment is found to be an important driver of economic fluctuations, accounting for up to half of the forecast error variance of aggregate variables at business cycle frequencies. Furthermore, sentiment displays a common pattern for real GDP, investment, and consumption growth, where a significant part of the sluggish recovery following a recession can be attributed to the persistent pessimistic views of agents. Sentiment also explains a substantial fraction of the high inflation experienced during the ’70s and early ’80s.

Benhabib et al. (2015) formulated the Keynesian insights in their study entitled "Sentiments and Aggregate Demand Fluctuations," where the aggregate demand derived from sentiments can generate product fluctuations under rational expectations. When production decisions must be made on inadequate information about demand, optimal decisions based on sentiments can generate stochastic self-fulfilling rational expectations equilibria in standard economies without persistent informational frictions, externalities, nonconvexities, or strategic complementarities in production.

Benhabib et al. (2016) in another study entitled "Sentiments, Financial Markets, and Macroeconomic Fluctuations" investigates how financial information frictions can generate sentiment-driven fluctuations in asset prices and self-fulfilling business cycles. Their model demonstrates that sentiment shocks can generate persistent output, employment, and business cycle fluctuations, and it offers some new implications for asset prices over business cycles.

Chahrour and Gaballo (2015), in their article "On the Nature and Stability of Sentiments," showed that non-trivial aggregate fluctuations might originate with vanishingly-small common shocks to either information or fundamentals. These sentiment fluctuations can be driven by self-fulfilling variation in either first-order beliefs (as in Benhabib, Wang, and Wen, 2015) or higher-order beliefs (as in Angeletos and La'O, 2013). They show how the signal structures required for such fluctuations can arise endogenously in a simple monetary model where agents learn from prices. Away from the limit, the same signal structures can deliver strong amplification of aggregate shocks.

Milani (2017), in his review of "Sentiment and the U.S. Business Cycle," introduces “sentiment” in a medium-scale DSGE model of the U.S. economy and tests the empirical contribution of sentiment shocks to business cycle fluctuations. The results show that exogenous variations in sentiment are responsible for a sizable (above forty percent) portion of historical U.S. business cycle fluctuations. Sentiment shocks related to investment decisions, which evoke Keynes’ animal spirits, play the largest role. When the model is estimated, imposing the rational expectations hypothesis, instead, the role of structural investment-specific and neutral technology shocks significantly expands to capture the omitted contribution of sentiment.

Levchenko and Nayar (2018) proposed in their article "TFP, News, and Sentiments: The International Transmission of Business Cycles," a novel identification scheme for a non-technology business cycle shock, that we label sentiment. It is a shock orthogonal to identified surprise and news TFP shocks that maximize the short-run forecast error variance of an expectational variable, alternatively a GDP forecast or a consumer confidence index. They showed US sentiment shock produces a business cycle in the US, with output, hours, and consumption rising following a positive shock, and accounts for the bulk of US short-run business cycle fluctuations. The sentiment shock also has a significant impact on Canadian macroaggregates.

3 Model

The model is based on Benhabib et al. (2015), consisting of a representative household, firms, and the government-Central Bank. Households obtain utility from consumption of goods and services, leisure and real money balance. They keep a part of his income in bonds and decide on the labor supply in each period.

The key feature of our model is that production and employment decisions by firms, and consumption and labor supply decisions by households are made before goods being produced and exchanged and before market-clearing prices are realized. To provide an early road map, we start by describing the sequence of actions by consumers and firms, the information structure, and the rational expectations equilibria of our benchmark model.

1) At the beginning of each period, households form expectations on aggregate output/income based on their sentiments. They also form demand functions for each differentiated good based on their sentiments and the idiosyncratic preference shocks on each good, contingent on the prices to be realized when the goods markets open.
2) Like households, firms also believe that aggregate output/demand could be driven by sentiments. Unlike households, firms do not directly observe households' sentiments or idiosyncratic preference shocks. Firms instead receive a noisy signal about their demand, which is a mixture of firm-specific demand (idiosyncratic preference shocks) and aggregate demand (sentiments).
3) Given a nominal wage, households make labor supply decisions based on their sentiments and the expected real wage, and firms make employment and production decisions based on their signals. At this point, the goods markets have not yet opened, goods prices have not been realized, and there is no guarantee that labor demand will automatically equal labor supply and that the labor market will clear. We will show, however, that in equilibrium, where the distribution of sentiments is pinned down, labor supply will always equal labor demand.
4) Goods markets open, goods are exchanged at market-clearing prices, and the real wage and actual consumption are realized.

In this case, there can be two equilibria that each of them forms a rational expectations equilibrium, in the sense that for each realization of the sentiment shock, 1. The labor demanded by firms and supplied by households (based on expected real wages) will be equal; 2. Goods demanded by households and supplied by firms (based on expected prices) will be equal; 3. The expected aggregate output based on consumer sentiments will be equal to the realized aggregate output produced by firms conditioned on their signals for demand, and the expected prices and real wages will be equal to the realized prices and wages (Benhabib et al., 2015).

3.1 Households

The benchmark model features a representative household that consumes a continuum of consumption goods. Each of them is produced by a monopolistic producer indexed by $j \in [0,1]$. The continuum of consumption goods C_{jt} is aggregated into a "final" consumption good C_t according to the Dixit–Stiglitz aggregator

$$C_t = \left[\int \epsilon_{jt}^{1/\theta} C_{jt}^{(\theta-1)/\theta} dj\right]^{\theta/(\theta-1)} \quad (1)$$

where $\theta > 1$ is the elasticity of substitution, ϵ_{jt} is a log-normally distributed independent and identically distributed (i.i.d.) idiosyncratic shock with unit mean. The exponential $\frac{1}{\theta}$ on the shock ϵ_{jt} is a normalization device to simplify expressions later on. The household decision issue can be considered in a two-step function. First, it will always be optimal, regardless of the level of C_t that the household decides on, to buy a combination of the consumer goods continuum, C_{jt}, which minimizes the cost of reaching this level of final consumer goods. Secondly, considering the cost of reaching the given level of C_t, the household selects the optimal C_t, N_t, and M_t.

Assuming that Ψ_t is Lagrange coefficient of the first problem, the price index is obtained as follows:

$$\Psi_t \equiv \left[\int \epsilon_{jt} P_{jt}^{1-\theta} dj\right]^{1/(1-\theta)} \equiv P_t \quad (2)$$

The Lagrange coefficient is the total price index for consumption, so concerning each consumption level C_t and relative prices of goods $\frac{P_t}{P_{jt}}$, the household's optimal consumption demand for each good is given by:

$$C_{jt} = \left(\frac{P_t}{P_{jt}}\right)^{\theta} \epsilon_{jt} C_t \quad (3)$$

Subsequently, the representative household derives utility from aggregate consumption C_t, leisure $1-N_t$, and real money balance according to the following utility function, as an MIU[1] function:

[1] Money in Utility

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, N_t, \frac{M_t}{P_t}) \equiv logC_t + \psi_n(1 - N_t) + \psi_m \log(\frac{M_t}{P_t}) \quad (4)$$

In this function, $0 < \beta < 1$ is a discount factor, ψ_n is inverse elasticity of labor supply, and ψ_m is inverse elasticity of money demand. Households in each period are going to supply N_t unit of labor and K_t unit of capital to firms and earn W_t and R_t respectively. Furthermore, households receive total factor payment W_t N_t + R_t K_t and dividend payments from intermediate goods-producing firms, $\prod_t$. It should be noted that N_t and K_t are respectively the sum of capital and labor supplied to each of the firms, such that:

$$N_t = \int_0^1 N_t(j)dj \qquad K_t = \int_0^1 K_t(j)dj$$

Based on these assumptions, the household budget constraint is as follows:

$$\int_0^1 P_{jt}C_{jt}dj + P_tI_t + M_t + B_t \leq R_tK_{t-1} + W_tN_t + M_{t-1} + \Pi_t - T_t + (1 + i_{t-1})B_{t-1} \quad (5)$$

Where, P_{jt}, goods price, P_t, price indexation, I_t, investment, B_t, Nominal value of bonds, and T_t is a lump-sum tax on households.

Also, the budget constraint (5) can be simplified as follows:

$$P_tC_t + P_tI_t + B_t \leq R_tK_{t-1} + W_tN_t + M_{t-1} - M_t + \Pi_t - T_t + (1 + i_{t-1})B_{t-1} \quad (6)$$

$$C_t + I_t + \frac{B_t}{P_t} \leq \frac{R_t}{P_t}I_t + \frac{W_t}{P_t}N_t + \frac{M_{t-1}}{P_t} - \frac{M_t}{P_t} + \frac{\Pi_t}{P_t} - \frac{T_t}{P_t} + (1 + i_{t-1})\frac{B_{t-1}}{P_t} \quad (7)$$

On the other hand, private capital accumulation is formed based on the $K_t = I_t + (1 - \delta)K_{t-1}$ relationship. According to the budget constraint, the problem of optimizing a household is introduced using the Lagrangian equation (8).

$$L = E_0 \int_{t=0}^{\infty} \beta^t \left\{ \left[logC_t + \psi_n(1 - N_t) + \psi_m \log(\frac{M_t}{P_t}) \right] + \Lambda_t \left[\frac{R_t}{P_t}K_{t-1} + \frac{W_t}{P_t}N_t + \frac{M_{t-1}}{P_t} - \frac{M_t}{P_t} + \frac{\Pi_t}{P_t} - \frac{T_t}{P_t} + (1 + i_{t-1})\frac{B_{t-1}}{P_t}C_t - K_t + (1 - \delta)K_{t-1} + \frac{B_t}{P_t} \right] \right\} \quad (8)$$

The first-order conditions for a household are as follows:

$$\frac{\partial L_t}{\partial C_t} = \frac{1}{C_t} - \Lambda_t = 0 \tag{9}$$

$$\frac{\partial L_t}{\partial N_t} = -\psi_n + \Lambda_t \frac{W_t}{P_t} = -\psi_n + \Lambda_t w_t = 0 \tag{10}$$

$$\frac{\partial L_t}{\partial K_t} = -\Lambda_t + \beta E_t[r_{t+1} + (1-\delta)]\Lambda_{t+1} = 0 \tag{11}$$

$$\frac{\partial L_t}{\partial\left(\frac{M_t}{P_t}\right)} = \frac{\partial L_t}{\partial(m_t)} = \frac{\psi_m}{m_t} - \Lambda_t + \beta E_t \Lambda_{t+1} \frac{P_t}{P_{t+1}} = 0 \tag{12}$$

$$\frac{\partial L_t}{\partial\left(\frac{B_t}{P_t}\right)} = \frac{\partial L_t}{\partial(b_t)} = -\Lambda_t + \beta E_t \Lambda_{t+1}(1+i_t)\frac{P_t}{P_{t+1}} = 0 \tag{13}$$

Using the first-order conditions, the Euler equation, labor supply, real money demand, Fisher's equation, and bond demand are obtained. The supply of labor is obtained from the solving simultaneously equations (9) and (10).

$$w_t = \psi_n C_t \tag{14}$$

To obtain the relation for the demand of the real money balance, we put relations (9) and (13) in (12), and get:

$$\frac{\psi_m}{m_t} = E_t\left(\frac{i_t}{1+i_t}\right)\frac{1}{C_t} \tag{15}$$

The Euler equation is obtained by putting Eq. (9) in Eq. (13):

$$\beta E_t \frac{1}{C_{t+1}} \frac{(1+i_t)}{\pi_{t+1}} = \frac{1}{C_t} \tag{16}$$

And the next equation of Fisher's relationship, or the relationship between the rate of capital rent and the nominal return on the bonds of one period, is derived by placing relation (13) in relation (11).

$$E_t\left[\frac{(1+i_t)}{\pi_{t+1}}\right] = E_t[r_{t+1} + (1-\delta)] \tag{17}$$

3.2 Firms

Firms make production decisions before the goods markets open, and trade takes place. Firms thus naturally try to obtain information (through market surveys or forecasting agencies or early sales) about the specific demand C_{jt} for their products and the associated aggregate demand C_t before production and hiring decisions. They face a nominal wage W_t and a downward sloping demand curve given by (3), but prices, the real wage, and aggregate output have not yet been realized. We assume, therefore, that firms make optimal employment and production decisions based on market signals about household sentiments Z_t and idiosyncratic demand shocks ε_{jt}. In particular, as in the Lucas island model, we assume that firms receive a noisy signal s_{jt} that is a weighted average of firm-level demand ϵ_{jt} and the expected aggregate demand of households,

$$s_{jt} = \lambda log \in_{jt} + (1-\lambda) log Z_t + \vartheta_{jt} = \lambda \varepsilon_{jt} + (1-\lambda) z_t + \vartheta_{jt} \tag{18}$$

Where $\lambda \in [0,1]$ is the weight parameter, and ϑ_{jt} is an idiosyncratic noise that further contaminates the signal. The firms, therefore, face a signal extraction problem even if the variance of ϑ_{jt} is zero ($\sigma_{\vartheta}^2 = 0$) because uncertainty about the aggregate and idiosyncratic components of demand is not resolved until outputs are sold and markets are cleared by equilibrium prices.

Based on the signal, each firm chooses its employment and production to maximize expected profits. The final product Y_t is produced through a continuum of Y_{jt} intermediate goods. Assuming that all intermediate goods are incomplete substitutes with constant elasticity of substitution θ, the corresponding aggregator function can be defined as:

$$Y_t \leq \left[\int_0^1 \in_{jt}^{1/\theta} \ Y_{jt}^{(\theta-1)/\theta} dj\right]^{\theta/(\theta-1)} \qquad ,\theta > 1 \tag{19}$$

Regarding the relative price, final goods producer selects intermediate goods Y_{jt} to maximize its profit. So the optimization issues are:

$$\max_{Y_{jt}} E\left\{P_t \left[\int_0^1 \in_{jt}^{1/\theta} \ Y_{jt}^{(\theta-1)/\theta} dj\right]^{\theta/(\theta-1)} - \int_0^1 P_{jt} Y_{jt} dj\right\} \tag{20}$$

The first-order condition shows the following demand function for firm j's:

$$Y_{jt} \equiv \left(\frac{P_{jt}}{P_t}\right)^{-\theta} \in_{jt} Y_t \tag{21}$$

Which indicates the demand for goods j as a function of its relative price and final production.

Z_t denotes the consumer sentiments about aggregate output Y_t at the beginning of period t. In other words, we treat sentiments as the source of consumer expectations of aggregate income. At this point production has not taken place, so the market-clearing prices P_{jt}, the aggregate price index P_t, the real wage $\frac{W_t}{P_t}$, the profit Π_t, and aggregate output Y_t have not been realized. As a result, the actual output Y_t, actual consumption C_t, actual investment I_t and actual expenditure of government G_t are not yet observable. Based on its sentiments about aggregate output, the household believes that the aggregate level of consumption, investment, and government expenditure is $C_t^e + I_t^e + G_t^e = Z_t$, the aggregate price is P_t^e, and the expected profit is Π_t^e, which all depend on the anticipated aggregate output level Z_t.

$$Y_t = Z_t \tag{22}$$

Intermediate goods-producing firm:

The intermediate goods-producing firm j uses capital and labor services, K_{jt} and N_{jt}, to produce a differentiated output Y_{jt} according to the following constant-returns-to-scale technology:

$$Y_{jt} = A_t N_{jt}^{1-\alpha} K_{jt}^{\alpha} \quad , \alpha \in (0\,,1) \tag{23}$$

Where A_t is a technology shock that is common to all intermediate goods-producing firms. It is assumed that technology shock will follow the autoregressive process:

$$A_t = A_{t-1}^{\rho_A} \exp(e_{A_t}) \tag{24}$$

where $\rho_A \in (-1\,,1)$ is an autoregressive coefficient, and e_{A_t} is normally distributed with zero mean and standard deviation σ_A.

Firm Pricing:

Each firm j has monopoly power in its products and therefore plays an important role in regulating prices. In doing so, a firm faces with a quadratic cost function to adjust the nominal price according to final goods, so we have:

$$\frac{\varphi_p}{2}\left(\frac{P_{jt}}{(\pi_{t-1}^{\chi})^{\mu}(\pi_t^{*\chi})^{1-\mu}(P_{jt-1})} - 1\right)^2 Y_t \tag{25}$$

Where $\varphi_p > 0$ is the price-adjustment cost parameter. This relationship, as emphasized in Rotemberg (1982), seems to take into account the negative effects of price changes on consumer-firm. These negative effects increase with the size of the price change and the overall scale of economic activity. As in Ireland (2007), we show the inflation of the Central Bank's target with π^*. $\pi_{t-1} = \frac{P_{t-1}}{P_{t-2}}$ is aggregate level of inflation in the past period.

The parameter μ lies between zero and one: $0 \leq \mu \leq 1$. According to this specification, the extent to which price setting is backward instead of forward-looking depends on how close μ is to one. When $\mu = 0$ ($\mu = 1$), firms find it freewill to adjust their prices in line with the Central Bank inflation target (the previous period's inflation rate). χ instead plays the same role in the degree of indexation in the Calvo model. Notice that in the presence of indexation, expected future inflation has a more limited impact on price setting, since firms realize that they will be able to reduce its impact on their relative price through the automatic indexation mechanism (albeit partially and with a lag), until they have a chance to re-optimize again (Gali).

With the price adjustment costs, the optimization problem of the intermediate firm is dynamic; the intermediate goods-producing firm j chooses contingency plan for N_{jt}, K_{jt}, and P_{jt} for all $t \geq 0$ in which present value of the expected profit flows are maximized:

$$\max_{\{K_{jt}, N_{jt}, P_{jt}\}} E_0 \sum_{t=0}^{\infty} \beta^t \lambda_t \left(\frac{\Pi_{jt}}{P_t} \middle| S_{jt} \right) \tag{26}$$

Where the instantaneous profit function is equal to:

$$\Pi_{jt} = P_{jt} Y_{jt} - W_t N_{jt} - R_t K_{jt} - P_t AC_{jt} \tag{27}$$

In the target function of the firm, the discount factor is determined by the process $\beta^t \Lambda_t$, in which the Λ_t is called the final utility of real income. The j^{th} firm performs its optimization according to the constraints (21), (22) and the Lagrange coefficient $\xi_t > 0$.

$$\ell = E_t \left\{ \sum_{t=0}^{\infty} \beta^t \lambda_t \left[\left(\frac{P_{jt}}{P_t} \right)^{-\theta} \in_{jt} Y_t - \frac{W_t}{P_t} N_{jt} - \frac{R_t}{P_t} K_{jt} - \frac{\varphi_p}{2} \left(\frac{P_{jt}}{(\pi_{t-1}^{\chi})^{\mu} (\pi_t^{*\chi})^{1-\mu} (P_{jt-1})} - 1 \right)^2 Y_t \right] + \xi_t \left[A_t N_{jt}^{1-\alpha} K_{jt}^{\alpha} - \left(\frac{P_{jt}}{P_t} \right)^{-\theta} \in_{jt} Y_t \right] \middle| S_{jt} \right\} \tag{28}$$

The first-order conditions concerning N_{jt}, K_{jt}, and P_{jt} are as follows:

$$\frac{\partial \ell_t}{\partial N_{jt}} = (1-\alpha)\frac{\xi_t}{\Lambda_t}\frac{Y_{jt}}{N_{jt}} - \frac{W_t}{P_t} = 0 \tag{29}$$

$$\frac{\partial \ell_t}{\partial K_{jt}} = \alpha\frac{\xi_t}{\Lambda_t}\frac{Y_{jt}}{K_{jt-1}} - \frac{R_t}{P_t} = 0 \tag{30}$$

$$\frac{\partial \ell_t}{\partial P_{jt}} = E_t\left\{\Lambda_t(1-\theta)\left(\frac{P_{jt}}{P_t}\right)^{-\theta}\frac{\in_{jt}Y_t}{P_t} - \Lambda_t\varphi_p\left(\frac{P_{jt}}{(\pi_{t-1}^{\chi})^{\mu}(\pi_t^{*\chi})^{1-\mu}(P_{jt-1})} - 1\right)\frac{Y_t}{P_{jt-1}} + \beta\Lambda_{t+1}\varphi_p\left(\frac{P_{jt+1}}{P_{jt}} - 1\right)\frac{Y_{t+1}P_{jt+1}}{P_{jt}^2} + \xi_t\theta\left(\frac{P_{jt}}{P_t}\right)^{-\theta-1}\frac{\in_{jt}Y_t}{P_t}\right\}\Big|S_{jt} = 0 \tag{31}$$

By simplifying the equations (29) and (30) and dividing them into each other, there is a relation between the substitution of labor and capital inputs:

$$w_t = (1-\alpha)\frac{\xi_t}{\Lambda_t}\frac{Y_{jt}}{N_{jt}} \tag{32}$$

$$\mathrm{r}_t = \alpha\frac{\xi_t}{\Lambda_t}\frac{Y_{jt}}{K_{jt-1}} \tag{33}$$

$$\frac{w_t}{\mathrm{r}_t} = \frac{(1-\alpha)}{\alpha}\frac{K_{jt-1}}{N_{jt}} \tag{34}$$

Then: $K_{jt-1} = \frac{\alpha}{(1-\alpha)}\frac{w_t}{\mathrm{r}_t}N_{jt}$

In equations (32) and (33), the term ξ_t/Λ_t is the real final cost of $mc_t = MC_t/P_t$. Also, the Lagrange coefficient ξ_t is related to the function of the technology. As in Ireland (1997) and Dib (2003), the terms (33) and (34) point out that the markup price, q_{pt} (which measures the ratio of price to marginal cost) is equal to Λ_t/ξ_t.

Given that the firm has constant returns to scale, we can find the real marginal cost mc_t by setting the level of labor and capital equal to the requirements of producing one unit of a good $A_tN_{jt}^{1-\alpha}K_{jt-1}^{\alpha} = 1$ or:

$$A_tN_{jt}^{1-\alpha}K_{jt-1}^{\alpha} = A_tN_{jt}^{1-\alpha}\left(\frac{\alpha}{(1-\alpha)}\frac{w_t}{\mathrm{r}_t}N_{jt}\right)^{\alpha} = A_t\left(\frac{\alpha}{(1-\alpha)}\frac{w_t}{\mathrm{r}_t}\right)^{\alpha}N_{jt} = 1$$

that implies that: $N_{jt} = \frac{\left(\frac{\alpha}{(1-\alpha)}\frac{w_t}{\mathrm{r}_t}\right)^{-\alpha}}{A_t}$

Then:

$$mc_t = \left(\frac{1}{1-\alpha}\right)w_t\frac{\left(\frac{\alpha}{(1-\alpha)}\frac{w_t}{\mathrm{r}_t}\right)^{-\alpha}}{A_t}$$

that simplifies to:

$$mc_t = \left(\frac{1}{1-\alpha}\right)^{1-\alpha}\left(\frac{1}{\alpha}\right)^{\alpha}\frac{w_t^{1-\alpha}r_t^{\alpha}}{A_t} \tag{35}$$

Marginal cost does not depend on *j*: all firms receive the same technology shocks, and all firms rent and hire inputs at the same price (Villaverde & Ramirez, 2006).

Further, since $Y_t = Z_t$, then after simplification, equation (30) is also as follows:

$$\Lambda_t(1-\theta)\left(\frac{P_{jt}}{P_t}\right)^{-\theta}\frac{E_t\{\in_{jt}Y_t|S_{jt}\}}{P_t} - \Lambda_t\varphi_p\left(\frac{P_{jt}}{(\pi_{t-1}^{\chi})^{\mu}(\pi_t^{*\chi})^{1-\mu}P_{jt-1}} - 1\right)\frac{E_t\{Y_t|S_{jt}\}}{P_{jt-1}} +$$
$$\beta\varphi_p E_t\left\{\Lambda_{t+1}\left(\frac{P_{jt+1}}{(\pi_t^{\chi})^{\mu}(\pi_{t+1}^{*\chi})^{1-\mu}P_{jt}} - 1\right)\frac{P_{jt+1}E_t\{Y_{t+1}|S_{jt}\}}{P_{jt}^2}\right\} +$$
$$\xi_t\theta\left(\frac{P_{jt}}{P_t}\right)^{-\theta-1}\frac{E_t\{\in_{jt}Y_t|S_{jt}\}}{P_t} = 0$$

$$E_t\{\in_{jt}\,Y_t|S_{jt}\} = E_t\{\exp(\varepsilon_{jt}+z_t)|s_{jt}\} = \exp\left\{[E_t(\varepsilon_{jt}+z_t)|s_{jt}] + \frac{1}{2}var[(\varepsilon_{jt}+z_t)|s_{jt}]\right\}$$

$$E_t[(\varepsilon_{jt}+z_t)|s_{jt}] = \frac{cov(\varepsilon_{jt}+z_t, s_{jt})}{var(s_{jt})}s_{jt} = \frac{\lambda\sigma_\varepsilon^2+(1-\lambda)\sigma_Z^2}{\lambda^2\sigma_\varepsilon^2+(1-\lambda)^2\sigma_Z^2+\sigma_\vartheta^2}\left(\lambda\varepsilon_{jt} + (1-\lambda)z_t + \vartheta_{jt}\right)$$

$$B = \frac{\lambda\sigma_\varepsilon^2+(1-\lambda)\sigma_Z^2}{\lambda^2\sigma_\varepsilon^2+(1-\lambda)^2\sigma_Z^2+\sigma_\vartheta^2}\, E_t\{Y_t|S_{jt}\} = E_t\{\exp(z_t)|s_{jt}\} = \exp\left\{[E_t(z_t)|s_{jt}] + \frac{1}{2}var[(z_t)|s_{jt}]\right\}$$

$$E_t[(z_t)|s_{jt}] = \frac{cov(z_t, s_{jt})}{var(s_{jt})}s_{jt} = \frac{(1-\lambda)\sigma_Z^2}{\lambda^2\sigma_\varepsilon^2+(1-\lambda)^2\sigma_Z^2+\sigma_\vartheta^2}\left(\lambda\varepsilon_{jt} + (1-\lambda)z_t + \vartheta_{jt}\right)$$

$$B_1 = \frac{(1-\lambda)\sigma_Z^2}{\lambda^2\sigma_\varepsilon^2+(1-\lambda)^2\sigma_Z^2+\sigma_\vartheta^2}$$

$$E_t\{Y_{t+1}|S_{jt+1}\} = E_t\{\exp(z_{t+1})|s_{jt+1}\} = \exp\left\{[E_t(z_{t+1})|s_{jt+1}] + \frac{1}{2}var[(z_{t+1})|s_{jt+1}]\right\}$$

$$E_t[(z_{t+1})|s_{jt+1}] = \frac{cov(z_{t+1}, s_{jt+1})}{var(s_{jt+1})}s_{jt+1} = \frac{(1-\lambda)\sigma_Z^2}{\lambda^2\sigma_\varepsilon^2+(1-\lambda)^2\sigma_Z^2+\sigma_\vartheta^2}\left(\lambda\varepsilon_{jt+1} + (1-\lambda)z_{t+1} + \vartheta_{jt+1}\right)$$

$$\Omega_s = var[(\varepsilon_{jt}+z_t)|s_{jt}] = var(\varepsilon_{jt}+z_t) - \frac{[cov(\varepsilon_{jt}+z_t, s_{jt})]^2}{var(s_{jt})}$$

$$\Omega_s = \sigma_\varepsilon^2 + \sigma_z^2 - \frac{\left(\lambda\sigma_\varepsilon^2+(1-\lambda)\sigma_z^2\right)^2}{\lambda^2\sigma_\varepsilon^2+(1-\lambda)^2\sigma_z^2+\sigma_\vartheta^2} = \frac{(1-\lambda)^2\sigma_\varepsilon^2\sigma_z^2+\sigma_\varepsilon^2\sigma_\vartheta^2+\lambda^2\sigma_\varepsilon^2\sigma_z^2+\sigma_z^2\sigma_\vartheta^2-2\lambda(1-\lambda)\sigma_z^2\sigma_\vartheta^2}{\lambda^2\sigma_\varepsilon^2+(1-\lambda)^2\sigma_z^2+\sigma_\vartheta^2} = \frac{(2\lambda-1)^2\sigma_\varepsilon^2\sigma_z^2+\sigma_\varepsilon^2\sigma_\vartheta^2+\sigma_z^2\sigma_\vartheta^2}{\lambda^2\sigma_\varepsilon^2+(1-\lambda)^2\sigma_z^2+\sigma_\vartheta^2}$$

$$\Omega_s = \sigma_\varepsilon^2 + \sigma_z^2 - \frac{\left(\lambda\sigma_\varepsilon^2+(1-\lambda)\sigma_z^2\right)^2}{\lambda^2\sigma_\varepsilon^2+(1-\lambda)^2\sigma_z^2+\sigma_\vartheta^2} = \frac{(1-\lambda)^2\sigma_\varepsilon^2\sigma_z^2+\sigma_\varepsilon^2\sigma_\vartheta^2+\lambda^2\sigma_\varepsilon^2\sigma_z^2+\sigma_z^2\sigma_\vartheta^2-2\lambda(1-\lambda)\sigma_z^2\sigma_\vartheta^2}{\lambda^2\sigma_\varepsilon^2+(1-\lambda)^2\sigma_z^2+\sigma_\vartheta^2} = \frac{(2\lambda-1)^2\sigma_\varepsilon^2\sigma_z^2+\sigma_\varepsilon^2\sigma_\vartheta^2+\sigma_z^2\sigma_\vartheta^2}{\lambda^2\sigma_\varepsilon^2+(1-\lambda)^2\sigma_z^2+\sigma_\vartheta^2}$$

$$\Omega_{s_1} = var\left[(z_t)\middle|s_{jt}\right] = var(z_t) - \frac{\left[cov(z_t, s_{jt})\right]^2}{var(s_{jt})}$$

$$\Omega_{s_1} = \sigma_z^2 - \frac{\left((1-\lambda)\sigma_z^2\right)^2}{\lambda^2\sigma_\varepsilon^2+(1-\lambda)^2\sigma_z^2+\sigma_\vartheta^2} = \frac{\lambda^2\sigma_\varepsilon^2\sigma_z^2+\sigma_z^2\sigma_\vartheta^2}{\lambda^2\sigma_\varepsilon^2+(1-\lambda)^2\sigma_z^2+\sigma_\vartheta^2}$$

$$\Lambda_t(1-\theta)\frac{1}{P_t}\left(\frac{P_{jt}}{P_t}\right)^{-\theta}\exp\left\{B\left(\lambda\varepsilon_{jt}+(1-\lambda)z_t+\vartheta_{jt}\right)+\frac{1}{2}\Omega_s\right\} - \Lambda_t\varphi_p\left(\frac{P_{jt}}{\left(\pi_{t-1}^{\chi}\right)^{\mu}\left(\pi_t^{*\chi}\right)^{1-\mu}P_{jt-1}}-1\right)\frac{1}{P_{jt-1}}\exp\left\{B_1\left(\lambda\varepsilon_{jt}+(1-\lambda)z_t+\vartheta_{jt}\right)+\frac{1}{2}\Omega_{s_1}\right\} + \beta\varphi_p\Lambda_{t+1}\left(\frac{P_{jt+1}}{\left(\pi_t^{\chi}\right)^{\mu}\left(\pi_{t+1}^{*\chi}\right)^{1-\mu}P_{jt}}-1\right)\frac{P_{jt+1}}{P_{jt}^2}\exp\left\{B_1\left(\lambda\varepsilon_{jt+1}+(1-\lambda)z_{t+1}+\vartheta_{jt+1}\right)+\frac{1}{2}\Omega_{s_1}\right\} + \xi_t\theta\frac{1}{P_t}\left(\frac{P_{jt}}{P_t}\right)^{-\theta-1}\exp\left\{A\left(\lambda\varepsilon_{jt}+(1-\lambda)z_t+\vartheta_{jt}\right)+\frac{1}{2}\Omega_s\right\} = 0$$

In a symmetric equilibrium, all intermediate goods-producing firms make identical decisions, so that $K_{jt}=K_t$, $N_{jt}=N_t$, $P_{jt}=P_t$, $Y_{jt}=Y_t$, $\prod_{jt}=\prod_t$, and $\varepsilon_{jt}=\varepsilon_t$. Then:

$$\frac{w_t}{\mathrm{r}_t} = \frac{(1-\alpha)}{\alpha}\frac{K_{t-1}}{N_t} \tag{36}$$

$$(1-\theta)\exp\left\{B(\lambda\varepsilon_t+(1-\lambda)z_t+\vartheta_t)+\frac{1}{2}\Omega_s\right\} - \varphi_p\left(\frac{P_t}{\left(\pi_{t-1}^{\chi}\right)^{\mu}\left(\pi_t^{*\chi}\right)^{1-\mu}P_{t-1}}-1\right)\frac{P_t}{P_{t-1}}\exp\left\{B_1(\lambda\varepsilon_t+(1-\lambda)z_t+\vartheta_t)+\frac{1}{2}\Omega_{s_1}\right\} + \beta\varphi_p\frac{\Lambda_{t+1}}{\Lambda_t}\left(\frac{P_{t+1}}{\left(\pi_t^{\chi}\right)^{\mu}\left(\pi_{t+1}^{*\chi}\right)^{1-\mu}P_t}-1\right)\frac{P_{t+1}}{P_t}\exp\left\{B_1(\lambda\varepsilon_{t+1}+(1-\lambda)z_{t+1}+\vartheta_{t+1})+\frac{1}{2}\Omega_{s_1}\right\} + \frac{\xi_t}{\Lambda_t}\theta\exp\left\{B(\lambda\varepsilon_t+(1-\lambda)z_t+\vartheta_t)+\frac{1}{2}\Omega_s\right\} = 0$$

$$(1-\theta)\exp\left\{B(\lambda\varepsilon_t+(1-\lambda)z_t+\vartheta_t)+\frac{1}{2}\Omega_s\right\}-\varphi_p\left(\frac{\pi_t}{\left(\pi_{t-1}^{\chi}\right)^{\mu}\left(\pi_t^{*\chi}\right)^{1-\mu}}-1\right)\pi_t\exp\left\{B_1(\lambda\varepsilon_t+(1-\lambda)z_t+\vartheta_t)+\frac{1}{2}\Omega_{s_1}\right\}+\beta\varphi_p\frac{\Lambda_{t+1}}{\Lambda_t}\left(\frac{\pi_{t+1}}{\left(\pi_t^{\chi}\right)^{\mu}\left(\pi_{t+1}^{*\chi}\right)^{1-\mu}}-1\right)\pi_{t+1}\exp\left\{B_1(\lambda\varepsilon_{t+1}+(1-\lambda)z_{t+1}+\vartheta_{t+1})+\frac{1}{2}\Omega_{s_1}\right\}+\theta mc_t\exp\left\{B(\lambda\varepsilon_t+(1-\lambda)z_t+\vartheta_t)+\frac{1}{2}\Omega_s\right\}=0 \tag{37}$$

It is also assumed that the firm-specific demand (idiosyncratic preference shocks) also follows the autoregressive process:

$$\varepsilon_t=\varepsilon_{t-1}^{\rho_\varepsilon}\exp\left(e_{\varepsilon_t}\right) \qquad e_{\varepsilon_t}\approx N(0\,,\sigma_{\varepsilon_t}^2) \tag{38}$$

3.3 Government and Monetary Authorities

One part of the current study is modeling government and Central Bank. Due to the lack of independence of the Central Bank in Iran, we model the government and Central Bank in one sector.

It is assumed that the government's goal is to keep its budget balanced. In this case, the Central Bank will also act in such a way that the government will achieve its main goal. The government is trying to balance its costs through income from household taxes, sales of bonds, and oil revenues. In the case of budget balances through these three types of income, there will be no money creation, and the Central Bank will be able to implement monetary policy without considering the government's budget constraints. But despite these three sources of revenue, a deficit occurs, then the government will finance its budget deficit through borrowing from the Central Bank (money creation, or withdrawal of its deposits at the Central Bank) which means financial domination.

It is noteworthy that the sale of foreign exchange earnings from oil revenues by the government will also be reflected in the monetary base. Therefore, what is reflected in government budget in the form of changes in the monetary base is the combination of oil revenues and withdrawal of government deposits at the Central Bank. With this description, in mathematical terms, the budget constraint is:

$$G_t+(1+i_{t-1})\frac{b_{t-1}}{\pi_t}=\tau_t+m_t-\frac{m_{t-1}}{\pi_t}+b_t \tag{39}$$

Where G_t is government expenditure, M_t represents the monetary base.

The monetary base (Central Bank balance sheet) is defined as Equation 40, where DC_t is the domestic credit and FR_t of the foreign reserves (net foreign assets) of the Central Bank. In fact, in this regard, most of the commercial banks are also owned by the government. Therefore, the net debt of the government to the Central Bank and the net debt of banks to the Central Bank constitute, in total, domestic credits.

$$M_t = DC_t + FR_t \tag{40}$$

By dividing the sides of this relationship by P_t, the real monetary base will be obtained. Therefore, it is assumed that the accumulation of the real foreign assets of the Central Bank follows the rule of equation 42.

$$m_t = dc_t + fr_t \tag{41}$$

$$fr_t = \frac{fr_{t-1}}{\pi_t} + \omega or_t \tag{42}$$

In this respect, it is assumed that the accumulation of foreign assets of the Central Bank is such that it depends on the number of direct sales of oil revenues (or_t) by the government to the Central Bank. In other words, it is assumed that the government sells $\omega \in (0, 1)$ percent of its oil revenues directly to the Central Bank to be converted to Rial, and holds $1\text{-}\omega$ of it in the National Development Fund (NDF). Therefore, deciding how to spend the oil revenues is determined by the parameter ω. $1\text{-}\ \omega$ percent of the oil revenue in each period is deposited into the NDF (43).

$$ndf_t = \frac{ndf_{t-1}}{\pi_t} + (1-\omega)or_t \tag{43}$$

Also, it is assumed that oil revenues follow a first-order autoregressive process such as Equation 44.

$$or_t = or_{t-1}^{\rho_{or}} \exp\left(e_{or_t}\right) \qquad e_{or_t} \approx N(0\,, \sigma_{or_t}^2) \tag{44}$$

Regarding the monetary policy principle, the basis for this policy rule is to understand that a proper monetary policy must be sensitive to both real GDP and inflation, and that interest rates should be considered as a modifiable and flexible policy tool. In this regard, in most studies, Taylor's (1993) rule is used. Based on this rule, the monetary authority implements appropriate decisions through the change in the nominal rate, as a policy tool and about the diversion of production and inflation from its target values. Empirical studies in Iran's economy show that there was no explicit targeting of inflation or economic growth in monetary policy. Due to the grammatical of determining the interest rate in Iran's economy, to simulate this rule, we need to make changes in the volume of money as the basis of policymaking. In some DSGE models designed for the Iranian economy, the growth rate of money is considered as a monetary policy tool. Changes in the volume of money are considered as a monetary policy tool in this study. Based on monetary policy reaction function, the policymaker determines the growth rate of money in a way that achieves its two goals, namely, the reduction of production deviation from the potential output and the diversion of inflation from target inflation. But the Central Bank did not have explicit targets to be announced to the public. However, due to the targeting of development programs, policymakers always try to pursue an implicit goal. Accordingly, in the response function introduced here, it is assumed that target inflation is an invisible variable that has only been available to policymakers, and no other economic agents are aware of it.

It is assumed that this implicit target inflation follows the first-order autoregressive process in which the coefficient of the model is close to one (ρ_{π^*}). Therefore, the conditional mathematical expectation of target inflation in the period *t* is very close to the mathematical expectation of inflation in the past period. The reason for this assumption is that the monetary policymaker tries to keep target inflation regularly over time, but sometimes it fails to achieve this goal. According to these explanations, the non-linear monetary policy reaction function is defined as follows:

$$\left(\frac{mb_t}{\overline{mb}}\right) = \left(\frac{mb_{t-1}}{\overline{mb}}\right)^{\rho_{mb}} \left(\frac{\pi_t}{\bar{\pi}}\right)^{\lambda_\pi} \left(\frac{y_t}{\bar{y}}\right)^{\lambda_y} \exp(\nu_t) \tag{45}$$

$$\pi_t^* = (\pi_{t-1}^*)^{\rho_{\pi^*}} exp(e_{\pi_t^*}) \tag{46}$$

In which mb_t is the nominal money growth, which is obtained from the following equation:

$$mb_t = \frac{M_t}{M_{t-1}} = \frac{P_t m_t}{P_{t-1} m_{t-1}} = \frac{m_t}{m_{t-1}} . \pi_t \tag{47}$$

Further, it is assumed that government expenditures follow the autoregressive process:

$$G_t = G_{t-1}^{\rho_G} \exp(e_{G_t}) \qquad \rho_G \in (-1\,,1) \qquad e_{G_t} \approx N(0\,,\sigma_{G_t}^2) \tag{48}$$

3.4 Market Clearing Conditions

For the market to be balanced, aggregate supply must be equal to aggregate demand (the sum of consumption, private investment, and government expenditures).

$$Y_t = C_t + I_t + G_t + \frac{\varphi_p}{2}\left(\frac{P_{jt}}{(\pi_{t-1}^{\chi})^{\mu}(\pi_t^{*\chi})^{1-\mu}(P_{jt-1})} - 1\right)^2 Y_t \tag{49}$$

3.5 Steady-State

After defining the economic equilibrium, steady-state values must be defined. Some of the endogenous variables have already been determined (exogenously), such as productivity. We rewrite the equations in terms of the simplest to the most complex equations so that all variables are obtained in terms of parameters.

$$\bar{A} = 1 \qquad \bar{\pi} = 1.15 \qquad \overline{or} = 1 \qquad \bar{G} = 1$$

$$\bar{\imath} = \frac{\bar{\pi}}{\beta} - 1 \qquad \bar{r} = \frac{1}{\beta} - (1 - \delta)$$

$$\overline{mc} = \frac{1}{\theta}\left[\varphi_p(\bar{\pi}^{1-\chi\mu} - 1)\bar{\pi}^{\chi\mu} - \beta\varphi_p(\bar{\pi}^{1-\chi\mu} - 1)\bar{\pi}^{\chi\mu} + \theta - 1\right]$$

$$\bar{w} = (1-\alpha)\left(\overline{mc}\left(\frac{\alpha}{\bar{r}}\right)^{\alpha}\right)^{\frac{1}{1-\alpha}}$$

$$\bar{C} = \frac{1}{\psi_n}\bar{w}$$

$$\bar{m} = \frac{\psi_m}{\psi_n}(1-\alpha)\left(\frac{\bar{\pi}}{\bar{\pi}-\beta}\right)\left(\overline{mc}\left(\frac{\alpha}{\bar{r}}\right)^{\alpha}\right)^{\frac{1}{1-\alpha}}$$

$$\bar{K} = \frac{\bar{C}+1}{\left[\left(\frac{(1-\alpha)}{\alpha}\frac{\bar{r}}{\bar{w}}\right)^{1-\alpha}\left(1-\frac{\varphi_p}{2}(\bar{\pi}^{1-\chi\mu}-1)^2\right)-\delta\right]}$$

$$\bar{N} = \frac{(1-\alpha)}{\alpha}\frac{\bar{r}}{\bar{w}}\bar{K}$$

$$\bar{I} = \delta\bar{K}$$

$$\bar{Y} = \bar{N}^{1-\alpha}\bar{K}^{\alpha}$$

$$\overline{fr} = \omega\left(\frac{\bar{\pi}}{\bar{\pi}-1}\right)$$

$$\overline{ndf} = \left(\frac{\bar{\pi}}{\bar{\pi}-1}\right)(1-\omega)$$

$$\overline{dc} = \bar{m} - \overline{fr}$$

$$(1-\theta)\exp\left\{B(\lambda + (1-\lambda)log\bar{Z}) + \frac{1}{2}\Omega_s\right\} - \varphi_p(\bar{\pi}^{1-\chi\mu} - 1)\bar{\pi}^{\chi\mu}\exp\left\{B_1(\lambda + (1-\lambda)log\bar{Z}) + \frac{1}{2}\Omega_{s_1}\right\} + \beta\varphi_p(\bar{\pi}^{1-\chi\mu} - 1)\bar{\pi}^{\chi\mu}\exp\left\{B_1(\lambda + (1-\lambda)log\bar{Z}) + \frac{1}{2}\Omega_{s_1}\right\} + \theta\overline{\mathrm{mc}}\exp\left\{B(\lambda + (1-\lambda)og\bar{Z}) + \frac{1}{2}\Omega_s\right\} = 0$$

$$\bar{Z} = \bar{Y}$$

$$\bar{Z} = \left(\frac{\bar{r}}{\bar{\alpha}}\frac{1}{\left(\overline{mc}\left(\frac{\alpha}{\bar{\bar{r}}}\right)^{\alpha}\right)^{\frac{1}{1-\alpha}}}\right)^{1-\alpha}\frac{\frac{1}{\psi_n}(1-\alpha)\left(\overline{mc}\left(\frac{\alpha}{\bar{\bar{r}}}\right)^{\alpha}\right)^{\frac{1}{1-\alpha}}+1}{\left[\left(\frac{\bar{r}}{\bar{\alpha}}\frac{1}{\left(\overline{mc}\left(\frac{\alpha}{\bar{\bar{r}}}\right)^{\alpha}\right)^{\frac{1}{1-\alpha}}}\right)^{1-\alpha}\left(1-\frac{\varphi p}{2}(\bar{\pi}^{1-\chi\mu}-1)^2\right)-\delta\right]}$$

4 Calibration, Data, and Estimation

The Bayesian method and the Metropolis-Hastings algorithm are used to estimate the parameters of this model. With this algorithm, five parallel chains with a volume of 700,000 are extracted to obtain the posterior density of the parameters. Since there are seven structural shocks in the model, there is the maximum possible use of the seven visible variables to estimate the model. Therefore, five visible variables, namely production, inflation, the growth rate of the monetary base, government expenditures, and oil revenues, have been used. The first two variables indicate the general state of the economy, the growth rate of the monetary base is a representative of monetary policy, government expenditures reflecting financial policy and oil revenues reflect the role of oil in the economy. For this purpose, quarterly adjusted GDP data, inflation of consumer price index, growth of monetary base, government expenditures, and oil revenues during the period from 2004 to 2015 have been used. The entire procedure is implemented in DYNARE for MAT LAB.

Before estimating the parameters, the parameters that are not needed for estimation must be specified, and their values calibrated. Some parameters are extracted from the values of the steady-state of variables, so there is no need to estimate them. One of these parameters is the capital depreciation rate. According to the law of motion for capital:

$$K_t = I_t + (1 - \delta)K_{t-1}$$

The relationship in steady-state will be as follows:

$$\bar{K} = \bar{I} + (1 - \delta)\bar{K}$$
$$\bar{I} = \delta\bar{K}$$
$$\delta = \frac{\bar{I}}{\bar{K}}$$

Therefore, assuming that the average investment and capital represent the amount of the steady-state of these variables, we can achieve the rate of depreciation of private capital. Also, in cases that parameter was estimated in previous studies, those estimates are considered as the initial parameter information. If none of these two methods are applicable, the researcher's guess about the parameter is assumed to be the initial information. The "identification" order is used to indicate which parameters are measurable. Some parameters have not been estimated to be identified, as shown in Table 1.

Table 1
Calibrated Model Parameters

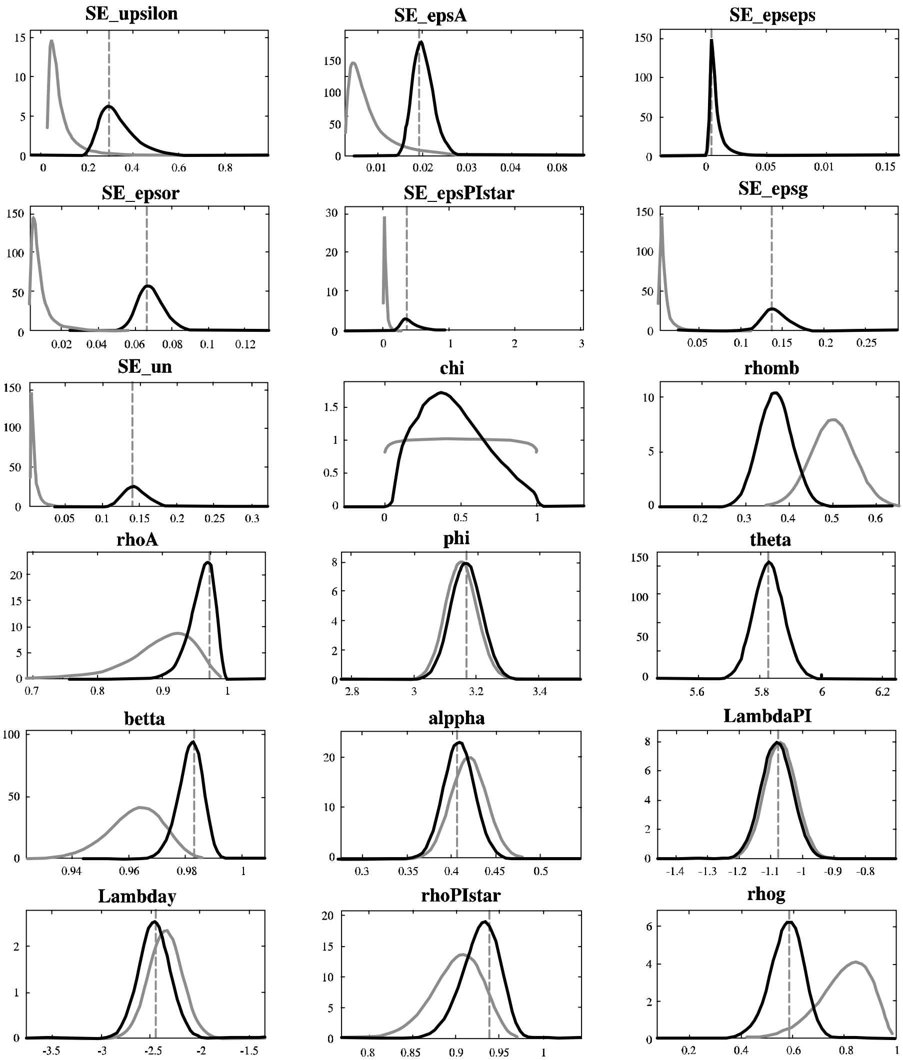
param	Definition	Calibration	source
ψ_m	Inverse elasticity of money demand	0.24	Bahrami and Rafea (2014)
ω	Percentage of sales of oil revenues to the Central Bank	0.8	Tavakolian (2015)
δ	capital depreciation rate	0.04	Research calculations
μ	Weight parameter in inflation indexation	0.5	Ascari et al. (2011)
σ_z^2	Variance of sentiment	0.35	Research calculations

Source: Research Findings.

Table 2
Estimating Model Parameters

Param	Definition	Prior Distributions	Prior Mean (Prior st.dev)	Estimation (Posterior st.dev)
θ	Elasticity of intertemporal substitution	Gamma	5.83 (0.05)	5.8271 (0.0206)
φ_p	Price adjustment costs	Gamma	3.15 (0.05)	3.1654 (0.0391)
β	Intertemporal discount factor	Beta	0.962 (0.01)	0.9827 (0.0031)
α	Share of capital in the production function	Beta	0.42 (0.02)	0.4063 (0.0175)
χ	Weight parameter in price indexation	Beta	0.5 (0.285)	0.4162 (0.1661)
λ_π	Monetary policy response to inflation	Normal	-1.070 (0.05)	-1.0798 (0.0518)
λ_y	Monetary policy response to output	Normal	-2.35 (0.17)	-2.4502 (0.0762)
λ	Weight parameter in the received signal of firm	Beta	0.4 (0.0697)	0.3565 (0.1)
ρ_A	Autoregressive coefficient of technology shock	Beta	0.9 (0.05)	0.9747 (0.0219)
ρ_ε	Autoregressive coefficient of idiosyncratic demand shocks	Beta	0.5 (0.1)	0.5 (0.0986)
ρ_{π^*}	Autoregressive coefficient of target inflation	Beta	0.9 (0.03)	0.938 (0.0143)
ρ_G	Autoregressive coefficient of government expenditure	Beta	0.8 (0.1)	0.5861 (0.0507)
ρ_{or}	Autoregressive coefficient of oil revenues shock	Beta	0.8 (0.1)	0.9127 (0.0327)
ρ_{mb}	Autoregressive coefficient of money growth in the monetary reaction function	Beta	0.5 (0.05)	0.3654 (0.0364)
ψ_n	Inverse elasticity of labor supply	Gamma	4.77 (0.05)	4.7683 (0.0323)
σ_v	The Standard deviation of the monetary policy shock	Inv. Gamma	0.01 (∞)	0.1408 (0.0149)
σ_A	The standard deviation of the technology shock	Inv. Gamma	0.01 (∞)	0.0194 (0.0024)
σ_{or}	The standard deviation of oil revenues shock	Inv. Gamma	0.01 (∞)	0.0664 (0.0072)
σ_g	The Standard deviation of the government expenditure	Inv. Gamma	0.01 (∞)	0.1374 (0.0149)
σ_υ	The Standard deviation of idiosyncratic noise	Inv. Gamma	0.1(∞)	0.2967 (0.0733)
σ_ε	The Standard deviation of the idiosyncratic demand shock	Inv. Gamma	0.01 (∞)	0.0046 (0.0061)
σ_{π^*}	The Standard deviation of target inflation shock	Inv. Gamma	0.05(∞)	0.3694 (0.1108)

Source: Research Findings.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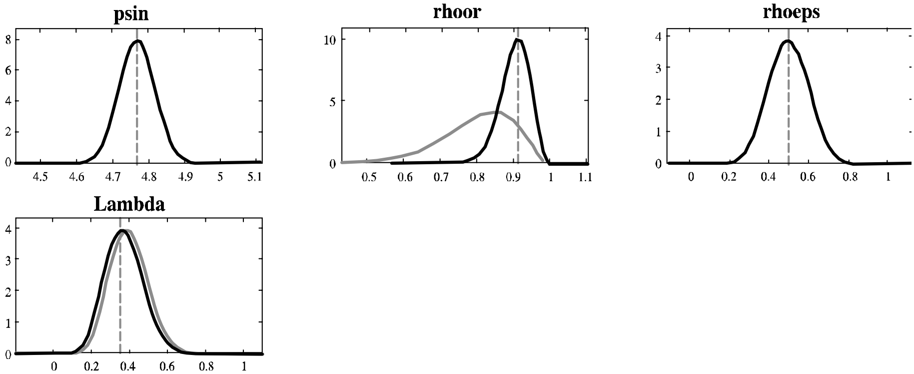

Figure 1. Prior and Posterior Density of Parameters Based on the Metropolis-Hastings Algorithm

For estimation, at first, the distribution, mean, and prior standard deviation for the parameters should be determined. Considering the initial values for the mean and standard deviations of parameters, we can estimate the parameters using the Bayesian method. The distribution, mean, and prior standard deviation and the results of parameters estimation and their standard deviation (i.e., mean and standard deviation of posterior) are presented in Table 2. In this table, the prior density for each parameter is selected based on the characteristics of that parameter and the density characteristics. For example, we choose an Inverse Gamma distribution for the standard deviation of shocks because it has positive support. We allowed for an infinite variance to allow for the searching algorithm to explore a big portion of the support, although lower weights are given to higher values. The persistence parameters of the shocks are assumed to have a Beta distribution because it is bounded between 0 and 1.

The prior density of parameters, along with the estimated posterior distribution based on the Metropolis-Hastings algorithm, is reported in Figure 1. Adjustment of prior density and posterior of some parameters in this chart means that either the previous information about these parameters is completely correct or that data cannot estimate these parameters. If any of these two states is correct, the result will be that these parameters are calibrated in some way.

As shown in Table 2, the discount factor is very high, which is rarely seen in DSGE models in Iran. Also according to Figure 1, the posterior values for the parameters of the autoregressive coefficient of the oil revenues shocks, government expenditures, and money growth are different from their prior mean, which contains new information for the data to the previous information. Also, the matching of the calculated modes for each parameter with maximum logarithms of prior density in some parameters shows that their estimation is not completely accurate.

To verify the validity of the Bayesian method, two univariate and multivariate diagnostic tests are used. Based on the univariate test, in-sample and intra-sample variance of all the parameters converge to each other and eventually stabilized horizontally and, considering that in the multivariate test, in-sample and intra-sample variance also converge to a constant value, it can be said that the estimated results by Bayesian method are good.

The green vertical line is the posterior mode obtained from the posterior kernel maximization. The darker distribution is posterior, and the brighter one is the prior distribution.

- **Analysis of Bayesian Response Functions**

In this section, we examine the graphs of the impulse response functions (IRF) by inserting a shock of one standard deviation on the endogenous variables of the model. These functions represent the dynamic behavior of the endogenous variables over time. As mentioned, they are quantitatively distinguishable for some endogenous variables. However, as we shall see below, only the impulse response functions of five macroeconomic variables, namely, output, consumption, investment, real money balance, and inflation, are discussed after the occurrence of impulses.

  - Idiosyncratic demand shocks

The occurrence of idiosyncratic demand shocks on output, investment, employment, and consumption has a primary positive effect and only negative impact on inflation. This shock causes an initial increase in output, which will exacerbate the demand for real money balances. From a theoretical point of view, the growth of money supply and the volume of liquidity should lead to an increase in the price index and inflation, but since the shock is at the level of the firm's idiosyncratic demand, the level of inflation has been reduced initially. This shock also increases the level of investment, employment, real interest rate, and consumption temporarily. Adjustment of the effect of the idiosyncratic demand shocks on output, investment, employment, real interest rate, and inflation occurs in short-term and discharging of its effect takes less than five periods, but for consumption, this effect will disappear after 20 periods. The fluctuation range of the consumption variable is also greater than the other variables indicated by the gray shaded areas.

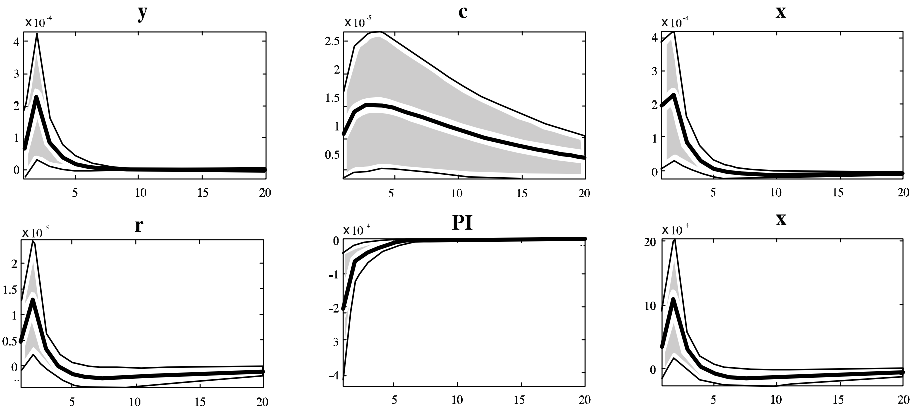

Figure 2: Impulse Response Functions to an Idiosyncratic Demand Shock

- Idiosyncratic noise shocks

The fluctuations at the level of macro variables with the appearance of idiosyncratic noise are no different from the case of an idiosyncratic demand shock. The occurrence of idiosyncratic noise impacts on output, investment, employment, real interest rate, and consumption has a primary positive effect. But harms inflation, and it is just different in the amount of change from the previous one: in this case the initial change after the shock is much higher and then returns to the equilibrium level after a short time. For example, a 1% increase in idiosyncratic noise initially increases 3.5% of output and 5% of investment, which is far from the amount of output and investment changes in the previous state. This is applicable for other variables. In this case, although the initial change in macro variables is much higher than the idiosyncratic demand shock, fluctuations domain of these variables is much less than the idiosyncratic demand shock until it reaches a stable level after the idiosyncratic shock.

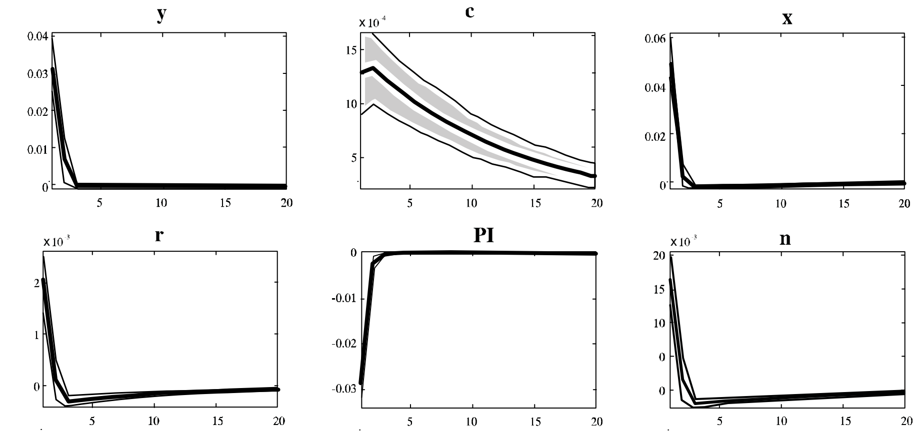

Figure 3. Impulse Response Functions to an Idiosyncratic Noise Shock

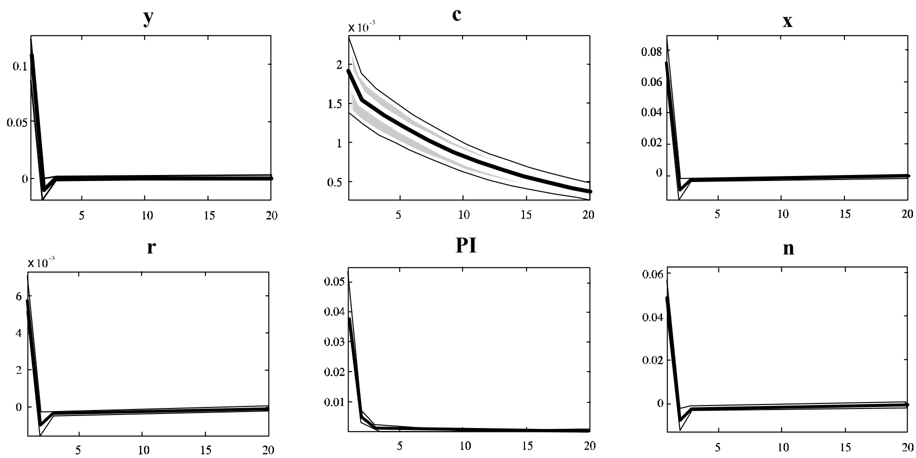

Figure 4. Impulse Response Functions to a Monetary Shock

- Monetary shocks

The following diagram also shows the impulse response functions of a monetary shock equivalent to a standard deviation. By impressing a monetary shock to the economy, it will increase inflation and thus reduce the real wages of labor and the real rent of capital. Reducing real wages and real rent will increase labor and capital demand and thus increase output. After a while, inflation caused by monetary shocks causes a deflationary reaction of the government in the form of a monetary contraction policy and a decrease in the growth rate of money, and thus a decrease in the monetary base, which will lead to a reduction in output, government expenditure, and investment. On the other hand, considering the effect of monetary impulse on real variables, the hypothesis of money neutrality in the Iranian economy is not accepted at least in the short term.

5 Conclusion

In this study, a dynamic stochastic general equilibrium model for a small closed economy (Iranian economy) has been developed in the framework of the new Keynesian school, in which the role of sentiments on macroeconomic variables is discussed. The key feature of the model is that employment and production decisions by firms, and consumption and labor supply decisions by households are made before goods being produced and exchanged and before market-clearing prices are realized. In the firm's section, we assumed that they received a noisy signal s_{jt}, which is a weighted average of firm-level demand ϵ_{jt} and the expected aggregate demand of households. Based on the signal, each firm has its employment and production to maximize expected profits. By applying the signal, the Phillips curve also faces fundamental changes, which affects the inflation, and subsequently the difference in the Phillips curve effect on the fluctuations of other endogenous variables, after applying shock to endogenous variables. This change is evident in idiosyncratic demand shock and noisy shock because, after a shock, the inflation initially decreased and then increased and goes back to the level of equilibrium. Also, applying sentiment in the model influenced the estimation of the parameters and caused the difference in the estimated parameters in sentiment state with the normal state estimated in other studies, as shown in Table 2. We also evaluated the impulse response functions by implementing various shocks, including idiosyncratic demand shocks and idiosyncratic noise shocks. The results show that with the occurrence of these two shocks, fluctuations in the level of macro variables do not differ in terms of the sign of the initial effect. Idiosyncratic demand and noise shocks impact on output, investment, employment, and consumption has a primary positive effect; it just has negative effects on inflation; they are different in the number of variations; so that in the case of idiosyncratic noise shock, the initial change after the shock is much higher. Then it returns to the equilibrium level for a short time. These shocks have led to an initial increase in output, which exacerbated demand for real money balance, but instead of rising in the price index and inflation, the level of inflation initially declined. Also, these shocks will temporarily increase the level of investment, employment, and consumption. Adjustment of the effects of these shocks on output, investment, employment, and inflation is also short-term, but for consumption, this effect takes more time to return to its previous stable level. The volatility range of the consumption variable is also higher than other variables.

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