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RESEARCH PAPER

Optimal Monetary Policy with Heterogeneous Agents in Iran (1989-2017): A Model Based on Time Consistency Problem

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Abstract
Policy rules as one of the most acceptable methods in monetary policies are among the significant characteristics of researches about policymaking. A policy rule states how the policy tools should react to changes in economic situations. Understanding the tools and criteria of monetary policies such as changes in target inflation, changes in relative weights of prices stability and employment, and its effect on different sections of society including households and economic firms can help economic policymakers to increase the effectiveness of monetary policies. This paper studies the time consistency and structure of optimal monetary policy from the viewpoint of public sector finance concerning the heterogeneous behavior of economic agents in form of keeping liquidity and nominal assets in Iran. The study utilizes time-series data quarterly from Q1 1989 to Q4 2017. A new Keynesian dynamic stochastic general equilibrium (DSGE) models have been developed for monetary policy analysis in open economies. Results show that the redistribution effect of monetary policy leads to breakage of the link between time consistency and high inflation; a characteristic that belongs to optimal monetary and fiscal policies.
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JEL Classification: E52, J22, H31, E31.

Introduction

Monetary policy is a concept and indication of the ability and capability of the economic policymaker and its impact on macroeconomic variables. Not only is the main purpose of monetary policy and, consequently, monetary policymaker is to control the general price level and maintain the national currency value, but also to enhance economic activities and increase production. Therefore, policymakers seek to use instruments that will accelerate the achievement of the set of determining goals and result in the least welfare loss to society. The ultimate goal of economic policy research is to provide recommendations on how to manage economic policies. The use of policy rules, as one of the most acceptable methods for studying monetary and fiscal policies, is one of the most prominent features of policy research in the last few decades (especially since the 1990s).

The purpose of this paper is to study the structure and the time consistency of optimal monetary policy from a public finance perspective in an economy where agents are heterogeneous in holdings of currency and other nominal assets. The seminal work of Calvo (1978) and Lucas and Stokey (1983) illustrates that in a monetary economy a benevolent

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policymaker has the incentive to tax outstanding nominal assets via unanticipated inflation when lump-sum taxation is not available. On this basis, lack of commitment has been advocated as a potential explanation of persistently high inflation and high public deficits. In the presence of nominal assets and distortionary taxation, rational agents anticipate the policymaker's incentive to revise the policy in the direction of higher money growth. This leads to high inflation in equilibrium. Moreover, the equilibrium inflation rate is positively correlated with the level of outstanding nominal government debt.

Lucas and Stokey (1983) and Chamley (1985) argue that time consistency of optimal monetary policy can be achieved if the monetary authority can commit to a path for nominal prices. Persson et al. (1987) exhibit a particular debt management strategy, involving both nominal and indexed government bonds of various maturities that can remove the problem of time inconsistency. The findings in this paper suggest that optimal monetary policy could be made time consistent by influencing the distribution of government debt. This argument is not new. Hamilton (1795) argued in favor of the Federal assumption of the states' war debt as a way to reduce the risk of monetization. Debt assumption would provide powerful government creditors with a strong incentive to support Federal tax legislation, making the use of inflation to raise revenues less likely.

In this paper, we describe a cash-credit good economy in which households have different preferences over cash and credit goods and differ in holdings of nominal bonds. Households chose consumption and labor supply and are subject to proportional labor income taxation. The government issues money and nominal debt and collects labor income taxes to finance an exogenous stream of government spending. Monetary and fiscal policy redistributes resources across households. Inflation weighs more heavily on households who consume a greater fraction of cash-goods and unanticipated inflation hits holders of nominal assets. The share of labor income tax revenues collected from each type of household is proportional to supply labor, which is inversely related to outstanding nominal wealth.

A growing literature has emerged in recent years that aims at re-examining some important macro questions through the lens of monetary models with heterogeneous agents. Models in this literature commonly assume the presence of idiosyncratic shocks to individuals' income, together with the existence of incomplete markets and borrowing constraints. Those features are combined with the kind of nominal rigidities and monetary non-neutralities that are the hallmark of New Keynesian models (Kaplan et al., 2018).

Optimal monetary policy with heterogeneous households depends on the balance of monetary and financial policy in economic efficiency and redistributing wealth among households. If the outstanding government debt is not large, the optimal monetary policy under the commitment is time consistent when more weight is given to households that hold a large fraction of their wealth as cash. If outstanding government debt is large in the economy, then for achieving Pareto optimal, households should use a large fraction of their wealth to buy credit goods or government debt securities because under these conditions the government seeks to reduce the rate of monetary growth and increase taxes on labor supply. Therefore, when the government debt is large in the economy and households hold a high fraction of government securities, the optimal monetary and fiscal policy is time consistent. Accordingly, the main question of this paper is whether the optimal monetary policy is time consistent or not under the conditions that economic agents have heterogeneous decision-making behaviors.

This paper is organized as follows. In section two, previous studies have been investigated. Section three is devoted to model the optimal monetary policy. Section four presents the result of the empirical model estimation and section five concludes and presents policy implications.

Literature Review

A growing literature has emerged in recent years that aims at re-examining some important macro questions through the lens of monetary models with heterogeneous agents. Models in this literature commonly assume the presence of idiosyncratic shocks to individuals' income, together with the existence of incomplete markets and borrowing constraints. Those features are combined with the kind of nominal rigidities and monetary non-neutralities that are the hallmark of New Keynesian models. Following Kaplan et al. (2016), we refer to those models as HANK models (for "Heterogeneous Agent New Keynesian" models).

Two key lessons can be drawn from this literature. Firstly, taking into account agents' heterogeneity is important to understand the transmission of monetary policy, including the relative contribution of direct and indirect effects (Kaplan et al., 2018) or its redistributive effects across income groups (Auclert, 2019). Secondly, the transmission of monetary policy and its aggregate effects may vary significantly depending on the prevailing fiscal policy, as the latter determines how the implementation of monetary policy affects the distribution of individual income and wealth among agents with different marginal propensities to consume.

Trust in monetary policy announced by policymakers is of great importance. If economic agents believe that policymakers are determined to reduce inflation, they will predict that prices will decrease in the future. Therefore, if policy declarations by policymakers are not acceptable, the policy will not have a positive effect. If policymakers believe that economic agents have predicted a low level of inflation, there would be a motive for adopting an expansionary monetary policy, although assuming that economic agents have rational expectations and they are aware of this motive for policymakers. Therefore, economic agents know that if they anticipate the inflation being downward, an expansionary policy will be adopted, which will result in higher inflation. Consequently, they will increase their inflation expectations. Therefore, without increasing production, higher inflation occurs. Trust in monetary policy announced by policymakers is of great importance. If economic agents believe that monetary authority is prepared to reduce inflation, they anticipate that prices will decrease in the future, but if policy announcement by policymakers is not credible, the policy will not have a desirable effect. If policymakers believe that economic agents have anticipated a low level of inflation, there would be a motive for adopting a monetary contraction policy. Assuming that economic agents have rational expectations, they are aware of this incentive for policymakers. Therefore, economic agents know they are anticipating low inflation; contraction policy will be adopted, which will result in higher inflation. Consequently, they will increase their expected inflation, so without increasing production, higher inflation will occur. Therefore, if the monetary authorities have discretionary powers, they will have an incentive to cheat. Hence announced time-inconsistent policies will not be credible. Because the agents know the authorities' objective function for the implemented monetary policy, they will not adjust their inflationary expectations in response to announcements that are not credible, and in the absence of binding rules the economy will not be able to reach the optimal but time-inconsistent point, in other words, without increased production, inflation has increased. Because rational agents can anticipate the strategy of monetary authorities which possess discretionary powers, they will anticipate inflation. Hence policymakers should also equal supply inflation to its expected level by the private sector to prevent a squeeze on output. An optimal policy that is incredible due to time inconsistency will therefore be neither optimal nor feasible.

In a cash-credit good economy where households have different preferences overspending their liquidity on credit goods and various types of assets and bonds, households decide on the amount of consumption and supply of their labor based on the income from labor supply and assets from the previous period. The government's problem is to fund its expenditures through money, issue bonds, and earn money from taxes. If monetary and fiscal policies lead to a redistribution of financial resources among households, then inflation will have a greater impact on households that hold a larger share of their liquid assets like money and buy goods on credit. Unanticipated inflation also has effects on households holding nominal assets. The share of tax-based tax revenue derived from the supply of labor from each household is a proportion of the labor force supplied by the image of a person with wealth. The share of labor income tax revenues collected from each type of household is proportional to the labor supplied.

Nuo and Thomas (2017) considered the optimal monetary policy with heterogeneous agents. They show that under discretion, an inflationary bias arises from the central banks' attempt to redistribute wealth from creditors to debtors, who have a higher marginal utility of consumption. Under commitment, this inflationary force is counteracted over time by the incentive to prevent expected future inflation from lowering the price at which issuers of new bonds do so; under certain conditions, long-run inflation is zero as both effects cancel out asymptotically. They find numerically that the optimal commitment features first-order initial inflation followed by a gradual decline towards its (near zero) long-run value.

Debortoli and Galí (2017) investigated the monetary policy with heterogeneous agents' insights from TANK models. Heterogeneous agents New Keynesian (HANK) models are shown to differ from their representative agent (RANK) counterparts along two dimensions: differences in average consumption at any point in time between constrained and unconstrained households, and consumption heterogeneity within the subset of unconstrained households. These two factors are captured simply by two "wedges" that appear in an aggregate Euler equation, and whose behavior can be traced in response to an aggregate shock, allowing us to assess their quantitative significance. A simple two-agent New Keynesian (TANK) model abstracts completely from heterogeneity within unconstrained agents but is shown to capture reasonably well the implications of a baseline HANK model regarding the effects of aggregate shocks on aggregate variables. We discuss the implications of our findings for the design of the optimal monetary policy.

Lippi et al. (2015) study the optimal anticipated policy in a pure-currency economy with flexible prices and a nondegenerate distribution of money holdings. The economy features a business cycle and lump-sum monetary injections have distributional effects that depend on the state of the cycle. We parsimoniously characterize the dynamics of the economy and study the optimal regulation of the money supply as a function of the state under commitment. The optimal policy prescribes monetary expansions in recessions when insurance is most needed by the cash-poor unproductive agents. Conversely, the optimal policy prescribes monetary contractions during booms, so that the inflationary effect of the occasional expansions is undone.

Gornemann et al. (2012) investigate optimal monetary policy with heterogeneous agents. In this study, they build a New Keynesian model in which heterogeneous workers differ about their employment status due to search and matching frictions in the labor market. This study uses this laboratory to quantitatively assess who stands to win or lose from unanticipated monetary accommodation and who benefits most from systematic monetary stabilization policy. Also, substantial redistribution effects of monetary policy shocks are investigated in this study which states a contractionary monetary policy shock increases income and welfare of the wealthiest 5 percent, while the remaining 95 percent experience lower-income and welfare. Consequently, the negative effect of a contractionary monetary policy shock on social welfare is larger if heterogeneity is taken into account.

Mattesini and Nisticò (2010) analyze the optimal behavior of the Central Bank in an economy characterized by balanced growth. They show how trend-growth affects the dynamics of inflation, the preferences of a welfare-maximizing Central Bank, and optimal monetary policy. They also show that the optimal monetary policy response to cost-push shocks is not invariant to trend growth and that countries with lower trend growth have substantially higher incentives to commit to simple rules, both from a welfare and price-stability perspectives.

Guender (2003) appends an instrument rule to a simple stochastic macroeconomic model by examining the optimal monetary policy under inflation targeting so that in the forward-looking framework, this instrument rule minimizes the economic loss function and optimizes the values of the parameters. It is shown that the size of the policy parameter depends on the sources of uncertainty, the policymaker's preferences, and both parameters of the model.

Khalili Araghi and Gudarzi (2016) investigate the inflation persistency regarding the heterogeneous behavior of economic agents. For this, the data they used from 1991-2015 was based on seasonal data and Dynamic Stochastic General Equilibrium models. The innovation of this paper is the Calvo pricing assumption regarding the lag in inflation rate and indexing parameter in which inflation persistency conditions computing will be more relevant to Iran's economy. The results showed that inflation expectations have a major role in inflation rate formation so that even if the inflation rate declines it will occur in a long time due to inflation persistency. It was cleared the prices have less reaction ability to inflation persistency. It is suggested to the monetary authorities by considering the domestic inflation targeting rule in addition to inflation control, they stabilize the domestic production in the natural level in which it is required the monetary authorities to have credibility in views of economic agents.

Shahmoradi and Sarem (2013) examine the optimal monetary policy and inflation targeting in Iran's economy. In this paper, by using dynamic stochastic general equilibrium, an optimal monetary rule was derived for the Central Bank of Iran. In this paper, the monetary transmission mechanism of the model includes four equations, aggregate demand, aggregate supply, oil price, and Taylor rule. This paper proved that the dynamic structure of aggregate demand relation, regarding monetary inflation in Iran, is a function of the money growth rate. With this assumption that the goal of Central Bank is to pursue target inflation rate and the output gap, and subject to monetary transmission mechanism, optimal rule of monetary policy obtained for Iran economy that is a function of inflation gap, output gap, and oil income growth rate. Estimation results show that the money growth rate has no effect on the output gap and fully reflexes inflation expectation. Moreover, a one percent increase in oil income causes a four percent increase in the inflation rate.

Ghorbannezhad et al. (2013) have tried to determine the optimal monetary and fiscal policy rules in Iran's economy. In this regard, using the optimal control theory, a loss function of the monetary and fiscal policymakers which including the squares of the inflation rate, output gap rate, the Gini coefficient, the deviation of the volume of liquidity growth, and the deviation of the volume of government spending growth from the previous period, were minimized using the three constraint equations of Phillips, aggregate demand and income distribution curves. The optimal monetary and fiscal policy rules were derived under carrying out energy prices reform scheme. By solving a constraints optimization problem with optimal rules in a macroeconomic model, the optimal values from 1390 to 1394 were predicted. The results suggest that using the optimal monetary and fiscal policy rules, we can improve the performance of the goal macroeconomics variables under carrying out energy prices reform scheme. By adopting optimal rules, inflation, as one of the important problems of the economy of Iran, can be controlled accompanied by to improve in the performance of macroeconomic variables such as economic growth and income distribution.

Tavakolian (2012) studied the rule-based or discretion behavior of the Central Bank using the Markov-switching approach, the Kalman Filter, and the Dynamic Stochastic General Equilibrium (DSGE) model. According to that monetary policy in Iran economy is not based on a specific rule, he first attempted to investigate monetary policy using modified Taylor rule, in which the growth rate of the monetary base is determined based on the deviation of inflation and output from their target values. What matters here is the appropriate criteria for the inflation target for this modified rule. Given the explicit inflation target in the law of development programs, as well as the existence of evidence that the policymaker is not committed to this target, it is assumed that the inflation target is implicitly determined in the Iran economy, which means that the policymaker has an aim for inflation, but this target is not publicly announced. With this assumption, the modified rule of monetary policy is estimated based on three approaches of Markov-switching, Kalman filter, and DSGE models. The results of these three approaches indicate that only in the late 70s and early 80s there was a rule in monetary policy and in most cases implicit target inflation was higher than target inflation considering in the five-year development program. The DSGE model is then solved for discretionary monetary policy and optimal monetary policy. The results of this approach indicate that in most cases, monetary policy has been taken in a discretionary manner. Also, the results of optimal monetary policy show that using this approach in monetary policy is the only way to achieve the target inflation of the five-year development program.

A Cash-Credit Good Economy with Heterogeneous Households

The monetary policymaker characterizes targeting to following optimal monetary policy which means that he chooses variables as a target and uses them as a guide to implementing monetary policy. Therefore, for this purpose, the target variable is introduced in the Central Bank loss function with a proper weight indicating its relative importance to other goals. In general, there are different views on the efficiency and effectiveness of a monetary policy, and there have been debates on monetary policy based on the rule and discretion.

A policy rule states how policy instruments should respond to changes in economic conditions. Today, there is a lot of tendencies to use policy rules as a guide for making policy decisions for employees and authorities of Central Bank (Zanganeh, 2009).

A rule can be defined as a systematic decision process that uses information consistently and predictably. The concept of monetary policy, the rule is the imposition of restriction to the discretion of the monetary policymaker. A rule involves the exercise of control over the monetary authority activities. Rules can directly limit the actions taken by a monetary authority.

In this section, it is assumed that there are two types of households that have different preferences for purchasing cash and credit goods. It is also assumed that in each period trade in goods and labor precedes trade in assets. This timing, introduced by Svensson (1985), implies that households cannot adjust the amount of currency available for purchases in the current period to changes in the inflation rate. Assume that according to the model of Svensson (1997), the monetary policy loss function is as follows. In this function, λ is the weight of the policymaker for the stability of production (around potential output). Anticipated inflation π and production y are obtained based on the following equations. Here, production is the amount of deviation from the natural output.

$$L(\pi_t, y_t) = 0.5[(\pi_t - \pi^*)^2 + \lambda y_t^2],\ \lambda > 0 \tag{1}$$

$$\pi_{t+1} = \pi_t + \alpha y_t + \varepsilon_{t+1} \tag{2}$$

$$y_t = \beta_1 y_t + \beta_2(i_t - \pi_t) + v_t \tag{3}$$
$$\alpha > 1, \beta_1 \leq 0, \beta_2 < 0$$

In the above equations, ε_t and v_t are shocks that are independent and identically distributed (i.i.d). In this framework, y is an endogenous variable. The Central Bank wants to determine the instrument at a time horizon of $\{i_t\}_{\tau=t}^{\infty}$, so that the loss function is minimized. From the first-order condition of this problem, it is implicitly possible to obtain a rule for the interest rate that minimizes the loss function ($E_t \sum_{\tau=t}^{\infty} \gamma^{\tau-t} L(\pi_t, y_t)$). This function is equal to:

$$i_t = \pi_t - \left(\frac{\alpha\gamma k}{\beta_2 \lambda}\right)[E_t(\pi_{t+2}) - \pi^*] - \frac{1+\beta_1}{\beta_2}(y_t) \tag{4}$$

$$k = 0.5\left\{\left(1 - \frac{\lambda-\lambda\gamma}{\alpha^2\gamma}\right) + \left[\left(1 + \frac{\lambda-\lambda\gamma}{\alpha^2\gamma}\right)^2 + \frac{4\lambda}{\alpha^2}\right]^{0.5}\right\} \tag{5}$$

In this case, the policymaker sets the initial interest rate equal to the target inflation rate. In addition, the policymaker responds to the deviation of anticipated inflation from the target, as well as the deviation of output from potential level through nominal interest rates. Interestingly, according to this rule, the Central Bank adjusts its policy interest rate based on anticipated inflation in two periods of the present time. If the anticipated inflation is consistent with the target and the output moves along the natural trend level, the policy interest rate is equal to inflation. Of course, it should be considered unpredictable stochastic shocks (such as ε_t and v_t) are affecting inflation, but monetary policy cannot cope with these shocks. In this case, actual inflation will be different from target inflation, even if the monetary policy is optimally regulated.

If the weight attached by the policymaker to the output deviation is zero, the Central Bank responds to current inflation by adjusting the interest rate. Simply, the policymaker sets the initial interest rate equal to the target inflation rate. In addition, the policymaker responds to the deviation of anticipated inflation from the target, as well as the deviation of output from potential level through nominal interest rates. The policy instrument in this case responds to the inflation rate, not because current inflation is targeted, but because current inflation affects inflation rate forecasting.

$$i_t = \pi_t - \frac{1}{\alpha\beta_1}(\pi_t - \pi^*) - \frac{1+\beta_1}{\beta_2}(y_t), \quad -\frac{1}{\alpha\beta_1}, -\frac{1+\beta_1}{\beta_2} > 0 \tag{6}$$

Households

In this model, households consume cash and credit goods and supply labor. Households are divided into two types, where $0< v_i <1$ is the fraction of type i agents, with $i =1,2$ and $\Sigma vi=1$. Households of the same type are identical. Households have preferences defined overconsumption of cash goods c_{i1}, consumption of credit goods c_{i2} and over hours worked n_i. Preferences are given by:

$$\sum_{t=0}^{\infty} \beta^t U^i(c_{it}, n_{it}) \tag{7}$$

$$c_i = h^i(c_{i1}, c_{i2})$$

In this model, households purchase consumption goods, supply labor, accumulate currency and trade one-period nominal discount bonds in each period. They enter a period with M_{it} units of currency and B_{it} unit of nominal bonds and are subject to cash in advance constraint, given by:

$$P_t c_{i1t} - M_{it} \leq 0$$

In this model, purchased bonds are held at time t and are exchanged in the asset market at time $t+1$. The total debt of the government and private sector held by agent i at the end of period t are shown by B_{it+1}. Households face the following constraint:

$$M_{t+1} + Q_t B_{it+1} \leq M_{it} + B_{it} - P_t c_{i1t} - P_t c_{i2t} + W_t(1 - \tau_t) n_{it} \tag{8}$$

where Q_t is the transaction price of the nominal bond, W_t denotes nominal wage, τ_t is the tax rate on labor income.

Firms

In this model, it is assumed that the production technology of the firm is linear, which requires labor for the production of consumer goods. The conditions are perfectly competitive and there is no uncertainty in the economy. Also, we are assuming that firms live for one period. The production technology of the firm is given by:

$$\sum_{j=1}^{2} y_{jt} \leq n_t \tag{9}$$

Where y_{1t} is the total production of cash goods and y_{2t} total production of credit goods at time t and n_t is aggregate labor. Perfect competition implies:

$$P_{1t} = P_{2t} = P_t = W_t$$

Where P_t is the price charged for consumption goods (goods purchased in cash and goods purchased on credit) and W_t the nominal wage at time t.

Government and Money Authority

The most important section of the present study is modeling government and Central Bank. Due to the lack of an independent Central Bank in Iran, the government and the Central Bank cannot be modeled in two separate parts, but both should be considered in the same framework. It is assumed that the goal of the government 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. Along with helping the government to achieve its goal, the Central Bank is trying to maintain price stability and increase economic growth, therefore, the Central Bank sets its policy to achieve these goals.

The government tries to finance current and development expenditures through a fixed tax on the household, government bonds, and oil revenues. If the government could balance its budget through these three types of income sources, monetary creation will not occur, and the Central Bank will be able to implement monetary policy regardless of the government budget constraint. But if government spending exceeds these revenues and the budget deficit happens, the government balances its deficit by borrowing from the Central Bank (or withdrawing its deposits from the Central Bank, which means money creation), the government will fund its budget deficit, which is called fiscal dominance. Therefore, changes in the monetary base in the state budget constraint are obtained from oil revenues and the withdrawal of government deposits from the Central Bank. In line with this explanation, the budget constraint is given by:

$$G_t + (1 + r_t)\frac{B_{t-1}}{P_t} + T_t = W_t \tau_t n_t + Z_t + \frac{B_t}{P_t} + \frac{(M_t - M_{t-1})}{P_t} \tag{10}$$

where $W_t\tau_t n_t$ is labor income tax revenue, Z_t fixed tax, B_t bonds, $\frac{(M_t-M_{t-1})}{P_t}$ changes in the money base, T_t government transfers, and G_t government expenditure. The monetary base is defined as follows:

$$MB_t = DC_t + FR_t$$

where DC_t is the domestic credit and FR_t is the foreign reserves (net assets of the foreign assets) of the Central Bank. In this equation, it is assumed that most of the 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 a total of domestic credits.

By dividing the two sides of this relation into P_t, the base real money will be the following. It is assumed that the stock of real foreign assets of the Central Bank is as follows:

$$mb_t = dc_t + fr_t$$

$$fr_t = \frac{fr_{t-1}}{\pi_t} + \omega o_t$$

In the above relation, it is assumed that the stock of foreign assets of the Central Bank depends on the government's direct sales of foreign exchanges from its oil incomes to the Central Bank. In other words, it is assumed that the government $\omega \epsilon\ (0, 1)$ percent of its dollars of oil revenues sold directly to the Central Bank and saves 1-ω percent of it in the National Development Fund. Therefore, the parameter ω determines how to spend new oil revenues. As a result, the actual stock of the fund follows the following process in which 1-ω percent of the oil revenue in each period is deposited into the fund.

$$nfr_t = \frac{nfr_{t-1}}{\pi_t} + (1-\omega)o_t$$

It is also assumed that oil revenues follow a first-order autoregressive process (log-linearized) as follows:

$$o_t = \rho_o o_{t-1} + \varepsilon_t^o, \varepsilon_t^o \sim iid.N(0, \sigma_o^2)$$

Considering that in the Iran economy, the main purpose of the Central Bank is to control the volume of money and liquidity rather than nominal interest rates; in this study, we use the rule similar to the Taylor rule, in which the primary instrument of the monetary policymaker is the liquidity growth rate instead of the nominal interest rate. In this rule, the two factors of the diversion of inflation from target and the output gap, as output deviation from its long-term trend, are important in determining the rate of liquidity growth. Target inflation rate (π^*) has been chosen 15% based on inflation targets of development programs. In the following, we plan to examine how the optimal monetary policymaker behaves in the implementation of this policy rule.

$$m_t = \alpha_0 + \alpha_1(\pi_t - \pi^*) + \alpha_2(y_t - y^*) + \varepsilon_t^m \quad (11)$$

where m_t is the rate of liquidity growth, $(\pi_t - \pi^*)$ the deviation of inflation from target, $(y_t - y^*)$ is the output gap. The disruption term ε_t^m follows a normal distribution with a mean zero ($\varepsilon_t^m \sim N(0, \sigma_r^2)$). If the estimated coefficient on the inflation gap is greater than one, the Central Bank will pay more attention to inflation in setting its monetary policy instruments.

The periods in which Central Bank potentially responses to inflation is called active monetary policy. Also, the periods in which Central Bank doesn't show an ability to respond to inflation is called passive monetary policy.

Equilibrium on the goods market requires:

$$\sum_{i=1,2} v_i\,(c_{i1t} - c_{i2t} - n_{it}) + \bar{G}_t = 0 \tag{12}$$

Equilibrium in the asset market requires:

$$\sum_{i=1,2} v_i\, B_{it+1} = B_{t+1} \tag{13}$$

$$\sum_{i=1,2} v_i\, M_{it+1} = M_{t+1} \tag{14}$$

To achieve an optimal monetary policy under commitment, an allocations $\{c_{i1t}, c_{i2t}, n_{it}\}_{i=1,2,t\geq 0}$ and the level of real balance holdings m_{i0} for i = 1, 2 solve the problem:

$$\max_{m_{10},\{c_{i1t},c_{i2t},n_{it}\}_{i=1,2,t\geq 0}} \sum_{t=0}^{\infty} \beta^t \sum_{i=1,2} \eta_i U^i(c_{it}, n_{it}) \tag{15}$$

Subject to:

$$\frac{u_{11t}}{u_{12t}} = \frac{u_{21t}}{u_{22t}}$$

$$\frac{u_{i1t}}{u_{i2t}} \leq 1, i = 1,2$$

$$\frac{u_{11t}}{u_{1nt}} = \frac{u_{21t}}{u_{2nt}}$$

$$\sum_{t=0}^{\infty} \beta^t\, [u_{i1t}c_{i1t} + u_{i2t}c_{i2t} + u_{int}n_{it}] = [u_{i10} + u_{i20}b_{i0}]\,\frac{m_{i0}}{p_0} \tag{16}$$

$$m_{20} = \phi_m m_{10}$$

Based on the optimization, type 1 agents are affected by the $(1-\tau_t)Q_{t-1}$, while type 2 agents are only affected by the tax rate on labor and positive nominal interest rates. A lower value of bond transaction price Q_t increases the price of consumption for type 1 agents. For type 2 agents, it corresponds to an increase in the price of cash goods relative to credit goods at time *t*. If cash and credit goods are gross substitutes, the level of credit good consumption will increase with nominal interest rates. If the weight of credit goods in type 2's utility function and the weight of type in government preferences are high enough, it will be optimal to set the discount rate positive, since this makes the price of consumption lower for type 2 relative to type 1. Therefore, an increase in inflation to redistribute resources across households of different types arises when the government does not have access to a full set of redistributional instruments.

If the government has access to individual specific proportional labor income taxation then in any Ramsey equilibrium $Q_t=1$ for $t \geq 0$. Intuitively, if the government can set different labor tax rates for different agents; this will result in equalizing the relative price of cash and credit goods. If $\bar{\eta}_1$ denotes Pareto weight, then to neutralize the effect of a fiscal policy, the following conditions must be satisfied:

$$\frac{u_{12t}/U_2^1}{u_{22t}/U_2^2} = \frac{\bar{\eta}_1}{v_1}\left(\frac{\bar{\eta}_2}{v_2}\right)^{-1}, t > 0$$

Empirical Model of Research

In this study, seasonal data of Iran economy for the period of Q1 1989 to Q4 2017 have been used to estimate the equations. We used Hodrick–Prescott filter to calculate the output gap as a difference between GDP and potential output. The consumer price index (base year= 2004) was used to calculate the inflation rate. Government tax revenues include direct income taxes (income tax on legal persons, personal income taxes, and wealth tax). All data on GDP and consumer price index, liquidity volume, current and development expenditures of the government, government debt to the Central Bank, and oil revenues have been received from the Central Bank website and time-series database.

In this research, the Bayesian method is used to estimate the parameters of the model, in which the initial values for the parameters are determined as the prior distribution, and these initial values are combined with the results of estimating maximum likelihood-based on actual data. If the initial information in the prior distribution is large and accurate and the maximum likelihood estimation cannot help to estimate the model, the calibration method can be used. But if the prior distribution is inaccurate, the maximum likelihood can be used. In the middle, the Bayesian method is a combination of two calibration methods and maximum likelihood.

To calculate the logarithmic-linear values of the variables (deviation from the variables steady state), the logarithm of the data was extracted using the Blanchard-Quah method and the Hodrick-Prescott filter (HP) with 677 cyclic components. Before estimating the model parameters, it is necessary to calibrate the parameters and indices that are in the form of quadratic or not necessary to estimate. These parameters are obtained through the steady-state values of the variables and the average of data of these ratios are considered as their steady-state values and there is no need for their estimation. To estimate the Bayesian parameters of the model, the distribution, mean, and standard deviation of the parameters of the model must first be determined. In Table 1, the distribution and the posterior and prior mean of parameters of the model are reported, which the prior mean values show the estimation of the parameters of the model using the Bayesian method.

Table 1. Posterior and Prior Distribution of Model Parameters

Parameter	Description	Prior and posterior distribution of model parameters		
		Distribution	Posterior mean	Prior mean
β	Household intertemporal discount rate	Beta	0.968	0.967
σ_C	The inverse of the intertemporal elasticity of substitution	Gamma	1.483	1.662
σ_L	The inverse of labor supply elasticity	Gamma	2.253	2.893
γ	elasticity Inverse of real money balance	Beta	1.58	1.07
ρ_l	Auto-regressive coefficient of labor income tax	Beta	0.98	0.90
ρ_{oilr}	Auto-regressive coefficient of oil income shock	Beta	0.265	0.260
ρ_g	Auto-regressive coefficient of government expenditures	Beta	0.778	0.879
ρ_{mg}	Auto-regressive coefficient of money growth in the monetary response function	Beta	0.901	0.899
ρ_{π^*}	Auto-regressive coefficient of Central Bank target inflation	Beta	0.42	0.967
λ_π	Sensitivity factor of Central Bank to inflation in the monetary response function	Normal	-1.42	-0.989
λ_Y	Sensitivity factor of Central Bank to output in the monetary response function	Normal	-2.34	-2.967

Parameter	Description	Prior and posterior distribution of model parameters		
		Distribution	Posterior mean	Prior mean
λ_{RER}	Sensitivity factor of Central Bank to exchange rate in the monetary response function	Normal	0.69	0.80
K_0	Auto-regressive coefficient of the exchange rate in the currency response function	Beta	0.95	0.90
K_1	Auto-regressive coefficient of output in the currency response function	Normal	-1.76	1-.90
K_2	Auto-regressive coefficient of the foreign reserve to the monetary base ratio in the currency response function	Normal	-1.40	-1.58
σ_{oilr}	The standard deviation of oil income shock	Inverse-gamma	0.46	0.42
σ_{tax}	The standard deviation of tax revenue shock	Inverse-gamma	0.42	0.35
σ_{mb}	The standard deviation of money supply shock	Inverse-gamma	0.043	0.092
σ_{g}	The standard deviation of government expenditures shock	Inverse-gamma	0.68	0.65

Source: Research finding.

Based on optimizations, the parameter σ represents the intertemporal elasticity of labor supply. So according to the estimations, the compensation elasticity of labor supply is 0.28, as a result, the interest elasticity of money demand is obtained 2.86. In the steady-state, the government debt to GDP ratio is 40.9% when τ=0.32.

Table 2. Benchmark Parameters Values

	α	β	Γ	v_1
	0.684	**0.968**	**1.07**	**0.523**
σ	0.7	0.8	0.9	1
ψ	0.576	0.558	0.598	0.574
ψ_1	0.862	0.845	0.828	0.813
ψ_2	0.862	0.845	0.828	0.813

Source: Research finding.

If $\eta_1 > \bar{\eta}_1$, the constraint of government debt in the CIA model will not be satisfied, which will lead to a small change in the price of cash goods relative to the consumer price index, therefore, a high increase in the level prices can lead to binding of constraints in the CIA model. In this model, there is a cash restriction for a person. So that a person can buy the cash goods or credit goods, with this constraint that the amount of cash goods purchases cannot exceed the amount of money he holds. However, if the government debt is large, then the government can rely on inflation tax and earn revenue by using distortionary taxes. In this situation, households will not be able to adjust their currency holdings in response to inflation. Accordingly, the equilibrium of the given model shows that if φ_m=φ_1, then time consistency exists. If the weight more heavily to households who use the currency for a greater fraction of their purchases on consumption goods is less than Pareto weight, then:

$$\lambda_1\psi_1 + \lambda_2\phi_m\psi_1 = 0, \sigma = 1 \text{ for } \eta_1 < \bar{\eta}_1$$

Heterogeneity in holdings of nominal wealth and the demand for cash goods implies that monetary policy has redistributional effects and the time consistency of the equilibrium depends on the balance between redistributional and efficiency incentives. This weak link between high inflation and time consistency leads to high rates of inflation being optimal even with commitment and credibility of government policy does not imply low inflation. In other words, the redistributional effects of inflation exist when the government is allowed to reassess the policy.

To evaluate the time consistency of optimal monetary policy, a Ramsey optimal policy approach is used. In this approach, the monetary authority has obliged himself to follow a specific policy framework. Therefore, the policymaker will minimize its losses to restrictions faced in the initial period and the resulting conditions will continue in subsequent periods. In other words, the policymaker does not violate his obligation to how to implement the policy with changes in economic conditions. Therefore, with this description, we should introduce a loss function for the monetary authority in Iran's economy. The loss function that is used in two optimal and discretionary monetary policy approaches is as follows:

$$L(\pi_t, y_t, \dot{m}_t) = \lambda_\pi(\pi_t - \pi^*)^2 + \lambda_y(y_t - y^*)^2 + \lambda_{\dot{m}}(\dot{m}_t - \dot{m}^*)^2 \quad (17)$$

where the growth rate of money base $\dot{m}_t$ is an instrument by which the monetary authority uses it to achieve two goals of controlling inflation and increasing economic activity, and $\dot{m}^*$ is the steady-state growth rate of the money base. Therefore, all the equations to minimize the above relation to these equations are considered in this section. From this, it becomes clear that one of the variables must be selected as a tool. In conventional literature, interest rates or inflation are usually chosen as the instrument. There is a quite technical reason why inflation rates are sometimes chosen as an instrument rather than the interest rate. Therefore, sometimes the instrument used in the technical process of solving monetary discretionary policy (as well as optimal monetary policy) is not necessarily an instrument used by the Central Bank. It should also be noted that the number of instruments used in solving the model is equal to the number of endogenous variables minus the number of equations of the model in which the Central Bank loss function is not included in the equations. With this description, the variable used in this article as an instrument is the growth rate of the money base. In the following, the model is solved as an optimal policy. Now, by solving the discretionary and optimal policy, we investigate the response functions of different shocks. The coefficients for the parameters of the optimal monetary policy rule are estimated as follows:

Table 3. Results of Estimation in the Case of Rule-based Monetary Policy

	α_0	α_1	α_2
Coefficient	4.309	0.694	0.00043
Significant level	0.004	0.000	0.003

Source: Research finding.

Generally, under the rule-based policy, the policymaker optimizes once and never re-optimizes. It is assumed that the policymaker can be loyal to his chosen policy and that the discount factor is large enough to allow the chosen policy to be considered as reputation equilibrium. The results of the estimation of the rule-based monetary policy in Iran's economy indicate that the estimated coefficient of inflation rate deviation from target is positive and statistically significant. In other words, the Central Bank significantly reduces the liquidity growth rate in response to an increase in the inflation rate. As we can see, the estimated value of this factor is smaller than one. This means during this period, the Central Bank did not attempt enough to control inflation to adjust its policy instruments or the rate of liquidity growth.

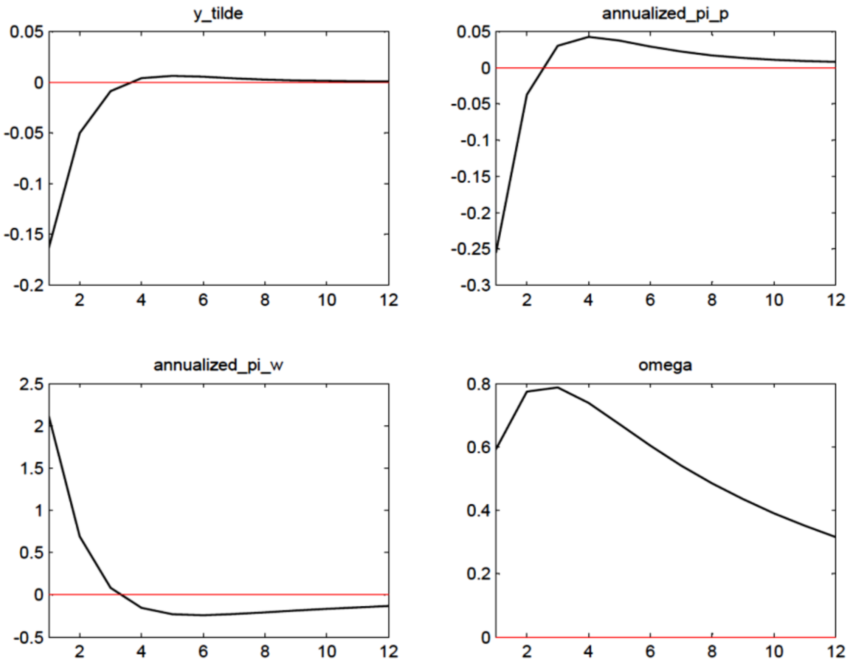

Figure 1. Monetary Policy Shock in the Rule-based Case
Source: Research finding.

The above figure illustrates the impulse response of relevant endogenous variables to one standard deviation of monetary shock in the rule-based case. After a monetary shock, inflation rises, and so the real wages of labor and the real rental price of capital are reduced. This would increase labor and capital and, consequently, increase production. On the other hand, inflation caused by monetary shocks causes monetary authorities to react disinflationary by applying a monetary contraction policy and reducing the growth rate of money volumes. Following the money base reduction, production, government spending, and investment are reduced.

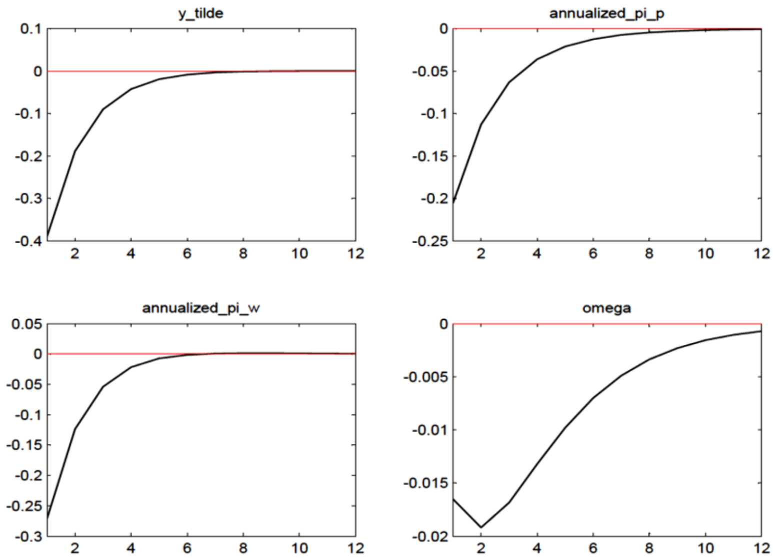

Figure 2. Monetary Policy Shock in the Discretionary Case
Source: Research finding.

According to Figure 2, the occurrence of a monetary shock in the discretionary policy rather than the rule-based policy will further increase output and this increase is more persistent. In other words, when the monetary authority performs the optimal monetary policy, the change in the threshold level of related inflation may have more realistic effects. Therefore, in an optimal condition, even if the target inflation is implicitly determined (this means only the monetary policymaker knows about the inflation but the economic agents are not aware of it and do not consider this on their price-taking decision), the inflation will be identifiable due to policymaker's commitment to a monetary policy. But, in the discretionary case, there is no obligation to any particular policy, and therefore no specific prediction of economic agents about inflation targeting can be identified. This helps to interpret the impulse response functions resulting from the occurrence of this shock in two cases of optimal and discretionary policies.

The estimated results indicate that the inflation is higher than the target inflation, therefore, the demand inflationary pressure forces the Central Bank to reduce the rate of growth of liquidity to reduce inflation, which, in a recession, will lead to worsen the stagnation and reduce output from its potential level. Therefore, based on the obtained results, it can be seen that optimal monetary policy is not time consistent under the condition that the behavior of economic agents in the Iran economy is heterogeneous due to the price-taking power of economic agents and price downward stickiness.

Conclusion

The purpose of this paper is to examine the time consistency of optimal monetary policy with heterogeneous economic agents in Iran. In this study, we utilize time series data quarterly from Q1 1989 to Q4 2017. A new Keynesian dynamic stochastic general equilibrium (DSGE) models have been developed for monetary policy analysis in open economies. I find that the presence of redistribution motives breaks the link between time consistency and high inflation which characterizes representative agent models of optimal fiscal and monetary policy. The incentive to generate unanticipated inflation depends crucially on the distribution of currency and other nominal assets, as well as on the distribution of political power. Optimal monetary policy is time consistent for a large class of economies. The model introduced in this paper was that households behaved differently in holding their currency available and nominal assets. Estimation results show that there is a direct link between the nominal volume of money and production due to inflation stability. In the estimated model, contractionary monetary policy will reduce inflation over time by controlling total demand. Subsequently, inflation reduction will have a positive and increasing effect on production. In contrast, expansionary monetary policy, although improving the output gap, will have its inflationary effects through the inflation equation and welfare loss function. Regarding the empirical results of the optimal monetary rule in Iran's economy, to achieve the target inflation rate, the output gap should also be considered in setting monetary policy. Based on the results, if the monetary authorities consider the two goals of inflation and the output gap in setting monetary policy, by increasing the weight of the output gap against the weight of inflation, the growth rate of the money supply will decrease. Regarding monetary policy under commitment and discretion, it can be argued that the time consistency in a given model depends on the weight given to heterogeneous households, Pareto optimality, the distribution of wealth and assets among households. Under monetary non-commitment, it will result in bias in the balance of the model and an increase in the government deficit due to the anticipated inflation in the economy.

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