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# Evaluation of the Welfare Effects of Different Monetary Rules during Boom and Recession Periods in the Iranian Economy

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***Abstract***

The main objective of this research is to rank different monetary rules in Iran based on welfare, considering boom and recession periods. In this study, a stochastic dynamic general equilibrium model of new Keynesians is developed for the Iranian economy. By introducing six different monetary policy rules, the welfare effects of shocks under these rules are compared. This research answers the question of which monetary policy rule can bring about a higher level of welfare during recession and boom periods, given the structure of the Iranian economy. To address this question, the first step involved identifying recession and boom periods in the Iranian economy from 1988 to 2022 using the Hodrick-Prescott filter and the Bry-Boschan algorithm. Subsequently, using existing data from the Iranian economy, various models were estimated, and calibration of the models during the recession and boom periods was conducted using results from other studies. Finally, the welfare losses of different monetary rules during recession and boom periods were calculated, considering individual shocks as well as the simultaneous introduction of five shocks to the economy. The results of this study indicated that if five shocks (monetary policy shock, preference shock, technology shock, oil revenue shock, and global price shock) are simultaneously applied to the Iranian economy, the generalized Cabrera et al. (2011) monetary rule experiences lower welfare losses in both recession and boom periods.

***Highlights***

- This paper deals with the calibration of parameters of a dynamic stochastic general equilibrium model over business cycles.
- The Hodrick-Prescott filter and the Bry-Boschan algorithm have been used to identify the business cycles of the Iranian economy.
- Based on the estimates, optimal monetary rules in the Iranian economy have been identified by considering various shocks during business cycles.

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## 1. Introduction

One of the important issues in policy discussions is the formulation of effective and efficient monetary policies. Empirical and theoretical evidence indicates that monetary variables influence macroeconomic variables in both the short and long run. Therefore, identifying the optimal policy rule is critically important for policymakers (Benchimol & Forkans, 2019).

Since the 1970s, economic theories aimed at achieving macroeconomic stability have primarily focused on monetary policies, particularly inflation targeting. However, after the 2007 crisis, attention has shifted towards understanding the capabilities and pathways of interaction between fiscal and monetary policies, as well as their effects on reducing economic fluctuations (Sobhanipour et al., 2022). Attaining these goals is made possible through modifications in the supply and price of money within the economy. Therefore, without the design and implementation of targeted, transparent, and proactive monetary policies that effectively influence key economic variables such as economic growth, inflation, and investment, it is impossible to create a non-inflationary and conducive environment for improving economic conditions (Mohammadi Khiareh et al., 2015). Consequently, under such circumstances, the design of optimal monetary policy rules to achieve objectives such as inflation control, production stability, and income distribution improvement is of paramount importance for the macroeconomic goals of the country (Farazmand et al., 2013).

Since Taylor's (1993) research, most studies have developed the reaction function of monetary authorities within a linear framework, overlooking the potential asymmetry in central bank preferences. Meanwhile, Cukierman (2002) states that although credible central banks strive to avoid negative output gaps and positive inflation gaps relative to their targets, they do not respond to positive output shocks and negative inflation shocks to the same extent (cited in Güney, 2018). One explanation for this behavior is that while most central banks are considered independent if they are accountable to higher-level policymakers, they may be influenced by business cycle fluctuations. Consequently, policymakers may exhibit asymmetric preferences based on the level of inflation and the output gap (Bec et al., 2002). One of the significant issues that has been at the center of attention for economists in developed and developing countries in recent decades is the impact of external shocks on the macroeconomic structure and ultimately its effect on social welfare. In the Iranian economy, where the government's economic performance is highly dependent on oil exports, external shocks lead to drastic changes in exchange rates and fluctuations in gross domestic product. In response to such conditions, monetary policymakers can enhance social welfare while stabilizing the macroeconomy by selecting a monetary rule that is appropriate for the economic conditions (Boroumand et al., 2019).

Since monetary policy regulation is one of the ways to deal with economic instability and avoid utilitarian actions, analyzing the welfare effects of monetary rules can help monetary policymakers and the central bank choose the appropriate monetary rule to improve economic performance. This necessitates an analysis of the welfare effects of different monetary policy rules tailored to the diverse conditions of the Iranian economy; also, the derivation of a welfare function allows for the ranking of different policy rules. In this regard, the main issue of this research is to evaluate and compare the welfare impact of different monetary rules, considering business cycles (recession and boom) in the Iranian economy. More precisely, in this research, the welfare effects of different monetary policy rules (6 rules) in Iran are evaluated, considering their asymmetric effects during boom and recession periods and considering different shocks (5 shocks).

Several studies have been conducted in the field of optimizing monetary policy rules. However, these studies mainly focus on determining the optimal monetary rules concerning oil and technology shocks, and the Taylor rule is considered the target-setting rule. Although in more recent studies, with the expansion of the open economy model, attention to fluctuations in external variables, including the exchange rate, has become more prominent in determining the optimal policy; however, the contribution of the present study compared to similar studies is still the inclusion of different target-setting rules for the central bank. Among the points of contribution and innovation of the present study is the consideration of different criteria and different scenarios for monetary rules in Iran. Another contribution is that in this study, monetary policy rules are ranked by considering periods of recession and boom and by considering different shocks, which has not been done in any of the studies conducted so far.

## 2. Literature Review

This section explains the theoretical and empirical framework related to social welfare. First, theoretical discussions will be addressed and then empirical studies will be reviewed.

### 2.1. Monetary & Rules policy

Monetary policy is a set of actions that the central bank employs to control the economic activities of a society. The main duty of the monetary policymaking institution is to control the price level, alongside maintaining a high level of economic output and supporting the national currency. The combination of these duties presents a minimization of the central bank’s loss function; therefore, it is logical for policies and policy instruments to be used for objectives that they have a comparative advantage in achieving (Dargahi & Sharbatoghli, 2011).

Monetary policy impacts the money supply and interest rates, thereby influencing various economic objectives such as employment and prices (Tabatabaie Zavareh et al., 2023). Therefore, for the successful and timely implementation of monetary policy, it is essential to have sufficient awareness of the transmission process of monetary policy, as well as the mechanism through which economic shocks transmit to economic variables (Bahrami & Ghorashi, 2011). Monetarists argue that in the long run, monetary policy does not affect production; however, in the short term, it can have an impact due to the incomplete understanding of economic agents (Tabatabaie Zavareh et al., 2023). On the other hand, New Keynesians, contrary to the monetary business cycle theory, believe that even anticipated monetary policy can create real effects on production and employment (Bahrami & Ghorashi, 2011).

This type of impact has led the government and the central bank, as the monetary authorities of the country, to consistently seek to utilize policy tools to mitigate the negative consequences arising from the aforementioned shocks to maintain the economy in a stable condition (Mohammadi Khiareh et al., 2015). In the event of an incorrect policy choice, the opportunity to remedy damages will be limited; therefore, the selection of tools and methods by the central bank for guiding monetary policy within the framework of monetary rules presents a significant challenge and holds considerable importance in scientific studies (Bayat et al., 2017).

The monetary rule is a descriptive guideline for guiding economic behavior in such a way that it leads to the use of information in a compatible and predictable manner through a systematic decision-making process (Bastani Far, 2011). Despite the lack of consensus among researchers regarding the precise definition of the term “monetary rule”, from Taylor’s perspective, who proposed one of the most well-known monetary rules, the monetary rule is a plan that expresses the conditions under which the monetary policymaker changes the intermediate targets of monetary policy to achieve the ultimate goal. In other words, monetary rules provide a condensed approach to summarizing the framework of monetary policies (Bayat et al., 2017; Khorsandi et al., 2012). Throughout the process of monetary rules, the monetary authority uses information in a compatible and predictable manner to determine how policy instruments should respond to changes in the target variables (Hemati, 2010); in other words, a monetary policy rule states how policy instruments should react to changes in the economic situation. The use of monetary policy rules, as one of the most widely accepted methods in economic studies, is one of the most prominent features of research related to policy-making in recent decades (especially since the 1990s) (Khalili Araghi, 2010) .

The discussion of rules as a scientific topic in monetary policy was first introduced by Simmons (1936). Subsequently, with Friedman’s (1969) study on the optimal amount of money, the concept of rules became a serious topic in monetary policymaking. Following the introduction of time inconsistency in monetary policy by Kydland & Prescott (1977), rule-based monetary policy emerged as one of the strategies to address time inconsistency in macroeconomics, particularly in monetary policy. The study by Kydland and Prescott (1977) marks a turning point in the discourse on monetary rules, leading to various subsequent studies and the proposal of multiple monetary rules (Taylor, 2018).

Generally, the monetary policy rule can be defined and designed based on the prevailing views within different economic schools of thought. The most well-known monetary policy rules include Friedman’s monetary rule, which is influenced by the monetary school, Kydland and Prescott's rule, which is rooted in New Classical economics, and Taylor's rule, which is derived from New Keynesian economics (Bastani Far, 2011).

According to Friedman's monetary rule, the optimal amount of money occurs where the opportunity cost of holding money by private firms equals the social cost of creating one unit of money. Since the marginal cost of creating money is zero, the optimal amount of money is at the point where the cost of holding money equals zero at the nominal interest rate (Friedman, 1969). Based on the Kydland and Prescott rule, within the framework of rational expectations formation, private firms take into account future monetary authority decisions when making current decisions regarding changes in consumption or investment (Kydland & Prescott, 1977). In Taylor's rule, the monetary authority must determine the nominal interest rate at time t based on the inflation gap and the output gap. Taylor (1993) suggests that the central bank should set the nominal interest rate in a way that makes it equal to a linear combination of the current inflation rate and the GDP output gap (Taylor, 1993).

### 2.2. Channels of influence of monetary policy

Effects of monetary policy on welfare arise through various channels, which are briefly introduced below:

Interest Rate Channel: The interest rate channel is one of the standard transmission mechanisms of monetary policy from the perspective of the neoclassical school. This means that a decrease in the real interest rate leads to an increase in investment. Low real interest rates stimulate production by increasing fixed business capital, household investments, spending on durable consumer goods, and capital stock. A contractionary policy, through an increase in interest rates, reduces investment and leads to unemployment due to lower investment levels; this reduction in investment also decreases production. During a recession, an expansionary policy is necessary to stimulate investment by lowering interest rates, which helps reduce unemployment through increased labor utilization and boost production. Conversely, an expansionary policy does not significantly aid periods of economic expansion as production is already at its highest levels and the economy lacks the capacity for further production. In such cases, it can be stated that the existing unemployment is at the natural rate of unemployment (mohammadi majd et al, 2023).

Exchange Rate Channel: The studies by Taylor (1993) and Obstfeld & Rogoff (1995) underscore the importance of the exchange rate channel in the transmission mechanism of monetary policy. In this channel, two key factors are important: first, the sensitivity of the exchange rate to changes in interest rates, and second, the degree of openness of the economy. The more open the economy, the greater the functionality and role of this channel (Bordon & Weber, 2010). Additionally, in countries with flexible exchange rates, the exchange rate channel can serve as a stronger mechanism for transmitting the effects of monetary policies (Mukherjee & Puzo, 2011). This channel becomes active when adjustments in the central bank's policy rates lead to leveraged changes in the short-term market, deposit rates, and loan rates. For instance, the implementation of a contractionary policy through the exchange rate channel can both lead to an increase in production due to higher demand for currency to secure financing and an appreciation of the exchange rate and can also result in decreased production due to the openness of the economy and an increased supply of currency for domestic investment. The net effect of these two influences will indicate the impact of contractionary monetary policy on production and, consequently, social welfare.

During a recession, when the economy is contracting and production is at its minimum, the implementation of a contractionary monetary policy that leads to reduced exports will further decrease production and exacerbate the recession. However, due to the decline in intermediate goods prices, there are expectations for reduced inflation and increased investment that could stimulate production. In periods of economic expansion, the decrease in interest rates as a result of contractionary monetary policy will not lead to increased investment since the economy is already operating at full employment. Furthermore, most financing for enterprises is sourced from internal resources, and there is little need for external financing. Thus, the channel of monetary policy impact via increased demand for currency from foreign financial sources will also be inactive. Nevertheless, a decrease in production due to increased interest rates and consequently higher investment costs during periods of expansion remains a possibility.

Credit Channel: Two mechanisms have been proposed to explain the relationship between the effects of monetary policies and the additional costs of external financing: the balance sheet channel and the bank lending channel. The extent to which these two factors affect firm behavior depends on the specific context (Mukhreh and Puzo, 2011).

Balance Sheet Channel: Jalili et al. (2018) state that monetary policy impacts the value of the assets that firms use as collateral. For instance, an expansionary monetary policy increases asset values, thereby enhancing the net worth of firms and their investment expenditures, ultimately leading to higher production. Conversely, the stronger the financial position of firms, the more they can finance a larger portion of their investments from internal funds. Since the additional costs of external financing are also affected, this leads to an increase in investment.

Bank Lending Channel: Kashyap & Stein (2000) state that the impact of monetary policy on bank lending behavior depends on the liquidity and financial balance sheets of banks. When monetary policy affects bank lending, it tends to result in a greater reduction in loans at banks with less liquid assets, while banks with higher liquidity exhibit less sensitivity to the implementation of monetary policies (Alfaro et al, 2004). Accordingly, contractionary monetary policy reduces bank deposits, and banks may find it difficult to easily replace the reduction in deposits with other sources of funding, leading to the exclusion of some borrowers from the credit cycle. Consequently, this results in decreased investment and real production (Sharifi Renani et al., 2010). During periods of economic expansion, the implementation of contractionary policies and an increase in interest rates lead to a reduction in production due to higher investment costs. However, during this time, the availability of borrowing or alternative financing methods can substitute for loans, making the reduction in production through this channel less pronounced. According to Hosseinzade et al. (2020), monetary policies are significantly more effective during recessions than in periods of expansion, as monetary policy through the bank lending channel serves as a key variable for ending a recession, with banks being the primary source of financing for producers during downturns.

Asset Price Channel: Monetarists believe that, in addition to the relative prices of assets, interest rates, exchange rates, and other factors previously discussed, money can also influence the relative prices of all assets and real wealth. In this regard, monetarists introduce the following two transmission channels:

Tobin's Q Theory of Investment: Keynesians believe that an increase in interest rates resulting from contractionary monetary policy makes bonds more attractive compared to other assets, leading to a decline in asset prices within the economy (Mishkin, 1997). At the aggregate level of firms, investment projects that were previously marginally profitable before the monetary contraction, and are not financed due to the decrease in Q, are eliminated, which in turn results in a reduction in production and employment (Ida, 2013).

Effects of Wealth on Consumption (Real Balance Effect): In a recessionary environment, the demand for products decreases, and the market value of corporate assets declines. Consequently, Tobin's Q becomes less than one, which imposes constraints on corporate investment. Under such conditions, the imposition of contractionary monetary policy—which raises interest rates and shifts capital toward bonds—results in further declines in asset prices and, consequently, reduced production. In contrast, during periods of economic expansion, Tobin's Q is generally greater than one. The application of contractionary monetary policy that leads to a decrease in Tobin's Q affects only a limited number of firms, with only marginal firms exiting the market as their Q falls below one. Conversely, expansionary monetary policy, by increasing market value, enables even firms with lower productivity to participate in the market cycle and enhance production (Heydari et al, 2023).

### 2.3. Empirical Studies

Rabiei et al. (2024) have compared and analyzed the effects of government spending shocks by separating their main components into two approaches to monetary policy: rule-based and discretionary. The results of this study, which was conducted with the help of designing and calibrating a stochastic dynamic general equilibrium model with a new Keynesian approach during the period 1991-2021, show that there is not much difference between rule-based monetary policy and discretionary policy in Iran. Nasiri et al. (2023) in a study aimed at achieving optimal monetary policy, used a key element in the effectiveness of these policies, which is the credibility of the monetary policymaker. The results of the model indicate that the credibility of the monetary policymaker in Iran is very low in both the inflation rate and the exchange rate. Examining the loss function of the economy is faced with unforeseen shocks, the use of discretionary policymaking due to the flexibility of the central bank has shown that in conditions where the monetary policymaker's policy in both scenarios gives the greatest weight to reducing the exchange rate gap and the same weight is allocated to other goals, the amount of loss is at its minimum possible value. McKay & Wolf (2023) examine optimal policy rules in business cycle models with nominal stickiness and heterogeneous households. They show that the optimal policy rule for a “dual-mission” central bank is one that cares only about inflation and output and is not affected by household heterogeneity. The optimal rule for a cryptographic planner also includes an additional distributional term that captures the effects of available policy instruments on consumption inequality. Kiaalhoseini et al. (2021) have investigated the policymaking behavior of the Central Bank of Iran in the form of the nonlinear McCallum rule and in the period 1989:4 to 2018:4 using Markov switching models, with the aim of examining nominal feedback rules in Iranian monetary policy. Given that the Central Bank does not announce specific and explicit production targets and inflation targets, the model estimation was performed assuming target inflation and unobservable target production. In this regard, the Bayesian Kalman filter method was used to estimate and estimate unobservable variables including inflation and nominal output growth, and then, using the estimation of state variables, modeling was performed within the framework of the Markov switching model, considering boom and bust regimes. The results show that the Central Bank gives more weight to the nominal output gap variable during a recession and more weight to the inflation gap variable during a boom. Maih et al. (2021) use a DSGE model to examine asymmetric monetary policy rules for the euro area and the United States. The results of the research using a Markov switching model show that until mid-2014, the European Central Bank's response to inflation above the target was stronger. Since 2014, the central bank's policy response has been symmetric. However, asymmetries in the policy of the Federal Reserve and the US banks still exist. Miranda (2020) evaluated the optimal monetary rules in a new Keynesian general equilibrium model for the Peruvian economy. This study showed that a rule based on domestic inflation forecasts and a rule based on the exchange rate performed well in the Peruvian economy. Researcher also showed that adding the nominal exchange rate to the monetary rule improved the model fit. Kanour et al. (2020) used dynamic stochastic general equilibrium models at investigating the optimal monetary policy rule considering the heterogeneity of economic agents' expectations in the form of models based on the behavior of economic agents in Iran. In this study, the effect of different formations of individuals' expectations on macroeconomic variables and the distributional effects of monetary policy considering different behaviors of economic agents were investigated by applying changes to the expectation solution model in dynamic stochastic general equilibrium models. The results show that under discretionary conditions, the monetary authority's attempt to redistribute wealth towards indebted households with a marginal utility of net wealth leads to changes in the inflationary bias. Erfani & Kasaipour (2019) studied changes in monetary policy during business cycles in the Iranian economy. They first showed, using a Markov cycle model that the behavior of monetary policy in the Iranian economy during 1991-2015 was mainly in line with business cycles. The researchers then designed a dynamic stochastic general equilibrium model appropriate to the structure of the Iranian economy and evaluated the optimal monetary policy during business cycles by considering financial dominance and institutional quality. The researchers' results showed that the coefficient of optimal monetary policy during business cycles decreases with a decrease in institutional quality and an increase in financial dominance. Also, if the policymaker's goal is only to stabilize inflation, the optimal monetary policy is independent of business cycles. In addition, if monetary policy is assumed to be completely independent, the coefficient of optimal policy takes the largest value compared to other assumed conditions. Gholizadeh Kenari et al. (2018) estimated Iran's optimal monetary policy rule for the period 1994 to 2015, with the aim of determining the optimal monetary policy rule, or in other words, the intermediate goal of optimal monetary policy to stabilize production and inflation, using the dynamic programming method. The results of optimization and achieving the optimal monetary rule in the first and second periods show that the sensitivity of the monetary policymaker to inflation deviation and output gap in the second period increased compared to the first period, and also that the reaction of the liquidity growth rate to the output gap was greater than the inflation deviation in the entire period under study. According to the results estimated in the period 1995-1995, the monetary policymaker can increase economic growth in the short term by monetary expansion, but must accept higher inflation and lower long-term growth, or obtain benefits in the form of reduced inflation and long-term growth by monetary contraction in return for paying the cost of reduced short-term economic growth. Patra et al. (2017) conducted a study to optimize monetary policy rules in India during the period 2000-2014. In this study, the weights of the policy rules were determined by minimizing the inter-period loss functions based on the variance of inflation and output. The results of this study show that, based on the standard Taylor rule, the optimal monetary policy in the Indian economy gives more weight to the output gap than to the inflation deviation.

Based on the studies reviewed in the research background section, numerous studies have been conducted in optimizing monetary policy rules. These studies mainly focus on determining the optimal monetary policy concerning oil and technology shocks, and the Taylor rule is considered the target-setting rule. Although in more recent studies, with the expansion of the open economy model, attention to fluctuations in external variables, including the exchange rate, in determining the optimal policy has become more prominent than before; however, the strength of the present study compared to similar studies is still the consideration of different target-setting rules; hence, the points of difference of the present study are the consideration of different criteria and different scenarios for monetary rules in Iran. Another point is that in this study, monetary policy rules are ranked by considering the conditions of the Iranian economy in terms of boom and recession, which is unprecedented in any of the studies conducted so far, and determining the optimal monetary rule in each period has been considered only in the present study. Hence, the present study uses a dynamic stochastic general equilibrium model to rank the optimal policy-making rules during business cycle.

## 3. Model environment

In the present research, a Dynamic Stochastic General Equilibrium (DSGE) model is employed within the framework of New Keynesian theory. The model consists of four main sectors, including households, firms, government, and the oil sector, referred to as agents. The state of the economy is defined as a flow of goods and services among economic agents. In this model, there exists a representative household that supplies labor to firms and purchases goods for consumption. Firms sell their differentiated goods in a monopolistic competition market. Additionally, a central bank is included that controls the growth rate of the money supply as a monetary policy tool. The government has the responsibility of maintaining the budget balance. The model's variables are affected by five different shocks, including monetary policy shocks, productivity shocks, preference shocks, oil revenue shocks, and global price level shocks. The employed model is a generalized framework for an open economy.

### 3.1 Households

Following Abel (1999) and Smets & Wouters (2002), it is assumed that there exists a representative household with an infinite horizon, whose consumption is a function of domestic goods CH and foreign goods CF, as shown in relation (1):

$$\mathrm{C_t} \equiv f\{C_{H_t}, C_{F_t}\} \tag{1}$$

Total household consumption is represented by relation (2):

$$P_t C_t \equiv [P_{Ht} C_{H_t} + S^* P_{Ft} C_{F_t}] \tag{2}$$

In this relationship, PHt represents the general price level of domestic goods, PFt represents the general price level of foreign goods, and S∗ denotes the nominal exchange rate. The price index of imported goods is influenced by international price shocks as expressed in relation (3):

$$\hat{P}_{Ft} = \hat{\rho}_{Ft} \hat{P}_{Ft-1} + \xi_{Ft} \tag{3}$$

The objective of the household is to maximize the expected value of the adjusted intertemporal utility function, subject to a budget constraint that shows expenditure less than or equal to income. Based on the objective function and the budget constraint, the Lagrange function for maximizing the household problem is derived as expressed in relation (4):

$$L = E_t \sum_{t=0}^{\infty} \beta^t \xi_{b,t} \left\{ \left[ \frac{c_t^{1-\delta}}{1-\delta} - \lambda_h \frac{h_t^{1+\eta}}{1+\eta} + \lambda_m \frac{m^{1-\tau}}{1-\tau} \right] + \lambda_t \left[ w_t h_t + r_t k_{t-1} + \frac{M_{t-1}}{P_t} + \frac{D_{t-1}}{P_t}\left(r_t^d + 1\right) + \frac{B_{t-1}}{P_t}\left(r_t^b + 1\right) - c_t - (k_t - (1-\delta)k_{t-1}) - m_t - d_b - b_t - ta_t \right] \right\} \quad (4)$$

$E_t$ represents the expectations operator, $0 \leq \beta^t \leq 1$ is the household's subjective discount factor, $\frac{1}{\delta}$ denotes the intertemporal elasticity of substitution in consumption, ct indicates the level of consumption of goods and services, $\frac{1}{\eta}$ represents the elasticity of labor demand, ht signifies the supply of hours worked, $\frac{1}{\tau}$ is the elasticity of money demand, mt is the real money balance, and ξ(b,t) denotes the preference shock as expressed in relation (5). This shock, along with all shocks mentioned in this study, follows an AR (1) process. The intertemporal substitution preference shock affects households in the following manner:

$$\xi_{b,t} = \rho_{b,t}\xi_{b,t-1} + \varepsilon_{b,t} \quad (5)$$

The production firms in the economy are owned by households, and each household begins each period with mt−1 units of money, dt−1 units of deposits, and bt−1 units of bonds, along with the income generated from them. Additionally, households provide lt units of labor to the production firms each period and, as shareholders, receive kt units of dividends, which correspond to wt and rt units of income from labor supply and firm shares, respectively. Households allocate their income among six categories: consumption of final goods ct, investment it, deposits dt, cash holdings mt, purchasing bonds bt, and tax payments at a rate t. Furthermore, $r_t^d$ and $r_t^b$ represent the interest rates on deposits and bonds, respectively. Considering that δ is equal to the depreciation rate, the capital stock in the economy is adjusted in each period according to the capital accumulation rule expressed in equation (6):

$$k_t = (1-\delta)k_{t-1} + i_t \quad (6)$$

From the maximization of the household utility function subject to its budget constraints, a set of relationships is derived based on the following calculations:

$$\frac{\partial L}{\partial c_t} = c_t^{-\delta} - \lambda_t \rightarrow \ \ \lambda_t = c_t^{-\delta} \quad (7)$$

$$\frac{\partial L}{\partial h_t} = -\lambda_h h_t^{\eta} + \lambda_t w_t = 0 \qquad w_t = \frac{\lambda_h h_t^{\eta}}{\lambda_t} \quad (8)$$

$$\frac{\partial L}{\partial m_t} = \lambda_m m^{-\tau} - \lambda_t + \beta E_t \frac{\lambda_{t+1}}{\pi_{t+1}} = 0 \quad (9)$$

$$\frac{\partial L}{\partial k_t} = \beta E_t \lambda_{t+1}(r_{t+1} + (1-\delta)) - \lambda_t = 0 \quad (10)$$

$$\frac{\partial L}{\partial b_t} = \beta E_t \frac{\lambda_{t+1}(1+r_t^b)}{\pi_{t+1}} - \lambda_t = 0 \tag{11}$$

By combining equations (7), (9), and (11), the demand function for the real money balance is obtained in the following form:

$$\lambda_m (m_t)^{-\daleth} = (\frac{r_t^b}{1+r_t^b}) c_t^{-\delta} \tag{12}$$

By combining equations (7) and (8), the supply function of labor is obtained in the following form:

$$w_t = \lambda_h \frac{h_t^{\eta}}{c_t^{-\delta}} \tag{13}$$

By combining equations (7), (10) and (11), the Euler equation is obtained in the following form:

$$\beta E_t \frac{c_{t+1}^{-\delta}}{\pi_{t+1}} = \frac{c_t^{-\delta}}{1+r_t^b} \tag{14}$$

The relationship between the rate of return on securities and the rate of capital rental is obtained by combining relationships (10) and (11).

$$r_t + (1-\delta) = E_t \frac{1+r_t^b}{\pi_{t+1}} \tag{15}$$

## 3.2 Producers of Final Goods

In this study, differentiated goods operate under conditions of monopolistic competition in the framework of a demand function1, following the work of Dixit & Stiglitz (1977). Thus, a chain of firms producing differentiated products combines a large number of intermediate goods to provide a basket of final goods to consumers in the form of a composite good. These intermediate goods are differentiated and imperfect substitutes for one another, and a constant substitution elasticity θ exists among them. The production of final goods Yt by firms is specified in equation (16):

$$Y_t = (\int_0^1 y_t\,(i)^{\theta-1/\theta})^{\theta/\theta-1} \qquad \theta > 0 \tag{16}$$

The goal of firms producing final goods is to maximize their profit. Thus, they purchase intermediate goods $y_t$ up to the point where their profit is maximized. Accordingly, the producer's objective is defined in equation (17):

$$\max_{y_t\,(i)} \left[ P_t Y_t - \int_0^1 P_t\,(i) y_t(i) di \right] \tag{17}$$

The constraint of intermediate goods firms is given by equation (18):

$$Y_t \le (\int_0^1 y_t\,(i)^{\theta-1/\theta})^{\theta/\theta-1} \qquad \theta > 0 \tag{18}$$

Solving the first-order condition for yt in terms of Yt yields a simplified form in equation (19):

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1 The aggregator producer generates a single good for supply from a set of goods that are imperfect substitutes for one another.

$$y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\theta} Y_t \tag{19}$$

Furthermore, the zero-profit condition for the producer of final goods is specified as follows:

$$P_t = [\int_0^1 p_t^{1-\theta}]^{\frac{1}{1-\theta}} \tag{20}$$

Equation (20) indicates that the share of good j at time t depends on the ratio of the price of good j to the prices of other goods.

### 3.3 Intermediate Goods Producers

The economy comprises a sequence of firms producing intermediate goods, each producing differentiated but substitutable goods. In this study, following komijani & tavakoliyanh (2011), the firm i produces $y_t(i)$ units of the intermediate good based on a Cobb-Douglas production function with constant returns to scale, combining technology, capital, and labor, as described in equation (21):

$$\mathrm{y_t(i)} \leq \mathrm{A_t}\big(\mathrm{K_t(i)}\big)^{\alpha}\mathrm{H(i)}_t^{1-\alpha}, \quad 0 < \alpha < 1 \tag{21}$$

In this equation, $A_t$ represents a technology shock, defined by equation (22):

$$\vartheta_{A,t} = \rho_{A,t}\vartheta_{t-1} + \xi_{A,t} \tag{22}$$

where $E(\xi_t) = 0$, and $\xi_t$ is normally distributed and independently and identically distributed over time.

It is also assumed that intermediate goods firms face adjustment costs when adjusting their nominal prices due to their extensive relationships with their customers, implying that money is not neutral in the model. The adjustment cost, representing nominal price stickiness, follows a quadratic function relative to output, based on the Rotemberg (1982) approach, and is presented in equation (23):

$$\mathrm{AC_{jt}} = \frac{\Psi_p}{2}(\frac{p_{jt}}{p_{jt-1}} - 1)^2 y_t \text{ و } \Psi_p > 0 \tag{23}$$

The problem faced by the intermediate firm is to choose levels of capital and labor that minimize cost:

$$L2 = r_t k_t + w_t l_t + \left[\frac{\Psi_p}{2}(\frac{p_{jt}}{p_{jt-1}} - 1)^2 y_t\right] + \mu_t(\mathrm{i})[\mathrm{y_t(i)} - \mathrm{A_t}\big(\mathrm{K_t(i)}\big)^{\alpha} H(\mathrm{i})_t^{1-\alpha}] \tag{24}$$

where $\mu_t(\mathrm{i})$ is $\mathrm{mc_t(i)}$ the marginal cost of producing one unit of the intermediate good i.

This study also considers the Calvo (1983) approach, where Ƶ percent of firms are unable to adjust their prices. According to Calvo's approach, firms that cannot adjust their prices do not have a choice regarding price levels, and their only problem is to choose levels of capital and labor. The remaining firms adjust their prices based on the most recent observed inflation rate, such that $p_t =$

$\pi_{t-1}p_{t-1}$. Then, the price selection problem for the 1−Ƶ percent of firms that can adjust their prices is:

$$E_t\sum_{j=0}^{\infty}(Ƶ\beta)^t\frac{\lambda_{t+j}}{\lambda_t}[p_t(i)-mc_t(i)](\frac{p_{jt}}{P_{t+i}})^{-\theta}Y_{t+i} \quad (25)$$

First-order conditions of the intermediate goods producer's maximization problem, with the help of relation (26), derive the New Keynesian Phillips curve:

$$y_t(i)=\left(\frac{P_t(i)}{P_t}\right)^{-\theta}Y_t \quad (26)$$

$$\max_{y_t(i)}\left[P_tY_t-\int_0^1 P_t(i)y_t(i)di\right] \quad (27)$$

$$\frac{\partial L2}{\partial l_t}=w_t-\mu_t(1-\alpha)A_tk_t^{\alpha}{}_t h_t^{-\alpha}=0 \quad (28)$$

$$\frac{\partial L2}{\partial k_t}=r_t-\mu_t\alpha A_tk_t^{\alpha-1}{}_t h_t^{1-\alpha}=0 \quad (29)$$

$$\frac{\partial L2}{\partial \mu_t}=y_t-A_t(k_t(i))^{\alpha}h_t(i)^{1-\alpha}=0 \quad (30)$$

By combining relations (28) and (29), the relationship between labor, capital, wage rate, and rental rate is obtained as follows:

$$\alpha w_th_t(i)=(1-\alpha)r_tK_{t-1}(i) \quad (31)$$

Also, the marginal cost is derived as follows, representing labor demand:

$$mc_t(i)=\alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}\alpha_t^{-1}r_{t-1}^{\alpha}{w_t}^{1-\alpha} \quad (32)$$

### 3.4 Government Sector

In this research, it is assumed that the government seeks a balanced budget and attempts to equate its expenditures, which include government spending and interest rate on bonds issued in the previous period, with its revenues, including total tax revenues, proceeds from the sale of bonds, oil revenues from sales and exports, and seigniorage. Relation (33) shows the government's budget constraint:

$$p_tG_t+(1+r_{t-1}^b)B_{t-1}=p_tta_t+B_t+oil_t+M_t-M_{t-1} \quad (33)$$

In this equation, $G_t$ represents government expenditure and $oil_t$ represents oil revenue.The real government budget constraint is following equation (34):

$$G_t+(1+r_{t-1}^b)\frac{B_{t-1}}{p_t}=ta_t+\frac{B_t}{p_t}+\frac{oil_t}{p_t}+\frac{M_t-M_{t-1}}{p_t} \quad (34)$$

The revenue from oil exports remains stable unless affected by an oil shock($\varepsilon_{oil}$):

$$\varepsilon_{oil,t}=\rho_{oil,t}\varepsilon_{t-1}+\xi_{A,t} \quad (35)$$

In such an economy, the gross domestic product (GDP) is derived from the sum of oil and non-oil production, according to equation (36):

$$GDP_t=Y_t+oil_t \quad (36)$$

### 3.5 Equilibrium

Economic equilibrium can be examined when households and firms solve their optimization problems, the government satisfies its budget constraint, and all markets are clear. Specifically, rational expectations equilibrium includes a sequence of exogenous variables that satisfy the set of equations derived from optimization, the government's budget constraint, and the market clearing conditions (Raeisi gavgani et al., 2018).

For clearing in the goods and services market, total supply needs to be equal to total demand. Thus, the equilibrium condition is the equality of aggregate supply and aggregate demand:

$$\mathrm{Y_t} + oil_t = C_t + I_t + G_t - \mathrm{NX_t} + \mathrm{AC_{jt}} \tag{37}$$

This means that the sum of non-oil and oil production is equal to the sum of consumption, investment, government expenditure, net exports, and price adjustment costs. Net exports are defined in the following equation (37):

$$\mathrm{NX_t} = Y_t - C_t + Open * \mathrm{P}_s \tag{38}$$

In relation (37), open refers to the ratio of the total value of exports and imports to the country's gross domestic product; As a result, economic openness affects the equilibrium level of the model variables by changing the country's net exports.

### 3.6 Central Bank

Generally, in the DSGE model, the monetary policymaker selects the interest rate as the policy instrument based on the Taylor rule. Thus, if inflation (production) is higher (lower) than its target or potential, according to the Taylor rule, the federal funds rate is increased (decreased) to eliminate the inflation (output) gap (Erfani & Shamsiyan, 2016). Since in Iran the interest rate is determined administratively and it is not possible to change it according to the Taylor rule, in this research, the money growth rate rule is used instead of the Taylor rule, and it is assumed that the central bank chooses the money growth rate (as a policy instrument) in a way that maximizes the level of social welfare. Based on this assumption, the central bank's reaction function, based on the study by Vaez Borzani et al. (2014), is considered in relation (39) and consists of the inflation gap ($\hat{\pi}_t$), output gap ($\hat{x}_t$), and the exchange rate gap ($\hat{e}_t$):

$$\begin{aligned} g_{m_t} &\\ = a_1 + \{\lambda_1\big(E_t(\pi_t - \pi_t^*)\big) + \lambda_2\big(E_t(x_t - x_t^*)\big) + \lambda_3\big(E_t(e_t - {e_t}^*)\big)\} &\\ + \xi_{g_{m_t}} & \end{aligned} \tag{39}$$

The central bank's reaction function is specified symmetrically, where $g_{m_t}$ is the money growth rate, and $\xi_{g_{m_t}}$ is the monetary policy shock, which is shown in relation (40):

$$\xi_{g_{m_t}} = \rho_{g_{m_t}} \xi_{g_{m_{t-1}}} + \varepsilon_{g_{m_t}} \tag{40}$$

Since the objective of the current study is to assess the welfare implications of different monetary policy rules over business cycles, we introduce six rules that have been considered in this research based on the economic conditions of Iran.

In all rules, $\widehat{M}_t$ represents the growth rate of money supply, ρπ, ρx, and ρe are the sensitivities of money supply growth to the inflation gap, output gap, and exchange rate gap, respectively.

Inflation Targeting Rule: This rule is one of the most important rules used in many studies to determine monetary policy. The Central Bank of Iran, in a statement in 2020, designated the inflation rate targeting as its monetary policy rule. The inflation targeting rule can be specified as follows:

$$\widehat{M}_t = \rho_\pi \hat{\pi}_t + \hat{\xi}_t \tag{41}$$

Fixed Official Exchange Rate Rule: Banerjee & Basu (2015) stated that in an emerging economy with financial frictions, inflation targeting has little advantage over a fixed exchange rate regime. The fixed exchange rate rule is particularly applicable in situations where the prices of many goods are a function of the exchange rate and the economy is facing exchange rate shocks because, in this rule, the monetary variables of the economy are determined in such a way that the official exchange rate remains fixed. This rule can be shown as in relation (42):

$$\widehat{M}_t = \rho_e \hat{e}_t + \hat{\xi}_t \tag{42}$$

Nominal Output Growth Rule: After the 2008 financial crisis and following criticisms leveled against the implementation of inflation targeting in emerging economies, the debate regarding the benefits of nominal income targeting in advanced economies gained traction. Output targeting means that a rate is determined for the real output growth, which can be the long-term trend or potential output. Then, the target inflation rate is added to it, and the sum of these two rates is determined as the target nominal income growth rate (Bayat et al., 2017). This rule can be shown in relation (43):

$$\widehat{M}_t = \rho_y \hat{x}_t + \hat{\xi}_t, \tag{43}$$

Taylor Rule: The Taylor rule functions almost as an optimal monetary policy rule (Rudebusch & Svensson, 1999, and Ball, 2012). The form of the Taylor rule varies due to differences in the specification of the Taylor rule in different studies. This rule does not have microeconomic foundations and is merely an econometric relationship that can vary from one study to another (Tavakolian & Sarem, 2016). By including money supply growth as the policy variable, the Taylor rule for the Iranian economy can be shown in relation (43):

$$\widehat{M}_t = \rho_\pi \hat{\pi}_t + \rho_x \hat{x}_t + \hat{\xi}_t \tag{44}$$

Cabrera et al. (2011) Rule: Cabrera et al. (2011), considering the limitations of the central bank in Peru, introduced a rule for monetary policy that simultaneously considers inflation, output, and the exchange rate. This rule can be shown as follows:

$$\widehat{M}_t = \rho_\pi \hat{\pi}_t + \rho_x \hat{x}_t + \rho_e \hat{e}_t + \hat{\xi}_t \tag{45}$$

This rule incorporates the nominal exchange rate channel in the transmission of monetary policy.

Generalized Cabrera et al. (2011) Rule: Since monetary policy may have a persistent component, some researchers, for example, Miranda (2020), have included the lagged value of the interest rate or money supply growth in the policy rule. Considering this in the short-term optimal rule of Cabrera et al. (2011), the following policy rule can be proposed for the Iranian economy:

$$\widehat{M}_t = \rho_M \widehat{M}_{t-1} + \rho_\pi \hat{\pi}_{d,t} + \rho_x \hat{x}_t + \rho_e \hat{e}_t + \hat{\xi}_t \qquad (46)$$

This rule incorporates a combination of the persistent component of monetary policy, domestic inflation, output gap, and the nominal exchange rate in monetary policy decisions.

### 3.7 Model parameterization

This research is applied in terms of its objective and is library-based in terms of data collection method. In this research, the Bayesian method and the Metropolis-Hastings algorithm are used to estimate the model parameters. Using the Metropolis-Hastings algorithm, a parallel chain is extracted to obtain the posterior density of the parameters. Since there are five structural shocks in the research model, it is possible to use five observable variables. Consequently, five observable variables including gross domestic product, consumer inflation rate, private consumption expenditure, government consumption expenditure, and fixed capital formation are used. Before estimating the model, the parameters need to be calibrated. Since this research aims to analyze the welfare effects of different monetary rules during periods of recession and expansion, it is necessary to parameterize the model according to recessions and expansions. For this purpose, data from 1988 to 2022 are used. The research data has been extracted from various information sources including the World Bank, the Central Bank of Iran, the National Productivity Organization, and the Statistical Center of Iran. To identify periods of recession and expansion, the Hodrick-Prescott filter and the Bry-Boschan algorithm are used. The Bry-Boschan algorithm (1971) is a computerized procedure for identifying peaks and troughs of a time series (Harding & Pagan, 2002):

## 4. Empirical Results

In this section, the welfare losses of each monetary rule are calculated based on the designed DSGE model, considering various monetary rules during periods of recession and expansion.

### 4.1 Calibrating the Model during Recession and Expansion

Initially, in this section, recession, and expansion periods are identified based on the Hodrick-Prescott filter and the Bai-Perron algorithm.

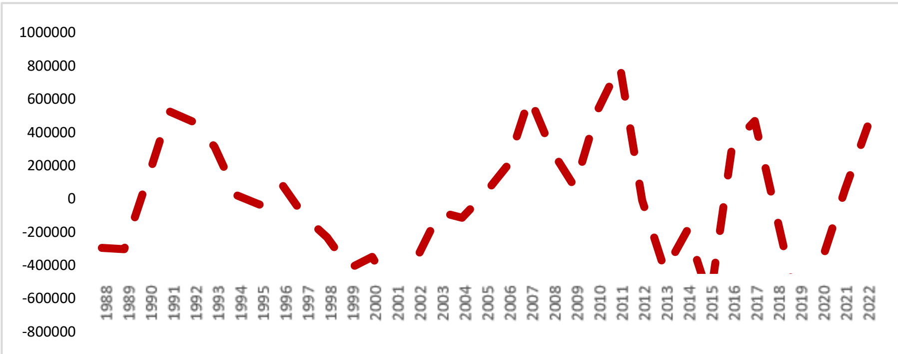


***Figure 1. Extraction of Economic Business Cycles in Iran from 1988 to 2022***
***Source:*** *Research Findings*

In Figure 1, the business cycles of the Iranian economy are extracted based on the reference variable of gross domestic product (GDP) at constant 2016 prices using the Hodrick-Prescott filter. The Bai-Perron algorithm can be employed to identify the periods of recession and Boom as shown in Table 1. As seen in Table 1, during the years 1988 to 2022, five expansion periods and four recession periods have been identified in the Iranian economy. By determining the recession and Boom periods, and relying on the existing data in the Iranian economy, the average values of some model parameters can be computed according to the recession and expansion periods. Indeed, the significant feature of this research lies in the attempt to calibrate the model parameters differently for recession and Boom periods based on the available data repository in the Iranian economy and the necessary estimates, to evaluate changes in monetary policies during business cycles more accurately.

***Table 1. Identification of business cycles based on Hodrick-Prescott Filter***

| Period | Type | Duration | Period | Type | Duration |
|---|---|---|---|---|---|
| 1988 to 1991 | Boom | 4 years | 2012 to 2015 | Recession | 4 years |
| 1992 to 2001 | Recession | 10 years | 2016 to 2017 | Boom | 2 years |
| 2002 to 2007 | Boom | 6 years | 2018 to 2019 | Recession | 2 years |
| 2008 to 2009 | Recession | 2 years | 2020 to 2022 | Boom | 3 years |
| 2010 to 2011 | Boom | 2 years | | | |

***Source:*** *Research Findings*

***Table 2. Methods for calibrating the parameters in business cycle***

| parameters | Symbol | Calculation method | Average parameter | |
|---|---|---|---|---|
| | | | Recession | Boom |
| Share of private consumption in GDP | cbar_ybar | National Accounts | 0.504 | 0.507 |
| Share of government consumption in GDP | gcbar_ybar | National Accounts | 0.131 | 0.128 |
| Share of net exports in GDP | gxbar_ybar | National Accounts | 0.219 | 0.220 |
| Share of fixed capital formation in GDP | i_itbar | National Accounts | 0.293 | 0.279 |
| Trade openness index | open | National Accounts | 0.421 | 0.445 |
| Capital elasticity of production | alpha | Account Sequence | 0.749 | 0.754 |
| Inflation coefficient in monetary function | Lambda1 | Markov Switching Model Selection and Estimation | 0.484 | 0.679 |
| Output gap coefficient in monetary function | Lambda2 | Markov Switching Model Selection and Estimation | 0.324 | 0.252 |
| Exchange rate coefficient in monetary function | Lambda3 | Markov Switching Model Selection and Estimation | 0.233 | 0.074 |
| Monetary policy shock autoregression coefficient | rhoeps | AR(1) Model Estimation | 0.995 | 0.996 |
| Oil revenue shock autoregression coefficient | rhoOil | AR(1) Model Estimation | 0.741 | 0.808 |
| World price shock autoregression coefficient | rhoPS | AR(1) Model Estimation | 0.947 | 0.968 |
| Technology shock autoregression coefficient | rhoTeta | AR(1) Model Estimation | 0.857 | 0.791 |
| Preference shock autoregression coefficient | rhoepre | AminiRad (2022) | 0.9 | 0.90 |
| Interperiod substitution elasticity of consumption | sigma | Markov Switching Model Estimation | 3.4 | 2.9 |
| Inverse of real balance of money elasticity | lambdam | Markov Switching Model Estimation | 0.522 | 0.373 |
| Inverse of Frisch labor elasticity | lambdah | National Accounts | 1.053 | 1.606 |
| Depreciation rate | Delta | National Accounts | 0.04 | 0.038 |

***Source:*** *Research Findings*

In Table 2, the values of the model parameters are presented according to the recession and expansion periods. To calculate the parameter representing the share of private consumption in GDP, the ratio of final private consumption expenditures to gross domestic product over the years 1988 to 2022 is computed, followed by averaging it according to the two periods of recession and expansion. Similarly, the share of government consumption in GDP, the net exports in GDP, and the share of fixed capital formation in GDP are calculated during the two periods of recession and expansion. To compute the trade openness index, the value of exports is summed with the value of imports and the result is divided by the gross domestic product, and then the average of this ratio is calculated for the two periods. For estimating the capital-output elasticity, data from the Central Bank's accounts are utilized. In this regard, the ratio of the total operating surplus and various incomes to gross domestic product is considered the capital-output elasticity, and the average value is calculated during the recession and expansion periods. The rate of depreciation of fixed capital is calculated by dividing the fixed capital consumption by the total capital stock available in the economy, with data available in the national accounts of the Central Bank. For calculating the importance coefficient of inflation, the output gap, and the exchange rate in the response function of monetary policymakers, different approaches are adopted for each monetary rule. In the first to fourth rules, these parameters are calculated based on the researcher's judgment, considering the status of these parameters during recession and expansion. For the fifth and sixth monetary rules, the importance coefficient of these parameters is estimated by employing a two-regime Markov switching model. As seen in the table 2, in the first regime (recession), the coefficients for inflation rate, output gap, and exchange rate are estimated at 0.484, 0.324, and 0.233, respectively. Additionally, the parameters for the inflation rate, output gap, and exchange rate in the second regime (expansion) are estimated at 0.679, 0.252, and 0.074, respectively. The autocorrelation coefficients for shocks related to monetary policy, oil revenue shocks, global price shocks, and technology shocks are estimated using a vector autoregression model during the two periods of recession and Boom. In the autoregressive relationship for global price shocks, the average consumer price index variable at the world level, with data obtained from the World Bank, has been utilized. Additionally, in the autoregressive relations for technology shocks, total factor productivity is employed, with data published by the National Productivity Organization of Iran. The inverse elasticity of real money balances and inverse elasticity of fresh labor are also calculated using Markov switching regression, where private consumption expenditures are regressed on real money balances and the number of employed persons. As shown in the table 2, in the first regime (recession) and the second regime (Boom), the inverse elasticity of real money balances is estimated at 0.373 and 0.522, respectively. Furthermore, in the first (recession) and second (Boom) regimes, the inverse elasticity of fresh labor is estimated at 1.053 and 1.606, respectively.

## 4.2 Checking the validity of the economic model

Figure 2 presents the results of the model parameter identification test. As can be seen in Figure 4, the estimated value of none of the parameters is equal to zero and the values of all parameters have been estimated successfully; therefore, the research model has acceptable identification power.

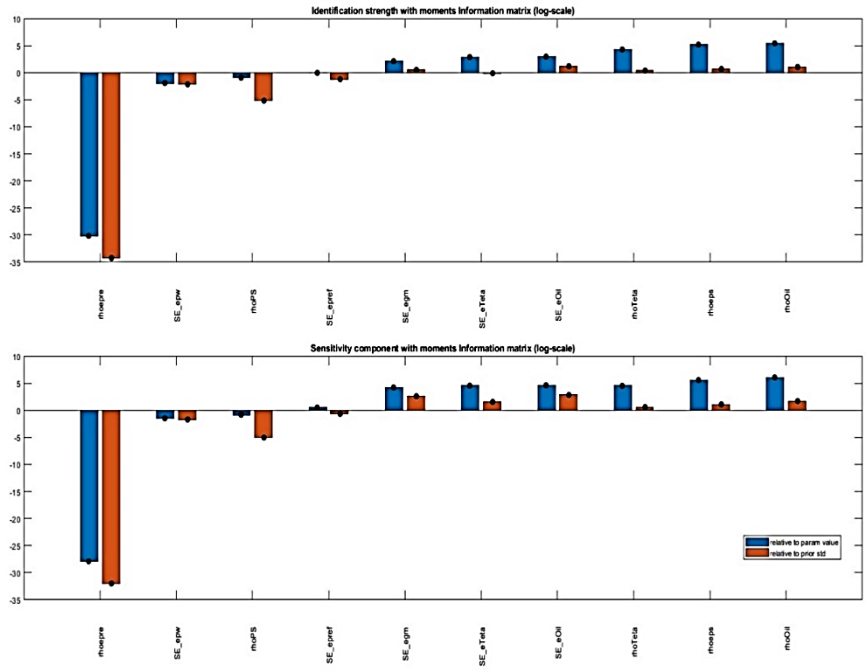


***Figure 2. The identification power of the general equilibrium model of the research***
***Source:*** *Research Findings*

## 4.3 Analyzing the response of social welfare to shocks and monetary rules

In Table 3, the welfare losses associated with various monetary rules during recession periods are calculated considering the impact of a monetary policy shock. As observable in the table, in the recession period, if only one monetary shock is introduced to the Iranian economy, the highest welfare loss occurs when the monetary policymaker adopts the nominal GDP growth rule as the basis for monetary policy. Conversely, during this period, the lowest welfare loss occurs when the monetary policymaker utilizes the generalized Cabrera & colleagues (2011) rule for adjusting monetary variables. According to this rule, the Central Bank must consider past values of monetary variables, inflation deviation from the target inflation, output gap, and changes in the exchange rate when targeting monetary variables.

***Table 3. Estimation of Welfare Losses of Monetary Rules during Recession Considering Single shocks***

| Monetary rules | Monetary shock | Technology shock | Preference shock | Oil revenue shock | Global price shock |
|---|---|---|---|---|---|
| Inflation targeting rule | 0.492 | 0.1987 | 0.0144 | 0.0841 | 0.0148 |
| Official exchange rate fixing rule | 0.6095 | 0.0293 | 0.0007 | 0.007 | 0.0002 |
| Nominal output growth rule | 1.6135 | 0.6211 | 0.0273 | 0.0841 | 0.0162 |
| Taylor rule | 1.0325 | 0.3621 | 0.0141 | 0.007 | 0.0087 |
| Cabrera et al (2011) rule | 0.6966 | 0.1971 | 0.0079 | 0.0841 | 0.0059 |
| Generalized Cabrera et al (2011) rule | 0.3067 | 0.1971 | 0.0079 | 0.007 | 0.0059 |

***Source:*** *Research Findings*

As shown in the table, if a technology shock is introduced to the Iranian economy during the recession period, the highest welfare loss occurs when the monetary policymaker adopts the nominal GDP growth rule as the basis for monetary policy. Furthermore, the lowest welfare loss occurs when the monetary policymaker employs the exchange rate stabilization rule to adjust monetary variables. Based on the evidence presented, if a preference shock were to be introduced to the Iranian economy during the recession period, the most significant welfare loss relates to when the monetary policymaker uses the nominal GDP growth rule. Conversely, the lowest welfare loss during this period transpires when the policymaker applies the exchange rate stabilization rule. Similarly, as observed in Table 3, if an oil revenue shock affects the Iranian economy during the recession period, the highest welfare loss relates to the nominal GDP growth rule, whereas the lowest welfare loss occurs when applying the exchange rate stabilization rule. Table 6 demonstrates that in the event of introducing a world price shock to the Iranian economy during the recession, the highest welfare loss is recorded when the nominal GDP growth rule is adopted, while the lowest welfare loss occurs when employing the exchange rate stabilization rule.

***Table 4. Estimation of Welfare Losses of Monetary Rules during Recession Considering All Shocks***

| Monetary rules | Production gap variance | Inflation gap variance | Exchange rate variance | Welfare loss |
|---|---|---|---|---|
| Inflation targeting rule | 194.4414 | 46.5904 | 1859.6315 | 0.7492 |
| Official exchange rate fixing rule | 194.5958 | 43.1541 | 112.0257 | 0.6461 |

| | | | | |
|---|---|---|---|---|
| Nominal output growth rule | 197.9549 | 43.1927 | 13648.1055 | 2.371 |
| Taylor rule | 196.5649 | 44.4668 | 3194.7691 | 1.4827 |
| Cabrera et al (2011) rule | 195.4066 | 44.9688 | 481.7486 | 0.9472 |
| Generalized Cabrera et al rule | 195.4066 | 44.9688 | 166.9402 | 0.5573 |

***Source:*** *Research Findings*

In Table 4, welfare losses of various monetary rules during recession periods are calculated considering the occurrence of all five shocks simultaneously. As observed in the table, if all five shocks are simultaneously introduced to the Iranian economy during the recession period, the highest welfare loss occurs when the monetary policymaker adopts the nominal GDP growth rule as a basis for monetary policy. The lowest welfare loss arises when the monetary policymaker utilizes the generalized Cabrera rule for adjusting monetary variables.

***Table 5: Estimation of the Welfare Loss of Monetary Rules during the Boom Period Considering Single shocks***

| Monetary rules | Monetary shock | Technology shock | Preference shock | Oil revenue shock | Global price shock |
|---|---|---|---|---|---|
| Inflation targeting rule | 0.3933 | 0.1106 | 0.0163 | 0.0968 | 0.0173 |
| Official exchange rate fixing rule | 0.4553 | 0.0133 | 0.0004 | 0.0066 | 0.0002 |
| Nominal output growth rule | 0.6446 | 0.2412 | 0.0220 | 0.1238 | 0.0186 |
| Taylor rule | 0.5195 | 0.1543 | 0.0116 | 0.0890 | 0.0101 |
| Cabrera et al rule | 0.4305 | 0.1115 | 0.0111 | 0.0831 | 0.0113 |
| Generalized Cabrera et al rule | 0.0774 | 0.1115 | 0.0111 | 0.0831 | 0.0113 |

***Source:*** *Research Findings*

In Table 5, welfare losses associated with various monetary rules during Boom periods are calculated based on different shocks. As seen in the table, if a technology shock is introduced to the Iranian economy during the Boom period, the highest welfare loss occurs when the monetary policymaker adopts the nominal GDP growth rule as a basis for monetary policy. Conversely, the lowest welfare loss transpires when the policymaker applies the exchange rate stabilization rule during this period. Similarly, if a preference shock were to affect the Iranian economy, the highest welfare loss corresponds to the nominal GDP growth rule, while the lowest loss arises from the exchange rate stabilization rule. Meanwhile, in the event of an oil revenue shock introduced during the Boom period, the highest welfare loss occurs under the nominal GDP growth rule, with the least welfare loss arising from implementing the exchange rate stabilization rule. Lastly, if a global price shock acts upon the economy during Boom, the nominal GDP growth rule once again results in the highest welfare loss, while the exchange rate stabilization rule results in the least.

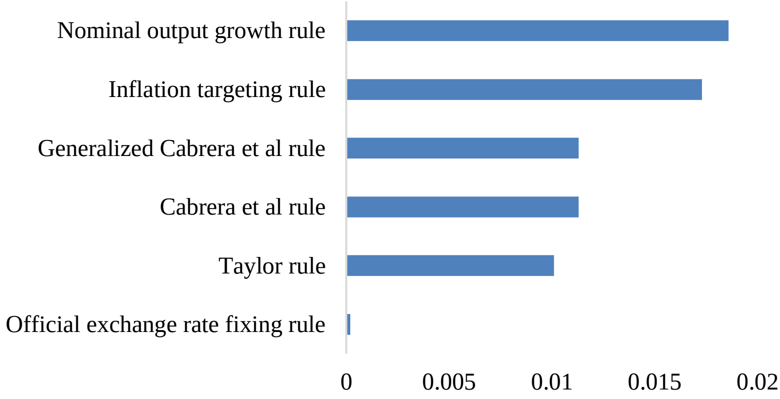


***Figure 3. Comparison of Welfare Losses of Various Monetary Rules during Recession Considering Simultaneous Five Shocks***
***Source:*** *Research Findings*

In Table 6, the welfare losses of different monetary rules during the Boom period are calculated by taking into account the simultaneous occurrence of all five shocks. As seen in the table, when all five shocks are simultaneously applied to the Iranian economy during the Boom period, the greatest welfare loss occurs when the monetary policymaker adopts the nominal GDP growth rule as the foundation for monetary policy. Additionally, during this period, the least amount of welfare loss occurs when the monetary policymaker utilizes the generalized Cabrera and colleagues' rule to adjust monetary variables.

***Table 6: Estimation of Welfare Losses of Monetary Rules during Boom Considering All Shocks***

| Monetary rules | Production gap variance | Inflation gap variance | Exchange rate variance | Welfare loss |
|---|---|---|---|---|
| Inflation targeting rule | 55.5979 | 25.6686 | 1914.1463 | 0.5695 |
| Official exchange rate fixing rule | 55.7413 | 22.4787 | 111.3554 | 0.4751 |
| Nominal output growth rule | 58.8596 | 22.5145 | 7425.1477 | 0.9769 |
| Taylor rule | 56.5693 | 24.6973 | 2284.5451 | 0.7460 |
| Cabrera et al rule | 56.3148 | 24.8801 | 1392.1331 | 0.6057 |

| | | | | |
|---|---|---|---|---|
| Generalized Cabrera et al rule | 56.3148 | 24.8801 | 258.8480 | 0.2527 |

***Source:*** *Research Findings*

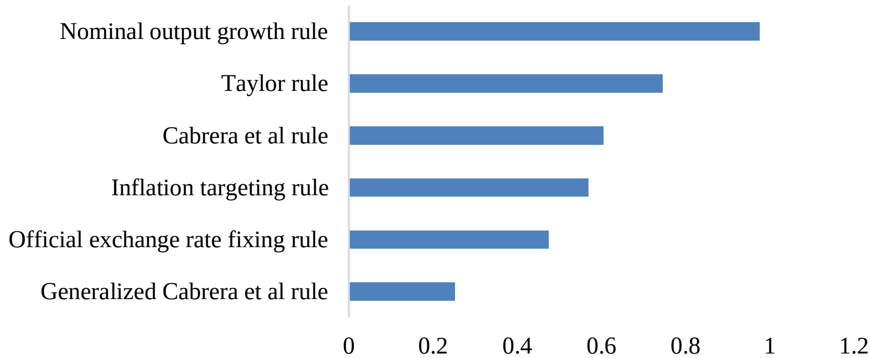


***Figure 4. Comparison of Welfare Losses of Various Monetary Rules during Boom Considering All Shocks***
***Source:*** *Research Findings*

As observed in Figures 2 and 3, the nominal GDP growth targeting rule has resulted in the highest welfare losses in the Iranian economy during both recession and Boom periods. This can be attributed to the failure to consider key variables such as inflation deviation from target levels and exchange rate fluctuations. Given that the inflation rate and exchange rate in Iran's economy have consistently undergone significant shocks in recent decades, and many individuals in the society consider these two variables in their decision-making processes, overlooking these factors in determining the targets of monetary policy has caused considerable welfare losses. Furthermore, based on the calculated welfare loss values, it can be argued that exchange rate stability has a higher priority than inflation deviation in the Iranian economy from a welfare perspective. The occurrence of currency crises in Iran has always been associated with sharp increases in price levels and decreases in economic growth. Therefore, currency crises and exchange rate instability have severely diminished purchasing power among households. Consequently, it seems that a relative stability of the exchange rate and preservation of the national currency value in Iran could facilitate economic growth and reduce inflation.

## 5. Concluding Remarks

In this research, a new Keynesian dynamic stochastic general equilibrium model was estimated for the Iranian economy. Following the design of the model, six different monetary policy rules were introduced to compare the welfare effects of shocks across alternative monetary policy regimes for Iran. This study aimed to answer the question of which monetary policy rule, considering the structure of the Iranian economy, could be more efficient from a welfare perspective during recession and Boom periods. The first step involved calibrating the model according to the recession and Boom periods. Next, welfare losses of different monetary rules during recession and Boom considering individual shocks as well as the simultaneous impact of all five shocks on the economy were calculated and compared.

The main findings of this research indicate that from 1988 to 2022, the ranking of monetary policy rules is influenced by the type of shocks affecting the economy. Based on the research results, if the economy simultaneously encounters five shocks, including monetary shock, preference shock, technology shock, oil revenue shock, and global price shock, the generalized Cabrera and colleagues' rule is the most effective monetary rule for stabilizing production, exchange rates, and inflation during both recession and Boom periods. According to this research's calculations during a recession, the weights assigned to the inflation deviation from target values, output gap, and exchange rate fluctuations are 0.522, 0.344, and 0.233, respectively. This means that if the Central Bank of Iran aims to maximize social welfare during economic recessions, it should determine its monetary policy targets in such a way that the weight of inflation deviation from the target is 0.522, the weight of the output gap is 0.324, and the weight of exchange rate fluctuations is 0.233. Furthermore, to maximize social welfare during the Boom period, the Central Bank of Iran should establish its monetary policy targets in a manner that the weight assigned to inflation deviation from the target equals 0.690, the weight of the output gap is 0.252, and the weight of exchange rate fluctuations is 0.074.

The research findings also demonstrated that exchange rate stability and the reduction of its fluctuations resulted in lower welfare losses compared to the inflation targeting rule and the nominal GDP growth targeting rule during both recession and Boom. This highlights the critical role of the exchange rate in the Iranian economy. Based on this finding, it is recommended that if the Central Bank of Iran aims to focus on a single variable for determining its monetary policy, it should prioritize reducing exchange rate fluctuations and maintaining the value of the national currency. Moreover, future researchers are encouraged to employ alternative indices for identifying business cycles and to compare their findings with the current study.

Given the impact of business cycles on the ranking of monetary policy rules in the Iranian economy, it is of great importance to accurately identify recession and boom periods; as a result, it is suggested that researchers use different methods of extracting business cycles, including using different univariate and multivariate filters and comparing their results with other statistical evidence of the Iranian economy (including unemployment rate, economic growth, and other economic criteria), to suggest the best method of extracting business cycles in the Iranian economy.

## Author Contributions

Conceptualization, all authors; methodology all authors; formal analysis, all authors; resources, all authors; writing—original draft preparation, all authors; writing—review and editing, all authors. All authors have read and agreed to the published version of the manuscript.

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## Conflicts of Interest

The authors declare no conflict of interest.

## Data Availability Statement

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## Appendix

### Linearized model

| |
|---|
| $\widehat{m}_t = \frac{\delta}{\text{T}}\hat{c}_t - \frac{1}{\text{T}}\bar{r}^b$ |
| $\widehat{w}_t = \eta h_t + \delta \hat{c}_t$ |
| $\hat{c}_t = \hat{c}_{t+1} - \frac{1}{\delta}[\hat{r}_t^b - \hat{\pi}_{t+1}]$ |
| $\hat{r}_t = \frac{1+k}{\delta+k}(\hat{r}_t^b - \pi_{t+1})$ |
| $\mathrm{y_t = A_t + \alpha(K_t)\ h(i)_t^{1-\alpha}}$ |
| $\widehat{mc}_t(i) = \alpha\left(\hat{R}_t\right) + (1-\alpha)\widehat{w}_t - \hat{\alpha}_t$ |
| $G_t + (1+r_{t-1}^b)\frac{B_{t-1}}{p_t} = ta_t + \frac{B_t}{p_t} + \frac{oil_t}{p_t} + \frac{M_t - M_{t-1}}{p_t}$ |
| $I_t = K_t - (1-\delta)K_{t-1}$ |
| $\mathrm{Y_t} + oil_t = C_t + I_t + G_t - NX_t + \mathrm{AC_{jt}}$ |
| $\vartheta_{A.t} = \rho\vartheta_{A,t-1} + e_{A,t}$ |
| $\epsilon_{oil.t} = \rho\epsilon_{oil,t-1} + e_{oil,t}$ |
| $\xi_{b.t} = \rho\xi_{b,t-1}e_{b,t}$ |
| $P_{pf.t} = \rho P_{pf,t-1} + e_{pf,t}$ |
| $\varepsilon_{gm.t} = \rho\varepsilon_{gm,t-1} + e_{gm,t}$ |