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Examining external shocks and welfare losses with emphasis on monetary rule

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Abstract

The economies of countries may face a variety of shocks driven by various factors, leading to high economic and non-economic costs. Therefore, it is essential to investigate different external shocks in the economy, as well as how these shocks can be managed. Accordingly, this study aims to investigate the effect of external shocks (global oil price shock, global inflation, and foreign interest) on macroeconomic variables. This study also seeks to examine a type of monetary policy consistent with Iran's economic conditions. Focusing on the New Keynesian School of thought, this study develops a stochastic dynamic general equilibrium (SDGE) model compatible with the situation of Iran. This model is comprised of these sectors: household, oil, non-oil, import, final goods production, and government. After performing linearization procedures, this study analyses the shocks responses and results, with a focus on the three rules of monetary policy (headline inflation, core inflation targeting, and exchange rate) for the purpose of optimal monetary policy. Studies show increasing number of variables being investigated, but in some cases, this trend has quickly reached stability, yielding an appropriate pattern for adopting the optimal policy. However, in some cases, including GDP, we experience a decreasing response of variables regarding the adoption of headline inflation and exchange rate policies. Consequently, it is necessary to evaluate the appropriate policy. Regarding the deadweight loss in relation to the three monetary rules, the findings of this study show that in the face of volatilities studied, household deadweight loss is affected more strongly by headline inflation rule than the other two policies. In contrast the exchange rate rule plays a less important in the amount of deadweight loss.

Keywords: external shocks, monetary policy, stochastic dynamic general equilibrium
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Introduction

As one of the most accepted methods in the study of monetary and fiscal policies, the use of policy rules is one of the most prominent features of policy research in recent decades, especially from the 1990s onwards [13]. A policy rule specifies how policy instruments should react to changes in the economy's situation. The ability of basic policy rules

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to be flexible in monetary and fiscal policies has long been desirable. Macroeconomics has also shown a keen interest in examining simple interest rate rules for monetary policy guidance. Furthermore, such rules can contribute to the relevance of using strategies for committing macroeconomic stability in theoretical models with nominal rigidity and imperfect competition [24].

For many years, the Friedman rule (1959) was the most well-known monetary rule in economic literature. However, this rule relied on uncertainty about the effectiveness of the monetary policy. In summary, Friedman argued that actively manipulating money supply in a system where the length of monetary policy is unpredictable can worsen economic fluctuations, hence proposed the rule of constant monetary growth [7].

The discussion of rules entered a fundamentally new space by Kydland and Prescott [14]. They demonstrated that the central bank's commitment to a pre-determined rule could have beneficial effects that discretionary policies do not have. Contrary to Friedman's argument in a particular model (quantitative theory of money), Kydland and Prescott's concepts can be used through various macroeconomic models [23]. In general, in the discretionary mode, the policymaker changes the policy depending on the current situation, and as the discretionary planner does not make any binding commitments for themselves, more flexibility can be exercised.

The idea that the commitment policy is a more appropriate version for the central bank is better long-term consequences and better monetary policy response to economic shocks, such as lower inflation. This occurs in the state of commitment, leading to less fluctuation in inflation and production.

Central banks utilize two main techniques to implement their policies: discretionary and applying policy rule processes. In 1936, Simmons first raised the issue of the difference between discretionary and systematic policymaking. The key difference between discretionary policy and a rule-based policy (commitment) is that both policies ultimately make actual production equal to potential production. However, the inflation rate resulting from commitment is expected to be lower than the inflation rate arising from discretionary policy. On the other hand, the monetary economics research has recently concentrated on inflation targeting policy as an indicator of monetary policy direction; an optimal policy refers to the policy that pushes inflation closer to the established optimal level [2].

Iran's economic experience in recent years has shown that discretionary monetary policies have resulted in a general increase of prices by increasing the growth of liquidity rather than affecting the real sector of the economy and economic growth. On the other hand, the government's fiscal policies have not been very effective, and only the government budget deficit has led to only a change in two important components of the monetary base, namely the public sector debt to the central bank and the net foreign assets of the central bank, therefore increasing liquidity and the general level of prices. As two indicators of economic instability, high average inflation and fluctuations are notable features of the inflation trend in recent years. A feature that has harmed the country's economy by fostering an atmosphere of uncertainty and volatility, which has destroyed the business environment and uncertainty for economic agents in the future [10].

Monetary policymaker behavior in line with macroeconomic goals can be perfectly achieved by minimizing welfare losses significant to policymakers. However, considering the characteristics of the country's economy, relying on the household, oil, non-oil, import, producer of final goods, and the government, the above study has considered an appropriate monetary policy to reduce losses.

Hassanzadeh Jazdani (2019) designed a random dynamic equilibrium model to study the effect of tax shocks on the consumption of domestic and imported consumer goods, labor income tax, and company tax on GDP variables and inflation. The findings show that tax bases on domestic and imported consumer goods consumption, taxes on labor income, and corporate taxes have smaller but significant effects on GDP and inflation. Among the tax bases examined, import tax has the most significant impact on changes in GDP and inflation. The lowest share in changes in GDP among the tax bases under consideration was taxing on the consumption of domestically produced goods, plus labor income tax had the lowest share in changes within inflation.

Salah manesh and Pour Javan [19] designed and calibrated a new Keynesian stochastic dynamic general equilibrium model, emphasizing stock market dynamics and examining the mechanisms of stock market channel influence on macroeconomic variables. In this respect, a DSGE model considering households, firms, the banking sector, government, and the central bank was designed, and after linearizing logarithms, the model parameters were calibrated using quarterly data of the years 1997-2017 with the findings of experimental studies [22]. The results indicated that a negative deviation of the adverse shock to stock prices through the channel of economic acceleration and bank capital leads to a decrease in production, consumption, investment, deposits, and inflation. Therefore macroeconomic variables are strongly linked to dynamics within a stock market.

Zahabi et al. [25] designed the proposed model in their study and calculated the coefficients of the extracted current account by applying the Bayesian approach. Subsequently, three policy rules were introduced to the model, and finally, the use of the compound inflation targeting rule combined with the exchange rate in the face of oil revenues increased the current exchange rate fluctuations further, compared to the use of the other two rules. It should be noted that the optimal policy rule is the rule that minimizes the welfare loss function in the face of any shock factors.

By establishing a capital account change channel through the entrance and outflow of foreign deposits, Zanous et al. [26] explored the influence of international financial integration on economic fluctuations using a stochastic dynamic general equilibrium model. The merger coefficient is defined in terms of the percentage of total deposits attracted from abroad. This coefficient can be amended under the influence of changes in effective domestic interest rates and global exogenous interest rates. The results show that the oil price shock fluctuates the variables of production, consumption, real exchange rate, and variables of the banking system, including deposits received and loans granted in cases of financial integration. However, there was no significant difference concerning inflation [1, 11] (oil price et al., 2007). Likewise, there was no noticeable difference in the response of variables in the two cases in response to the technology shock.

Using the data from post-World War II data on US corporate income tax changes, Futio et al. (2020) concluded that tax cuts' output effect on capital income depends on government debt. When the debt is large, it is more far-reaching than when debt is low. A stochastic dynamic equilibrium model with fiscal policy has been used to identify the mechanisms that can reflect the government-dependent tax effect. The result is that a reduction in capital gains tax is very dynamic that it is unlikely to lead to financial balance in the future. Once government debt increases, the likelihood of future fiscal adjustment increases, and the expansionary effects of lower capital gains taxes can be significantly reduced.

Using a multi-part stochastic dynamic equilibrium model, Antoswiewicz et al. [4] investigated the impact of two types of taxes in the EU. One type of tax is related to the tax on inputs used in energy, building, and transportation industries, while the other is connected to the tax on products of these industries. Findings show that these two types of taxes create conflicting incentives and have different effects on resource efficiency. However, introducing a tax on incentives has stimulated investment in efficiency-enhancing technologies. The findings suggest that substituting these tax revenues in reducing labor taxes will strengthen the positive effects of input tax.

Kim and Rescigno [15] examine the cyclical behavior of monetary and fiscal policies using a new Keynesian stochastic dynamic equilibrium model. In this paper, optimal monetary and fiscal policy in an economy where incomplete infrastructure development affects stabilization policies' dynamics and cyclical behavior is theoretically examined. By solving the Ramsey problem with a linear quadratic welfare loss function, the researcher concluded that optimal monetary and fiscal policy tends to behave periodically in the presence of incomplete infrastructure development. As a result, the economy experiences further fluctuations. Also, by gradually comparing different monetary policy regimes based on the Taylor rule, it was concluded that the inflation targeting rule reduces cyclical monetary and fiscal behavior and ultimately improves welfare [21].

Miao et al. estimated a DSGE model of stock market bubbles and the business cycle in the United States using the Bayesian method [17, 18]. Their findings reveal that emotional shock explains a sizable portion of stock market volatility and changes in investment, consumption, and product and that the driving factor behind simultaneous movements in stock prices and real economic values is significant [8, 12, 27].

Theoretical foundations

The central bank's policy rule is a policymaking process that consistently uses information and determines how monetary policy controllable tools respond to changes in targeted variables. The ability of policymakers or central banks to perform their objectives depends on possessing the right tools to reduce production, inflation volatility and inflation as a whole. However, the question is how these tools are used to achieve the ultimate goals through intermediate goals. There are two perspectives for answering this question: discretionary monetary policy and regular monetary policy.

Kydland and Prescott suggest that the monetary authority's expedient measures lead to short-run economic imbalances by introducing time inconsistencies. As a result, following a regulation can lessen the central banks' negative impact on discretionary policies.

On the other hand, Taylor argues that the true meaning of the rule must go beyond the concept of the rule, according to Kydland and Prescott, because a rule must be able to account for short-term imbalances in the economy based on the mechanism of automatic stabilization fix. Although Taylor does not deny the necessity of the rule, he emphasizes that expediency must also be considered in the context of the rule.

Monetary policy guidelines have improved in recent years when evaluating and describing the central bank's policy performance. However, there is still no conclusive consensus on the actual meaning of the phrase "monetary rule", but according to John Taylor, who offered one of the most well-known monetary rules, which later became the foundation of many global studies of banking policies in the subject. Central monetary policy is a program that clearly defines the conditions under which a monetary policymaker must change the intermediate goals of monetary policy.

The leading economics textbooks place more emphasis on monetary policy rules as a method of teaching monetary policy. In this regard, Kydland and Prescott [14] began a discussion Barro and Gordon [5] continued. They raised the inflation bias issue resulting from a discretionary monetary policy that incentivized inflation to achieve several alternative desirable goals. In this context, adherence to the monetary policy rule can create the necessary restrictions to correct the inflation bias. Parallel to the changes in "real business cycle" theory in the 1980s, another school of thought in the evolution of monetary policy thinking evolved, resulting in the requirement for the central bank to respond optimally to inflation variations.

As a result, "central bank independence" has remained in the spotlight since the early 1990s. The necessity to attain pre-determined inflation targets at low levels and discuss the rule versus diagnosis was further debated and deepened when the flaws in the monetary targeting method were found. Following the expansion of the literature on central bank independence, "inflation targeting" became the next step in the evolution of policy concepts. The optimal response of an independent central bank should be in the face of the current inflation rate deviation from the target inflation rate. However, studies have shown that, even with total independence, adopting inflation targeting using the monetary rule for the central bank is not the only criterion for ensuring price stability. What is evident is that both monetary and fiscal policy influence that price stability.

The optimal monetary rule is derived from the first-order condition for minimizing the inter-period loss function by limiting how the economy moves over time. Taylor introduced his famous rule in 1992, which was a simple instrumental rule. Svensson [20] re-expanded the discussion of the optimal monetary rule and used an inter-period optimization process to find the optimal monetary rule. Following Svensson, the optimal monetary rule was re-examined, and more research was conducted. In most research within the field, the central bank is assumed to have an intermediate loss function, typically a quadratic function of the product gap and the difference between inflation and the targeted rate.

In general, optimal monetary policy is the derivation of an optimal rule of conduct, according to which the central bank regulates and applies its monetary instrument. The term "optimal" means that the optimal rule is achieved through optimization over time. In the optimal monetary policy method, the objective function, often referred to as the loss function, is a function that the central bank is willing to minimize. The reasoning for the term "loss function" is that there are variables in the function, which causes social costs and costs producers and consumers, such as inflation. According to research, the loss function is expressed in diverse ways, and in general, according to research, this function has at least one variable and a maximum of three variables. Examples of variables include inflation, unemployment rate, production gap, and money supply growth rate [9].

Central banks demand a policy system to achieve their goals. At the heart of this system is the political regime, which is a decision-making framework. The monetary policy rule is set as a rule for monetary policy to be followed in the medium term in this regime. Monetary policy is organized around a precise and quantitative goal known to the public. Thus, targeting inflation as the latest monetary strategy by focusing on the domestic economy and an independent monetary policy and increasing the central bank's credit reduces the effects of inflation shocks.

Literature review

Akbari and Sharifzadeh (2017) investigate the determination of the monetary policy rule in the event of an oil revenue shock using a New Keynesian dynamic stochastic general equilibrium (DSGE) model with a preference for consuming domestic goods based on a Bayesian approach. This study categorizes household consumption into consuming domestically-produced and imported commodities. They find out that the optimal monetary policy in case of a shock to oil revenues consists of the Central Bank responding to the inflation and exchange rate gap. As the model parameter for the preference for consuming domestic goods increases, the welfare loss dramatically decreases in all policy rules. The study's policy recommendation highlights the importance of the exchange rate for the Ventral Bank at the time of the shock.

Zare, Nonejad, Haqiqat, and Asqari (2019) study the dynamics of exchange rates and the role of monetary and fiscal policies. They design a dynamic stochastic general equilibrium model for a small open economy from 1989 to 2015. The study reveals weak symptoms of Dutch disease in trade while showing the non-tradable sector to have flourished. Moreover, the study shows that prices have risen in the tradable sector, prices have decreased in the tradable sector, and the real exchange rate has decreased according to various scenarios. The study recommends adopting active fiscal policies to control exchange rate fluctuations.

Garusi and Afshari (2019) employ a Bayesian Vector Auto regression model to examine how macroeconomic shocks have affected Iran's housing sector investment from 1978 through 2017. The model includes the four macroeconomic shocks: monetary, fiscal, oil income, and exchange rate. Considering the results of the impulse response functions, the monetary and oil revenue shocks, respectively, exert the most and least enduring effects on real investment in Iran's housing sector. The highest investment fluctuations result from financial, monetary, exchange rate, and oil revenue shocks. Therefore, the policymakers must take note of the size and endurance of the shocks.

Borghe'ei and Mohammadi (2017) aim to determine the extent to which the exchange rate shifts, namely the relation between prices and exchange rate. Notably, the study considers the exchange rate an exogenous variable. This assumption matters because the exchange rate shift due to a specific shock differs from a foreign exchange rate shift due to a different shock. Thus, the study offers and simulates a dynamic stochastic general equilibrium model for the Iranian economy. It tests the model's accuracy using variables and seasonal data from 1988 to 2019.

The authors investigate the degree of exchange rate shift resulting from any economic shocks (technology, oil, foreign production, money demand, foreign interest rate, and monetary policy shocks). Finally, they calculate the aggregate exchange rate shift as the weighted sum of the coefficients of exchange rate shift, with the weights reflecting the relative weights of different shocks in explaining the exchange rate changes. The highest degree of long-term conditional exchange rate shift belongs to the Consumer Price Index, after the oil revenue and foreign production shocks, close to number 1 and complete shift. By contrast, the lowest shift occurs due to the technology shock.

Taking note of the limitations of the two-country (the United States and Canada) dynamic stochastic general equilibrium model, Hou et al. draw on a vector auto regression model. They seek to explore the effects of an oil price impulse on macroeconomic variables and the mechanism underlying the conveyance of this impulse in an oil-exporting country (Canada). The findings indicate that the oil impulses stimulate Canada's aggregate demand, shore up the Canadian dollar, improve the terms of trade (TOT), and reduce real wages. Furthermore, foreign disruptions, such as the United States' interest rate and oil prices, significantly influence Canada's economic activities.

Johans von Hafen (2015) investigates the importance of fiscal discipline in dealing with the oil shocks for a small, closed, oil-exporting economy. He highlights the role of fiscal policy as a mechanism for shifting the oil price shock in oil-exporting countries. The findings show that the dependence of the income structure of the governments on the sale of natural resources weakens the tax system and taxation power.

Guerra Sals (2014) uses a dynamic stochastic general equilibrium model for the Mexican economy as a small, open economy to shed light on how the oil price shocks impact consumption and public and private investment. When oil revenues are abundant, the government ramps up the public investment, remarkably boosting the private sector's productivity. However, it rapidly falls when oil revenues plummet. He then analyzes the public and private investment under circumstances where an oil fund is present. His observations establish that if an oil fund exists, the government invests the extra oil revenue in these funds, periodically using them. By comparing these two scenarios, he concludes that oil funds mitigate the influence of oil price fluctuations on the economy.

In a paper entitled "The Value of Fiscal Discipline for Oil-exporting Countries", Pieschacón (2012) utilizes a dynamic stochastic general equilibrium model for a small, open, oil-exporting economy analyzes the effect of oil price shocks on macroeconomic performance in Norway and Mexico. He suggests that fiscal discipline considerably affects the management of resources accruing from oil price shocks and the Dutch disease phenomenon. Also, he discusses the fiscal policies as the leading shift mechanism with a different financial structure, depicting Norway's oil fund as the essential source of controlling the instability resulting from oil shocks.

Material and methods

Using Medina and Soto [16] and Allegret and Benkhodja [3] models, this study emphasizes a Keynesian stochastic dynamic general equilibrium model for Iran as an oil-exporting economy to adopt an optimal monetary policy, considering shocks. For this purpose, the model is constructed according to the characteristics of Iran's economy as a small open oil-exporting economy.

The economic sectors included in this study are the household, oil sector, non-oil sector, import, final producer, and government, where households are considered to provide labor and capital to the oil producer and non-oil producers. The oil sector uses technology, capital, and labor to produce crude oil, exported entirely at world prices. According to the non-oil sector, it is assumed that there is an infinite number of non-oil commodity firms that produce specific commodities in a monopolistic competitive market, so the non-oil commodity firm possesses price placement powers in the Galvo model (1983) and Yun model (1996).

In the import sector, imported consumer goods are imported at world prices. These distinctive goods are sold by importers who use the Kalu and Yan pricing models within a competitive domestic monopolized market. Furthermore, the final product producer operates in a completely competitive environment, and for producing the final product, a combination of domestically produced goods and imported goods is used. The government also owns the oil sector, exports crude oil, imports refined oil at world prices, sells them to non-oil producers at subsidized prices, and finally assumes that the central bank has a short nominal interest rate. Finally, adjustments to the duration in response to inflation fluctuations using the Taylor -type monetary policy rule are made.

It is worth noting that stochastic dynamic equilibrium models, which were first developed as part of the real business cycle school, frequently attribute economic fluctuations to technological shocks and have little interest in assessing the impacts of monetary policy on the economy. Therefore, the advancement of the New Keynesian school and the gradual evolution of models within this school, plus the definition of nominal rigidity, attracted much attention from monetary circles to these models. As a result, building a stochastic dynamic equilibrium without taking nominal rigidity into account makes it impossible to examine the real effects of monetary policy. We can only examine the actual effects of monetary policy by introducing nominal rigidity and building this model in the New Keynesian paradigm.

Household

The representative household gains utility (c_t) and leisure $(1 - h_t)$, and the household preferences follow the expected utility function:

$$E_0 = \int_{t=0}^{\infty} \beta^t U(c_t, h_t) \tag{0.1}$$

In the above relation, β is the mental discount rate and is a function of household utility as follows:

$$u = \frac{c_t^{1-\gamma}}{1-\gamma} - \frac{h_t^{1+\sigma}}{1+\sigma} \tag{0.2}$$

γ The alternative inverse elasticity between consumption periods and σ is the inverse elasticity of the labor supply wage, h_t is the household labor supply for which the Cobb-Douglas function is defined as follows:

$$h_t = h_{o,t}^{\alpha_{ho}} h_{no,t}^{\alpha_{hno}}, \qquad \alpha_{ho} + \alpha_{hno} = 1 \tag{0.3}$$

$h_{o,t}$ and $h_{no,t}$show household working hours at time t within the oil and non-oil sectors. The parameters α_{ho} and $\alpha_{hno}$are the elasticity of labor replacement in the oil and non-oil sectors. It should be noted that the utility function $u(\cdot)$ is strictly infinite.

Oil sector

To model oil production, we assume that the oil sector in full competition uses capital technology $A_{o,t}$, labor $h_{o,t}$, capital $k_{o,t}$, oil factor O_t to produce crude oil and then exports based on international price $P_{o,t}^f$. The problem of maximization in the oil sector follows the following relation:

$$\max_{k_{o,t} h_{o,t}\ o_t} \left[e_t P_{o,t}^f Y_{o,t} - \ \mathcal{Q}_{o,t}\ k_{o,t} - w_{o,t}\ h_{o,t} - \ \ P_{o,t}\ O_t \right] \tag{0.4}$$

Production function in the oil sector, a Cobb-Douglas production function, and coefficients also show the share of each factor in oil production:

$$Y_{o,t} \leq \ A_{0,t}\ k_{o,t}^{\alpha_0}\ h_{o,t}^{\beta_0} O_t^{\theta_0} \qquad \alpha_0 + \beta_0 + \theta_0 = 1 \tag{0.5}$$

$\alpha_0, \beta_0, \theta_0$, represent the share of oil resources, labor, and capital for oil production

Non-oil sector

In this section, we assume that non-oil producers operate under conditions of monopoly competition. Based on this hypothesis, it is assumed that each company i produces non-oil goods based on the following production function:

$$Y_{o,t}\,(i) \leq \ A_{no,t}\ k_{no,t}^{\alpha_{n0}}\,(i)\, h_{no,t}^{\beta_{n0}}\,(i)\, Y_{o,t}^{I^{\theta_{no}}}\ (i) \qquad \alpha_0 + \beta_0 + \theta_0 = 1 \tag{0.6}$$

According to the time-dependent random rule, Calvo, every manufacturer in any period, has a fixed probability of price change [6]. Assuming that the producers of non-oil goods are unable to change their prices, the price indexation will be applied as follows: (π is the long-term average gross inflation rate)

$$P_{no,t} = \pi P_{no,t-1} \tag{0.7}$$

Import section

The manufacturer of the end product uses imported composite goods Y_{It}purchased in a competitive domestic monopolized market for their production needs. To produce Y_{It} the firm uses distinctive products "products produced by a chain of domestic importers and homogeneous intermediate goods produced abroad that are imported at the global price of P_t^f". Distinctive products are sold at $P_{It}(i)$ prices that follow the Kahlo adhesion pattern. The problem of importer maximization is as follows:

$$max_{P_{I,t}(i)}\ E_0 \sum_{s=0}^{\infty} (\beta\emptyset_I)^s \lambda_{t+s}(\pi^s \tilde{P}_{I,t}\,(i) - e_{t+s}\,(\mu + (1-\mu)\,\xi_t)\,P^f_{t+s})Y_{I,t+s}\,(i)\,, \tag{0.8}$$

The nominal price index of total imports evolves with an emphasis on the following return form:

$$(P_{I,t})^{1-\vartheta} = \phi_I(\pi P_{I,t-1})^{1-\vartheta} + (1-\phi_I)\left(\tilde{P}_{nT,t}\right)^{1-\vartheta} \tag{0.9}$$

Dividing Equation (0.8) by Pt results in the following real import price index:

$$(P_{I,t})^{1-\vartheta} = \phi_I\left(\pi\frac{P_{I,t-1}}{\pi_t}\right)^{1-\vartheta} + (1-\phi_I)(\tilde{P}_{I,t})^{1-\vartheta} \tag{0.10}$$

Final goods producer

It is assumed that the producer of the final goods operates in a fully competitive environment and uses CES technology to produce the final $\mathcal{Z}_t$ product, which includes domestic $Y_{no,t}$ non-oil production, and $Y_{I,t}$, imports. $\tau > 0$ is the alternative tension between non-oil products and imported goods and $\mathcal{X}_{NO}$ and $\mathcal{X}_I$ is the share of imported and non-oil goods in the final goods.

$$\mathcal{Z}_t = \left[\mathcal{X}_{no}^{1/\tau}\quad Y_{no}^{\tau-1/\tau} + \ \mathcal{X}_I^{1/\tau} Y_I^{\tau-1/\tau}\right]^{\tau/\tau-1} \qquad \mathcal{X}_{NO} + \mathcal{X}_I = 1 \quad \tau > 0 \tag{0.11}$$

By solving the problem, the following demand function is obtained:

$$Y_{I,t} = \chi_I\left(\frac{P_{I,t}}{P_t}\right)^{-\tau} z_t, Y_{no,t} = \chi_{no}\left(\frac{P_{no,t}}{P_t}\right)^{-\tau} z_t \tag{0.12}$$

Finally, the final commodity is divided between total consumption and total investment:

$$z_t = c_t + i_{o,t} + i_{no,t} \tag{0.13}$$

Government

According to a study, in an oil export economy, domestically refined oil is sold to non-oil companies at a price of $P_{o,t}$ which can be classed as the domestic price of fuel, subsidized by the government. By considering the study of Boaks et al. (2008) and Ben Bukha (2011), the domestic price of oil $P_{o,t}$ as a convex combination of its world price $P^f_{o,t}$ with a weight υ and the domestic price of the previous period, where the weight $(1-\upsilon)$ is determined as follows:

$$P_{o,t} = (1-\upsilon)\,P_{o,t-1} + \upsilon e_t\ \xi_t P^f_{o,t} \tag{0.14}$$

When $\upsilon = 1$, there is no subsidy, and the world price of oil determines the price. Furthermore, in the case of $\upsilon = 0$, the domestic oil price is wholly subsidized, and domestic companies buy oil at the price of $P_(o,t)$. As a result, the government budget is as follows:

$$\bar{\omega} \sum_{j=0,T,nT} W_{j,t}\ h_{j,t} + \ s_t P^f_{o,t} Y_{o,t} = \left(s_t \Xi_t P^f_{o,t} - P_{o,t}\right) Y^I_{o,t} + \ \omega_{o,t} h_{o,t} + q_{o,t} k_{o,t} \tag{0.15}$$

The left shows the government revenue equation, which includes general taxes, $\bar{\omega}$, and oil sales revenue $s_t P^f_{o,t} Y_{o,t}$ and the right shows government spending, which includes expenditures. Salary, return on capital $\omega_{o,t} h_{o,t} + q_{o,t} k_{o,t}$ in the oil sector and the amount of oil subsidies $\left(s_t \Xi_t P^f_{o,t} - P_{o,t}\right) Y^I_{o,t}$

Market clearing condition

In a symmetrical equilibrium, all importers and producers of non-oil products make the same decision as follows:

$$Y_{not}(i) = Y_{not}, \quad Y^I_{ot}(i) = Y^I_{ot}, \quad \tilde{p}_{not}(i) = \tilde{p}_{not}, \; Y_{It}(i) = Y_{It}, \quad \tilde{p}_{It}(i) = \tilde{p}_{It} \tag{0.16}$$

$$Y_t = \quad P_{no,t} Y^{va}_{no,t} + s_t \; P^f_{o,t} Y_{o,t} \tag{0.17}$$

Y_t, $Y^{va}_{no,t}$ are GDP and value-added output in the non-oil sector. The variable $Y^{va}_{no,t}$ is as follows:

$$Y^{va}_{no,t} = Y_{no,t} - s_t \; P^f_{o,t} \frac{Y^T_{ot}}{P_{no,t}} \tag{0.18}$$

Combining the household budget constraints, the unit period functions of the non-oil producing companies and the importers of foreign goods, and the first-order terms of the three segments and the use of the market settlement condition, the following current account equation is obtained:

$$\frac{b^f_t}{R^f_t k_t} = \frac{b^f_{t-1}}{\pi^f_t} + p^f_{o,t} y_{o,t}/\Xi_t - p^f_{o,t} Y^I_{ot} - (\mu + (1-\mu)\,\Xi_t) Y_{It}/\Xi_t \tag{0.19}$$

Monetary policy

For examining the appropriate monetary policy in the Iranian economy, the model should be solved by considering the monetary policy rule. In New Keynesian models, the number of equations available to the policymaker is less than the unknowns in the model. Now, to complete the model, an equation is considered the model's monetary policy behavior. This is usually the well-known Taylor rule, but when optimal monetary policy is considered, the targeting rule is based on specifying a loss function for policymaking and the policy objective instead of using the instrumental rule. The transition to minimize this loss function is such that no inconsistencies occur between times. This approach is made in discretionary policymaking with a slight difference in optimization. In both of these approaches (optimal and discretionary policymaking), it is impossible to estimate the parameters as the goal in both approaches when it comes to optimization. With these interpretations, this study introduces the loss function for the central bank, and two methods, optimal and discretionary, examine the model.

Solution method

Optimizing equations in the form of linear logarithms

Typically, general equilibrium patterns form a nonlinear set of differential equations, which is not adequate for practical analysis. It is impossible to find a stable uniform answer in most cases. However, once converted, it can provide the basis for a suitable device for experimental analysis. Therefore, it is significant in preparing a more straightforward pattern to construct a linear approximation of the original nonlinear pattern. In this case, the system of random differential nonlinear equations becomes a random differential linear system.

Data

One problem in applying stochastic dynamic general equilibrium models is their parameterization using economic statistics. There are two quantification methods and estimation for parameterization, the estimation itself can be done by generalized torque, maximum likelihood, or Bayesian methods. Calibration is essential in evaluating stochastic dynamic equilibrium models in real and New Keynesian schools, often based on quantifying pattern parameters based on related studies. In many countries, due to many studies on applying stochastic dynamic general equilibrium models, researchers often find the values of the parameters in their model without any concern for the accuracy of the data and information. Other researchers place reputable sites. Considering that many studies have been conducted in Iran in recent years using these models, we also use the parameter quantification method in this study with confidence in some studies. For quantifying other parameters, as mentioned above, the findings from previous studies have been used. Table 1 shows the calibrated parameters.

Table 1: Calibrated parameters and ratios of the model

Source	Value	Parameter	Description
Jalali-Naini and Naderian (2011)	0.985	β	Mental discount factor
Tavakolian and Jalali-Naini (2016)	1.57	γ	Reverse substitution elasticity between consumption periods
Tavakolian (2012)	2.17	σ	Reverse labor supply wage elasticity
Mehregan et al., 2017	0.042	δ	Capital depreciation rate
Result & discussion	0.81	$\frac{kno}{k}$	Stable ratio of capital in the non-oil sector to the total capital stock
Result & discussion	0.42	$\frac{c}{y}$	Stable ratio of consumption to GDP
Result & discussion	0.28	$\frac{I}{y}$	Stable ratio of investment to GDP
Result & discussion	0.19	$\frac{g}{y}$	Stable ratio of government spending to GDP
Result & discussion	0.26	$\frac{sp_o^f y_o}{y}$	Stable ratio of exports to GDP
Result & discussion	0.22	$\frac{sp_o^f y_o^i - sy_i}{y}$	Stable ratio of imports to GDP
Result & discussion	0.5	$\frac{sp_o^f \ y_o}{g}$	Stable ratio of oil export revenues to government expenditures

Source: Calculations performed

In the above study, the data of the seasonal time series 1370 to 1397, taken from the Central Bank, have been used to calculate the stable values of some variables in equilibrium.

Discussion and investigation of experimental results

As the following diagrams display, the effects of the mentioned external shocks on Iran's macroeconomic variables have been investigated. In the face of volatility, the impact of dynamic behavior of the model variables on the variables studied amount to one standard deviation over time. The diagrams also show variance and the amount of the relevant deadweight losses to compare and demonstrate the important effect of policies. It should be noted that the graph analysis is based on the three rules of monetary policy; namely, Headline inflation targeting, core inflation, and the exchange rate.

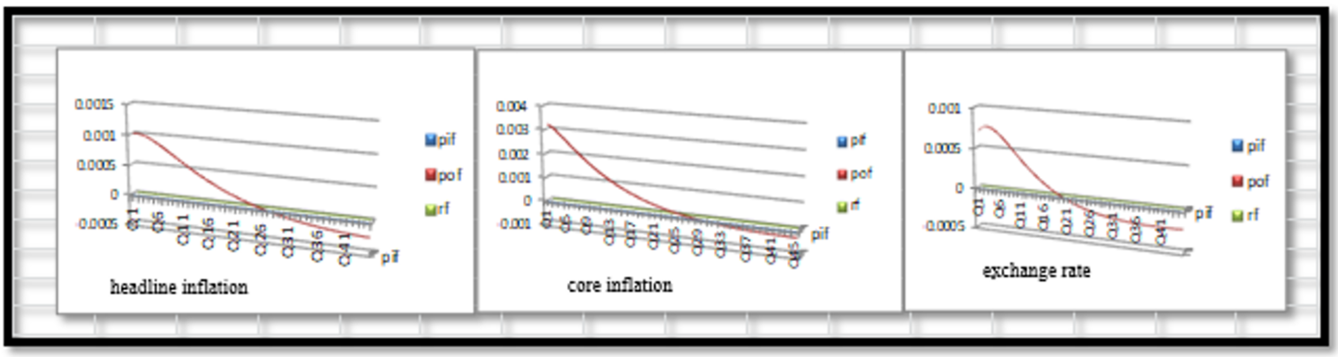

Figure 1: The effects of global inflation, foreign interest rate, and foreign oil price on consumption based on monetary rules

As the above Figure shows, the consumption soars due to the volatility of oil prices on international market. This trend reaches a long-term stability after 21 seasons based on the monetary policy rule and after 25 seasons based on the headline inflation rule. However, the external inflation volatility and foreign interest rate have not had any significant effect on the above variable. This indicates that the above variable is not affected by these shocks. It should be noted that the variable in question experiences more fluctuations under the core inflation rule than under the other two rules.

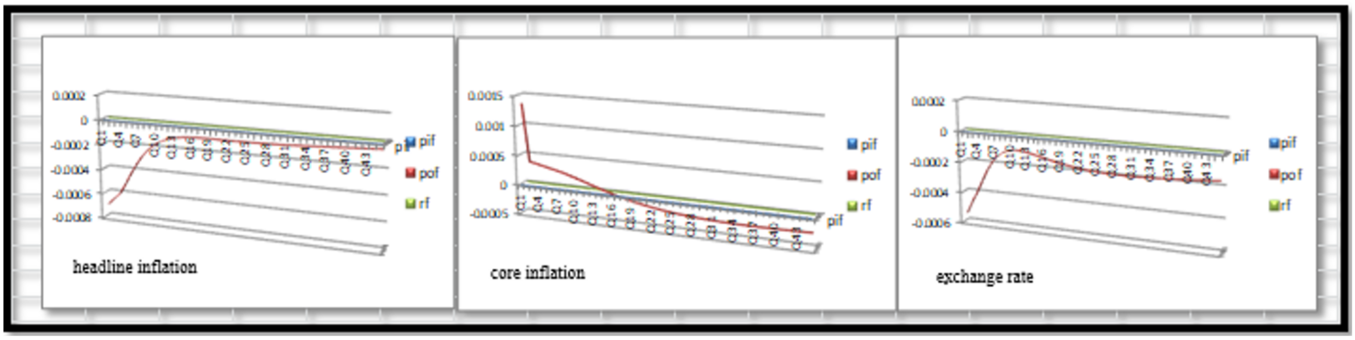

Figure 2: The effects of global inflation, foreign interest rate, and foreign oil price on GDP based on monetary rules

Given the monetary rules of Headline inflation and exchange rate, there is a declining effect of the studied shocks on the GDP. Such a declining trend moves towards stability within 10 seasons. The analysis of the diagram shows a very short-lived, positive upsurge of the variable under study and a rapid tendency towards stability based on the core inflation rule.

As Figure 2 displays, despite the insensitivity of the above variable to the volatilities of external inflation and foreign interest rates, based on the monetary rule of headline inflation, non-oil GDP has undergone a short-term decline over four seasons, reaching stability after a hike. This variable experiences an increasing trend in the face of exchange rate policy and core inflation, reaching stability quickly.

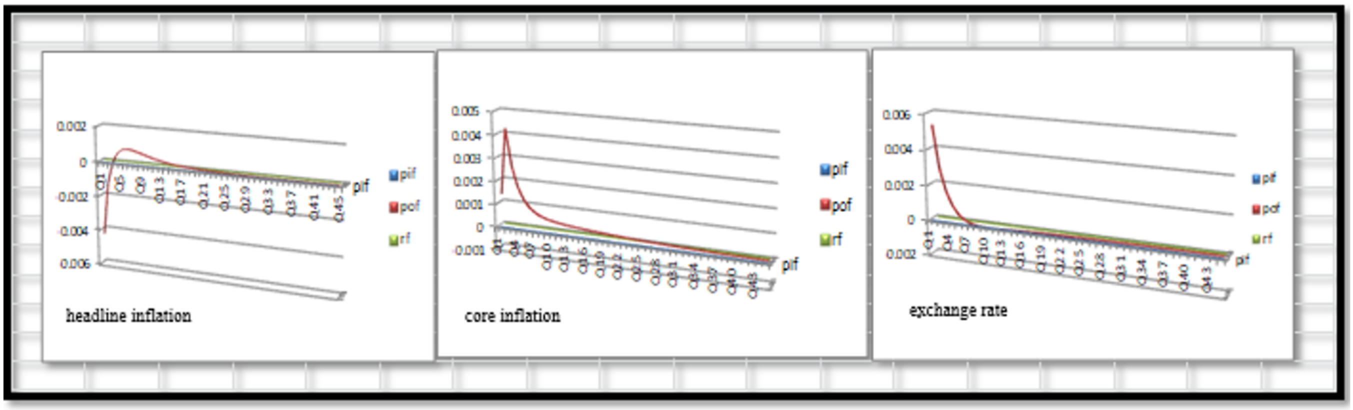

Figure 3: The effects of global inflation, foreign interest rate, and foreign oil price on non-oil GDP based on monetary rules

Table 2: Comparing the percentages of main variables variations based on monetary policies rules

Oil price on internatioaln market			Variable
Exchange rate	Core inflation	Headline inflation	
1.6	2.13	0.36	non-oil GDP
1.21	1.39	0.41	GDP
0.66	1.55	0.12	Consumption

Source: Calculations performed

According to Table 1, global inflation shock and foreign interest rate shock account for a small percentage of the fluctuations of the variables studied in relation to monetary policy rules. On the other hand, the variables studied experience more fluctuations in the face of external oil price shocks when there is more emphasis on the core inflation rule than other policies. In general, the examination of the percentages of changes triggered by shocks shows that the monetary policy shock (e_R1) (as shown in Equation 0.16) has a stronger effect than the other shocks examined.

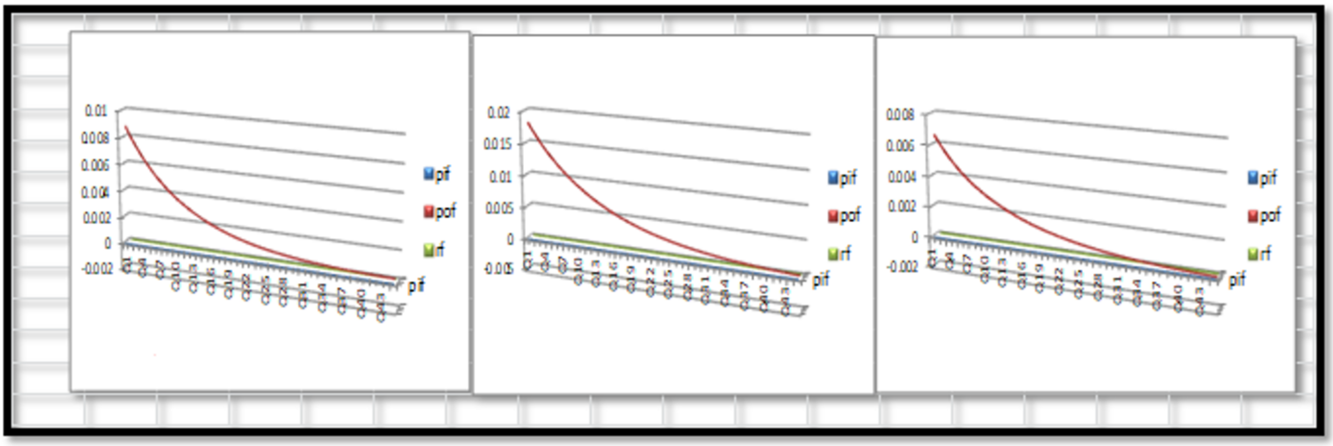

Figure 4: The effects of global inflation, foreign interest rate, and foreign oil price on capital based on monetary rules

According to Figure 4, there is a surge in capital stock during 31 seasons due to exchange rate shocks. Such a duration is notable despite the positive impact of the studied shocks to capital stock consistent with the approved policies compared to other rules implemented. Also, the effects of shocks ,as well as the importance of headline inflation monetary policies show the very short-lived incremental effects on import variable, lasting for about seven seasons, while the fluctuations are slightly higher in other cases (Figure 5).

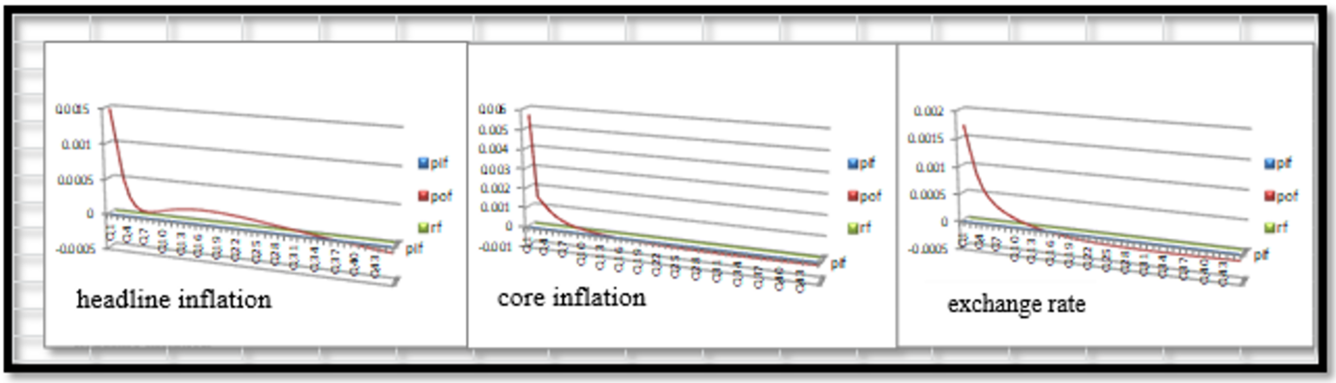

Figure 5: The effects of global inflation, foreign interest rate, and foreign oil price on imports based on monetary rules

Investigation of monetary policy rules-deadweight loss

In this section, the deadweight loss driven by external shocks is examined based on various monetary policy rules. Therefore, the deadweight loss is calculated using the mathematical expectation of the utility function. The welfare criterion is derived from the single-period utility function as follows:

$$E_0 \int_{t=0}^{\infty} \beta^t U(c_t \ , h_t) \tag{0.20}$$

The second-order approximation of the above equation is as follows

$$\mu(\cdot) \simeq \overline{\mu} + \overline{c}^{1-\gamma} E(\hat{c}_t) - \overline{h}^{1+\sigma} E\left(\hat{h}_t\right) - \frac{\gamma}{2}\overline{c}^{1-\gamma} E\left(var(\hat{c}_t) + \left[E(\hat{c}_t)^2\right]\right) - \frac{\sigma}{2}\overline{h}^{1+\sigma} E\left(var\left(\hat{h}_t\right) + \left[E\left(\hat{h}_t\right)^2\right]\right). \tag{0.21}$$

It should be noted that $(-)$ and $(^-)$ represent the stability of variables and the standard deviation from the stability state, respectively.

Table 3: Comparing the rules of monetary policy in terms of deadweight loss

Exchange rate	Core Inflation Rule	Headline Inflation Rule	Variable
2.57	2.58	2.6	A function of Central Bank loss

Source: Calculations performed

Based on the equations (0.20) and (0.21), the investigation of the effects of the policies on the amount of household deadweight loss at the time of volatilities indicates that the Headline inflation rule has a stronger impact on loss reduction than the other two policies, and the exchange rate rule makes less contribution to deadweight loss.

1 Conclusion

This study is aimed at investigating the role of monetary policy in rendering the Iranian economy as an oil-exporting country vulnerable to foreign shocks; therefore, an attempt was made to develop a New Keynesian dynamic general equilibrium model for Iran as an oil exporting economy by drawing on the models designed by Medina and Soto [16], as well as Albert et al. [3]. To this end, the model was constructed based on the characteristics of the economy of Iran as a small oil- exporting economy; that is, a stochastic dynamic general equilibrium model involving the oil sector along with the non-oil sector; special attention has been paid to the dependence of Iran's economy on the oil sector (oil and resulting export revenues appear as a separate sector and a funding source of the government budget).

Given the feature of nominal stickiness, etc., after optimization process was performed in the form of a linear logarithm, the relevant diagrams were created in order to select the optimal monetary policies, with a focus on the effects of the external shocks studied. It should be noted that the shocks were analyzed based on three rules of monetary policy: headline inflation targeting, core inflation, and exchange rate.

The graphs in this study indicate the significant effects of the external oil price shock, which should be taken into account when it comes to making monetary policies. However, the above variables are not very sensitive to the effects of global inflation and foreign interest rates. This deserves to be examined in more detail given the small size of Iran's economy. Yet, some diagrams indicate the short-lived effects of the above shocks on the variables studied, which entails making better economic conditions, as shown in diagrams 6-5 and vice versa. .

An examination of the percentages of changes in the variances of key variables (consumption, GDP, and non-oil GDP) demonstrates the importance of the external oil price shock, with more general studies showing monetary policy shock as having the biggest effect.

Regarding the deadweight loss in relation to three rules of monetary policy, this study suggests that in the face of the shocks studied, the amount of household deadweight loss is affected more strongly by headline inflation rule than the other two policies, while the exchange rate rule makes less contribution to the amount of deadweight loss . Finally, the policymaker must take into account the type and nature of the shocks to the economy when it comes to determining the policy rule. Consequently, it is necessary to adopt a policy that reduces the deadweight loss.

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