

Oil Price Shock and Optimal Monetary Policy in a Model of Small Open Oil Exporting Economy - Case of Iran¹

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Abstract

Oil price shocks are the main source of macroeconomic fluctuations in oil exporting countries. It is believed that appropriate monetary policy can help to stabilize these unwanted variations toward optimal allocations. A stochastic dynamic general equilibrium model featuring the properties of both cost push and wealth effect transmission channels is developed for the Iranian economy. In this context, it is possible to evaluate the role of monetary policy measures to accommodate supply side cost push effects and demand side wealth effect of oil price shock. This paper is intended to investigate the optimal monetary policy strategy for the economy of Iran and calibrated for its structural characteristics and patterns of external shocks. The comparative analysis of alternative monetary policies in terms of

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Ramsey, and optimal simple rules is performed based on key nominal and real variables variance reductions and the linear quadratic loss (LQ) function. Our findings show that domestic inflation targeting rule is the optimal monetary policy both in terms of stabilization performance and welfare costs. It must be mentioned that the addition of exchange rate to domestic inflation targeting rule has failed to improve the welfare measure and stabilization in comparison to domestic inflation targeting rule.

Key Words: *DSGE, Wealth effect, Ramsey Rule, Domestic inflation targeting regime*

JEL Classification: *C3, C6, D5, E4, E5*

1. Introduction

A large body of research shows that oil price fluctuations have considerable consequences on real economic activity and inflation. The macroeconomic consequences of an oil price shock on real activity are different in an oil exporting country from an oil importing country. Oil price shocks, defined as unexpected changes in the price of oil, have additional effects on oil exporting countries compared to their impact on oil importing economies. The economic implications of an increase in the price of oil in an oil importing country are mainly the creation of inflationary pressures due to increase in production costs, a decrease in productivity level, and contractionary effect on output due to a reduction in aggregate demand. Therefore, an oil price shock is considered as a bad issue for the oil importing countries. In contrast, in an oil exporting country, an oil price shock carries an additional effect. The economy as a whole receives a positive wealth effect through better terms of trade and increase in real oil revenues. Because of this second channel of transmission, additional inflationary pressures may be present due to the effects on marginal costs and aggregate demand. Naturally, the question of whether there is a positive or negative effect on output and consumption in oil exporting economies after hitting oil price shock arises. Barell and Pomerantz (2004) argue that the consequences of an oil price shock for inflation and output largely depend on the monetary policy response of the central banks. DeLong (1997), Barsky and Killian (1999), Hooker (1999) and Clarida, Gali and Gertler (2000) are among those who suggest that there is a role for monetary policy when dealing with oil price shock¹. Hunt, Isard and Laxton (2001) use the IMF multi-country model to suggest that the effects of oil price shocks on economic activity can be limited if appropriate monetary rules are

1. In the New-Keynesian school of economy the rationale for government intervention either in monetary or fiscal policy lies behind the existence of market failures arising from nominal or real rigidities. These rigidities move the economy apart from its Pareto optimal allocations and the role of monetary policy is to close or limit this gap.

chosen. In this line of reasoning, the role of monetary policy and optimal monetary policy determination in oil exporting countries may be different compared to the case when only the standard channels of shock transmission are considered.

This structural characteristic of oil exporting countries raises the question of the appropriate monetary policy for this kind of economies. There have been a few recent models that analyze oil shocks in a New-Keynesian framework. Studies like Leduc and Sill (2001), Kamps and Pierdzioch (2002), Medina and Soto (2005) and Deverux et al. (2006) have developed DSGE models to study the macroeconomic implications of alternative monetary policy rules, after oil price shocks for a small open economy. Kamps and Pierdzioch study the interaction between oil price shocks and monetary policy in a small open economy framework. In particular, they study the relative performance of alternative monetary policy rules and suggest domestic inflation targeting as the appropriate rule for an economy that faces an oil shock. Medina and Soto (2005) analyzed the effect of oil price shocks under alternative monetary policy rules. The authors developed an estimated DSGE model by Bayesian methods for Chile economy. The main results show that an increase in the real price of oil leads to fall in output and increase in inflation. The contractionary effect of the oil shock is mainly due to the endogenous tightening of the monetary policy. Deverux et al. (2006) compared alternative monetary policies for an emerging market economy that experienced external shock on interest rates and terms of trade. In particular, they investigated the importance of exchange rate flexibility in implementing such rules (a fixed exchange rate rule, and two types of inflation targeting rules). Their main finding is that the degree of pass-through in import prices is crucial in determining the stabilization properties of an inflation targeting regime. In all of these studies the oil price shock transmission channel is through cost push shocks and its effect on raising the production expenditure. However, Romero (2008) has contributed to this literature by considering a wealth effect that is present

in oil exporting countries, and that acts as an additional channel of transmission for oil price. He concluded that in this setting a monetary policy rule that reacts to consumption and not only final goods production is welfare superior.

In this paper, a dynamic stochastic general equilibrium model based on Romero (2008) has been developed for the economy of Iran as an oil exporting country to investigate the dynamic effects of external shocks and examine the optimal monetary policy rule. We apply the linear quadratic (LQ) approximation to the optimal monetary policy problem, as suggested by Benigno and Woodford (2007), and use the standardized algorithm proposed by Altissimo et al. (2005). While the solution to the optimal policy problem is a useful benchmark for monetary policy evaluation, it is not implementable from a central bank's perspective. To make our results easier to interpret, we approximate the welfare-maximizing policy rule with a set of simple rules reacting only to observable variables. We evaluate the overall performance and the stabilization properties of various simple monetary policy rules. The welfare maximization objective function as it is verified by Romero (2008) is proposed to be either with output gap or consumption gap to compare their relative performance. We have considered three alternative monetary policy rules in this regard: an inflation targeting rule, a domestic inflation targeting rule and fixed exchange rate rule. The stabilization performance of these monetary rules has been compared both with output gap and consumption gap based loss functions. These rules have been adopted because they feature the conduct of monetary policy in many oil exporting countries. It must be mentioned that the presence of oil component in CPI inflation raises the problem of targeting CPI inflation or domestic inflation in optimal monetary policies for the economy of Iran. This question arises due to the inclusion of real exchange rate channel of transmission for the oil price shock in this open economy. Having studied the model in the

closed form, where the exchange rate channel is absent, the results were completely different¹.

We present the details of general equilibrium model for the economy of Iran as an oil exporting small open economy in the next section. Then, we lay out the parameter calibration of the model and the method of solving the system of stochastic general equilibrium equations. We proceed by the specification of policymaker's problem and solution method. In the next section a comparative analysis between different monetary policy rules is conducted. At first, optimal Ramsey rule is compared to the estimated empirical rule and then optimal monetary policy in form of a set of optimal simple rules are approximated and compared according to their stabilization properties with the Ramsey fully optimal rule and the empirical rule. In the last section, the conclusions and recommendations have been proposed.

2. The Model

In this section we describe a dynamic stochastic general equilibrium (DSGE) model with nominal rigidity and assume a small open economy. The latter assumption implies that international prices, the foreign interest rate and foreign demand are not affected by domestic agent's decisions. The economy is populated by infinitely-lived representative household, final good producing firms, an oil producing firm and a monetary authority. Domestic households consume domestically-produced goods and imported differentiated foreign goods. It is assumed that home goods are partly sold domestically and partly exported abroad. Households supply their labor services to the competitive internal labor market² and receive their corresponding wages. Labor is perfectly mobile between the oil and non-oil sectors, and workers in both sectors are subject to the same competitive

1. Please refer to Rabee Hamedani & Pedram (2012).

2. Please note that the inclusion of wage rigidity (incomplete labor market) to this model examined for the Algerian, Mexican and Venezuelan economies does not change our result significantly. Please refer to Allegret & Benkhoddja (2010).

wage. Furthermore, households are the owners of firms producing domestic goods, and thus, they earn the profit of the firms. As a whole, households make saving decisions, consume domestic and foreign differentiated final goods and provide labor to both the final good and the oil sector.

Domestic firms produce a continuum of differentiated varieties of domestic goods. Labor and oil are the factors of production and firms possess monopolistic power over the variety of goods they produce and set prices as in Calvo (1983). Final good producing firms buy oil from the oil sector at a world determined exogenous given price. The oil sector maximizes profits, satisfies domestic demand for oil, and sells the residual to the rest of the world. Monetary policy is conducted as a Taylor type rule that incorporates interest rate inertia, GDP growth, inflation and real exchange rate. For simplicity, there is no fiscal sector.

Three key features distinguish this setup from an otherwise standard model. First, the oil sector competes for labor against the final goods sector. Second, there is an international oil market where the real price of oil is determined by cartel negotiations or other events that are exogenous to the economy. Third, changes in oil prices produce a wealth effect on oil-producing economies. These particular characteristics of the model will allow us to study the effects of oil price shocks on oil-producing economies. The following sections describe the model in greater detail.

3. Households

The domestic economy is inhabited by a continuum of households that derive utility from consumption of a composite good (C_t) and disutility from hours spent working ($1 - N_t^S$). The expected present value of the household utility is given by:

$$E_t \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t - \eta C_{t-1})^{1-\frac{1}{\sigma}}}{1 - \frac{1}{\sigma}} - \frac{(N_t^S)^{1+\frac{1}{\varphi}}}{1 + \frac{1}{\varphi}} \right] \quad (1)$$

where E_t denotes conditional expectation based on information set in period t . Parameter β is the subjective discount factor. Parameter σ shows the intertemporal elasticity of substitution, φ represents the Frisch elasticity of labor supply. As in Woodford (2003), the introduction of money balances in this model is abstracted and a cashless economy is proposed¹.

Consumption bundle (C_t) is a composite of domestic goods ($C_{H,t}$) and imported consumption goods ($C_{F,t}$) which are aggregated based on Dixit-Stiglitz method defined as:

$$C_t = \left[(1 - \gamma)^{1/\theta} C_{H,t}^{\theta-1/\theta} + \gamma^{1/\theta} C_{F,t}^{\theta-1/\theta} \right]^{\theta/\theta-1} \quad (2)$$

Parameter θ is the elasticity of substitution between domestic and imported goods and γ is their corresponding shares. Each consumer at each level of consumption purchases a composite of domestic and foreign goods to minimize the total cost of its consumption basket. The price index (P_t) for the consumption bundle is given by:

$$P_t = \left[\gamma P_{H,t}^{1-\theta} + (1 - \gamma) P_{F,t}^{1-\theta} \right]^{1/1-\theta} \quad (3)$$

where $P_{H,t}$ and $P_{F,t}$ are the price of domestic and imported consumption basket, respectively. Minimization of total consumption expenditure ($P_{H,t}C_{H,t} + P_{F,t}C_{F,t}$) results in the demand function for differentiated domestic and imported goods given by:

$$C_{H,t} = (1 - \gamma) \left(\frac{P_{H,t}}{P_t} \right)^{-\theta} C_t \quad (4)$$

1. The equilibrium in money market in New-Keynesian models is retained via interest rate relationship (like Taylor rule) instead of intersection of money demand and supply functions. However, it is possible to add the money demand function to the following model to derive the equilibrium money balances as well. For further information please refer to: Robert King (2000), "the new IS-LM Model, language, logic and limits", Federal Reserve Bank of Richmond, Working papers, pp. 51-53.

$$C_{F,t} = \gamma \left(\frac{P_{F,t}}{P_t} \right)^{-\theta} C_t \quad (5)$$

Households are considered Ricardian with the access to two assets of one period domestic savings (borrowing) (D_t) and one period foreign savings (borrowing) (B_t^*). There are no adjustment costs in portfolio composition. Therefore, each HH enters period t with nominal domestic savings (D_t) and nominal foreign saving ($\varepsilon_t B_{t-1}^*$). HH receives labor income ($W_t N_t^S$) and also receives profits Π_t and Π_t^O from both the final good producing firms and oil producing firm, respectively. Then, he uses these funds to finance consumption (C_t), and new amounts of domestic and foreign savings. As in Medina and Soto (2005), each time a domestic HH borrows from abroad, it must pay a premium over the international price of external borrowings. This premium is introduced in the model to obtain a well-defined steady-state for the economy. HH budget constraint is thus given by:

$$P_t C_t + E_t \{ Q_{t,t+1} D_{t+1} \} + \frac{\varepsilon_t B_t^*}{(1 + i_t^*) \Theta \left(\frac{\varepsilon_t B_t^*}{P_{X,t} X_t} \right)} = D_t + \varepsilon_t B_{t-1}^* + W_t N_t^S + \Pi_t + \Pi_t^O \quad (6)$$

where the foreign nominal interest is denoted by i_t^* and $Q_{t,t+1}$ represents the stochastic discount factor. The function $\Theta \left(\frac{\varepsilon_t B_t^*}{P_{X,t} X_t} \right)$ corresponds to the premium domestic HH have to pay each time they borrow from abroad, where B_t^* aggregated over all HH can be regarded as the net foreign asset position of the economy and $P_{X,t} X_t$ is the nominal value of exports. In steady state, the $\Theta(\cdot)$ function is parameterized as:

$$\left(\frac{\varepsilon_t B_t^*}{P_{X,t} X_t} \right) = e^{\left[\frac{\omega \varepsilon_t B_t^*}{P_{X,t} X_t} \right]} \quad (7)$$

The assumption of premium dependence on the aggregate net foreign asset position of the economy implies that HH takes $\Theta(\cdot)$ as given when deciding their optimal portfolios. It must be noted that $\Theta(\cdot)$ is strictly

decreasing in $\frac{\varepsilon_t B_t^*}{P_{X,t} X_t}$ when $\omega < 0$. This means that if the domestic economy is a net borrower, so that $B_t^* < 0$, then the domestic representative HH must pay a premium on top of the foreign interest rate i_t^* . On the other hand, if $B_t^* > 0$, the representative HH receives a lower return on savings.

Household maximizes (1) with respect to consumption, domestic and foreign savings (borrowings), and labor supply subject to the resource constraint (6). Therefore, it is possible to derive the optimal conditions for consumption-domestic saving decision, consumption-foreign saving decision and labor-leisure choice after solving for the first order conditions as:

$$E_t \left[\beta(1 + i_t) \frac{P_t (C_{t+1} - \eta C_t)^{-1/\sigma}}{P_{t+1} (C_t - \eta C_{t-1})^{-1/\sigma}} \right] = 1 \quad (8)$$

$$E_t \left[\beta(1 + i_t^*) \theta \left(\frac{\varepsilon_t B_t^*}{P_{X,t} X_t} \right) \frac{\varepsilon_{t+1} P_t (C_{t+1} - \eta C_t)^{-1/\sigma}}{\varepsilon_t P_{t+1} (C_t - \eta C_{t-1})^{-1/\sigma}} \right] \quad (9)$$

$$(N_t^s)^{1/\sigma} (C_t - \eta C_{t-1})^{1/\sigma} = \frac{W_t}{P_t} \quad (10)$$

where (8) is the Euler condition for the domestic saving denoting consumption- domestic saving optimal choice. Equation (9) is the Euler condition for the foreign savings denoting consumption- foreign saving optimal choice and equation (10) is the labor-leisure optimal choice representing the labor supply of the household. Combing (8) and (9) it is possible to obtain an expression for the uncovered interest parity (UIP) condition given by:

$$(1 + i_t) = (1 + i_t^*) \theta \left(\frac{\varepsilon_t B_t^*}{P_{X,t} X_t} \right) \frac{E_t \left[\frac{\varepsilon_{t+1} P_t (C_{t+1} - \eta C_t)^{-1/\sigma}}{\varepsilon_t P_{t+1} (C_t - \eta C_{t-1})^{-1/\sigma}} \right]}{E_t \left[\frac{P_t (C_{t+1} - \eta C_t)^{-1/\sigma}}{P_{t+1} (C_t - \eta C_{t-1})^{-1/\sigma}} \right]} \quad (11)$$

Note that the variable i_t^* and B_t^* which represent foreign interest rate and foreign savings evolve exogenously according to the following AR(1) process:

4. Domestic Firms (non-oil sector)

There is a continuum of final good variety producers. Oil $O_t(j)$ and labor $N_t(j)$ are factors of production for domestic firms to produce differentiated final goods. Cobb-Douglas production function with constant return to scale is considered for the technology as:

$$Y_{H,t} = A_t N_t(j)^\alpha O_t(j)^{1-\alpha} \quad (12)$$

where A_t represents the total factor productivity. It is assumed that this variable is exogenously determined and it evolves according to an AR(1) stochastic process:

$$\ln A_t = \rho_A \ln A_{t-1} + \varepsilon_{A,t} \quad , \quad \varepsilon_{A,t} \sim \text{IN}(0, \sigma_A) \quad (13)$$

where the parameter ρ_A is the autocorrelation coefficient showing the persistence of domestic production technology. $\varepsilon_{A,t}$ is an independent and identically distributed random variable with zero mean and standard deviation σ_A .

Domestic firms supply their output in a monopolistic market with differentiated goods and at the same time, they face a nominal rigidity that prevents them from adjusting their prices as in Calvo (1983). This assumes that firms adjust their prices infrequently. The adjustment occurs when they receive a signal. In every period, the probability of receiving such a signal (and thus adjusting prices) is $1 - \varphi$ for all firms, and independent of their history. Thus, if a firm receives a signal in period t , then it will optimally adjust the price of its variety $\bar{P}_{H,t}(j)$ so as to maximize

the present discounted value of the flows of profits according to the following problem:

$$\max_{\bar{P}_t(j)} \sum_{k=0}^{\infty} \phi^k E_t \{ Q_{t,t+k} Y_{H,t+k}(j) [\bar{P}_{H,t}(j)(1 + \zeta) - MC_{t+k}] \} \quad (14)$$

s.t.

$$Y_{H,t+k}(j) = \left(\frac{\bar{P}_{H,t+k}(j)}{P_{H,t+k}} \right)^{-\theta_H} (C_{H,t+k} + C_{H,t+k}^*) \quad (15)$$

where parameter ζ denotes the Pigovian subsidy to the firms. Equation (15) is the demand function for the differentiated goods that firm faces and here it is imposed as a restriction for optimization problem for price setting. The variable $C_{H,t+k}^*$ in (15) is the aggregate foreign demand for domestic goods and it is added to the demand function due to the inclusion of firm's export (foreign demand for domestic goods) to the foreign sector. This variable can be regarded as non-oil export in oil exporting countries. In equilibrium aggregate non-oil production ($Y_{H,t}$) equals aggregate domestic consumption ($C_{H,t}$) and aggregate foreign demand for domestic non-oil goods [non-oil export ($C_{H,t}^*$)]:

$$Y_{H,t} = \left[\int_0^1 Y_{H,t}(\ell)^{\frac{\theta_H-1}{\theta_H}} d\ell \right]^{\frac{\theta_H}{\theta_H-1}} = C_{H,t} + C_{H,t}^* \quad (16)$$

Nominal marginal costs (MC_t) in equation (14) can be derived considering the production function as:

$$MC_t = \frac{1}{\alpha^\alpha (1 - \alpha)^{1-\alpha}} \frac{W_t^\alpha (P_t^o)^{1-\alpha}}{A_t} \quad (17)$$

Now, if the optimization problem of non-oil firm is solved with respect to reset price $\bar{P}_t(j)$ control variable, the first order condition will be given by:

$$\bar{P}_{H,t}(j) = \bar{P}_{H,t} \frac{\theta_H}{(\theta_{H-1})(1 + \zeta)} \frac{\sum_{k=0}^{\infty} (\phi\beta)^k E_t \left[\frac{C_{t+k}^{-1}}{P_{t+k}} P_{H,t+k}^{\theta_H} Y_{H,t+k} MC_{t+k} \right]}{\sum_{k=0}^{\infty} (\phi\beta)^k E_t \left[\frac{C_{t+k}^{-1}}{P_{t+k}} P_{H,t+k}^{\theta_H} Y_{H,t+k} \right]} \quad (18)$$

As the price setting problem for all non-oil domestic firms in each period is similar, they will set the same price. Thus, the aggregate price index in this condition is:

$$P_{H,t} = \left[\int_0^1 P_{H,t}(j)^{1-\theta_H} dj \right]^{\frac{1}{1-\theta_H}} \quad (19)$$

Since there are an infinite number of firms, there will be exactly the fraction $1 - \phi$ firms which get to update in any period, and exactly the fraction ϕ firms which do not. Furthermore, since these firms are drawn randomly, looking at the distribution of any subset of firms is the same as looking at the distribution of all firms. This implies that the dynamics of the domestic price is given by the following law of motion:

$$P_{H,t} = \left[\phi P_{H,t-1}^{1-\theta_H} + (1 - \phi) \bar{P}_{H,t}^{1-\theta_H} \right]^{\frac{1}{1-\theta_H}} \quad (20)$$

This means that the aggregate price level is a convex combination of the reset price and the previous price level, just as assumed earlier.

5. Oil Sector¹

Oil producing firm encounters competitive market both in its oil supply and

1. There is a criticism to this method of modeling for the members of OPEC that they obey their allocated quotas and do not optimize their own oil production like a separate firm. It must be mentioned that OPEC member countries like Iran do not obey their allocated quotas. According to Colgan (2013) calculations, Iran has quota overproduction in 72% of months during 1982-2010. The correlation between oil production and quota for Iran is estimated to be 0.002.

labor demand. Therefore, oil prices (P_t^o) and wages (W_t) are given and profit maximizing oil producing firm has only one control variable of oil supply (O_t^s). Oil production technology operates under decreasing return to scale restriction. The oil supplied at first satisfies domestic oil demand of domestic non-oil sector and then export the residuals to the rest of the world. Profit maximization of the oil producing countries is hence as follows:

$$\max_{N_t^o} (P_t^o O_t^s - W_t N_t^o) \quad (21)$$

$$\text{s. t: } O_t^s = Z_t (N_t^o)^\nu \quad (22)$$

where parameter $1 < \nu < 0$ measures the labor share in oil production¹. Variables Z_t and N_t^o denote oil production productivity level and oil sector labor. Oil production technology as an exogenous variable evolves according to the following equation of:

$$\ln Z_t = \rho_Z \ln Z_{t-1} + \varepsilon_{Z,t} \quad (23)$$

where the parameter ρ_Z is the autocorrelation coefficient showing the persistence of oil production technology. $\varepsilon_{z,t}$ is an independent and identically distributed random variable with zero mean and standard deviation σ_z .

The first order condition with respect to oil supply (O_t^s) yields:

$$Z_t P_t^o (N_t^o)^{\nu-1} = W_t \quad (24)$$

Equation (25) can be regarded as the labor demand function for the oil sector. Decreasing return to scale is assumed for the oil production to guarantee the existence of unique equilibrium for the oil sector maximization problem.

1. This share of labor in oil production is measured for the representative oil exporting economy to be 0.03. It shows that the oil production is loosely geared to labor.

6. Foreign Economy

For simplicity, we assume a symmetric structure for the foreign sector. The foreign demand for domestic non-oil goods is given by the following expression:

$$C_{H,t}^* = \gamma^* \left(\frac{P_{H,t}^*}{P_{F,t}^*} \right)^{-\theta^*} C_t^* \quad (25)$$

where γ^* corresponds to the share of domestic non-oil goods in the consumption basket of foreign agents, and θ^* is the price elasticity of foreign demand. It is assumed that domestic firms cannot price discriminate across markets. Therefore, the law of one price holds for domestic non-oil goods sold abroad:

$$P_{H,t} = \varepsilon_t P_{H,t}^* \quad (26)$$

Real exchange rate defined as the relative price of the foreign consumption basket ($P_{F,t}^*$) to the price of the domestic consumption basket:

$$S_t = \frac{\varepsilon_t P_{F,t}^*}{P_t} \quad (27)$$

where by the assumption is that the price of foreign goods is the relevant international price to be used when constructing the real exchange rate. In other words, the share of oil and domestic goods on the foreign domestic consumption basket is negligible.

Additionally, the domestic real price of oil is given by the following expression:

$$\frac{P_{o,t}}{P_t} = \varepsilon_t \frac{P_t^{*o}}{P_t} = S_t \frac{P_t^{*o}}{P_{F,t}^*} \quad (28)$$

where P_t^{*o} is the price of oil in terms of foreign currency and the ratio $\frac{P_t^{*o}}{P_{F,t}^*}$ is assumed to evolve as a log-linear process of order one given by:

$$\ln \frac{P_t^{*o}}{P_{F,t}^*} = \rho_o^* \ln \frac{P_t^{*o}}{P_{F,t}^*} + \varepsilon_{o^*,t} \quad (29)$$

where the parameter $0 < \rho_o^* < 1$ and $\varepsilon_{o^*,t}$ are independent and identically distributed random variables with mean zero and standard deviation σ_{o^*} . Finally, the foreign demand for oil is given by:

$$O_{H,t}^* = \gamma_o^* \left(\frac{P_t^{*o}}{P_{F,t}^*} \right)^{-\theta_o^*} O_t^* \quad (30)$$

where O_t^* is the foreign oil demand that follows an AR(1) stochastic process with the persistence of ρ_o^* and standard deviation σ_{o^*} . The parameters γ_o^* and θ_o^* have the same interpretation as in (26).

7. Monetary Policy

Following Woodford (2003) cashless economy and in line with Monaceli and Gali (2007), we assume that the central bank adjusts the short-term nominal interest-rate¹, i_t , in response to fluctuation in inflation in the non-oil goods sector (domestic inflation) $\left(\frac{P_{H,t}}{P_{H,t-1}}\right)$, CPI inflation $\left(\frac{P_t}{P_{t-1}}\right)$, output gap $\left(\frac{Y_t}{Y}\right)$ and exchange rate $\left(\frac{\varepsilon_t}{\varepsilon_{t-1}}\right)$. The general functional form of the monetary policy rule in this economy can be written as the following Taylor-type relationship:

$$\frac{1+i_t}{1+i} = \left(\frac{1+i_{t-1}}{1+i}\right)^{\rho_i} \left(\frac{Y_t}{Y}\right)^{(1-\rho_i)\phi_y} \left(\frac{P_{H,t}}{P_{H,t-1}}\right)^{(1-\rho_i)\phi_{\pi_H}} \left(\frac{P_t}{P_{t-1}}\right)^{(1-\rho_i)\phi_{\pi}} \left(\frac{\varepsilon_t}{\varepsilon_{t-1}}\right)^{(1-\rho_i)\phi_{\varepsilon}} \quad (31)$$

1. Nominal interest rate is not the policy instrument for many oil exporting countries including Iran. However, it must be mentioned that this form of monetary policy rule can be easily translated to money via dynamic LM relationship. For more information please refer to: Robert King (2000), "The new IS-LM Model, language, logic and limits", Federal Reserve Bank of Richmond, Working papers, pp. 51-53.

where the variables without time subscripts denote the steady-state values of the corresponding variables. The first factor on the right hand side of equation (31) models the degree of interest rate smoothing. The second factor shows that the central bank responds to deviations of GDP from the steady-state level of economy. Similarly, the third and fourth factors represent the fact that the monetary authority reacts to changes in inflation in the non-oil goods sector and CPI inflation. The last factor is the reaction of the exchange rate fluctuations.

8. Equilibrium

For simplicity, we assume that there is no public spending. Therefore, the change in nominal monetary balances equals lump sum taxes. Aggregate equilibrium condition in each market is as follows:

$$\text{The labor market: } N_t^S = N_t + N_t^O \quad (32)$$

$$\text{Non-oil goods market: } Y_{H,t} = C_{H,t} + C_{H,t}^* \quad (33)$$

$$\text{Oil market: } O_t^S = O_t + O_t^* \quad (34)$$

From the budget constraint and the rest of aggregate equilibrium conditions, current account can be obtained as:

$$CA_t = P_{X,t}X_t - P_{M,t}M_t = \frac{\varepsilon_t B_t^*}{(1 + i_t^*)\theta \left(\frac{\varepsilon_t B_t^*}{P_{X,t}X_t} \right)} - \varepsilon_t B_{t-1}^* \quad (35)$$

where nominal exports ($P_{X,t}X_t$) value is defined as:

$$P_{X,t} \equiv \varepsilon_t P_{H,t}^* C_{H,t}^* + \varepsilon_t P_t^{*O} O_{H,t}^* = P_{H,t} C_{H,t}^* + P_t^O O_{H,t}^* \quad (36)$$

and nominal imports ($P_{M,t}M_t$) value is given by:

$$P_{M,t}M_t = \varepsilon_t P_{F,t}^* C_{F,t} = P_{F,t} C_{F,t} \quad (37)$$

Based on these relationships, it can be concluded that nominal GDP value is given by:

$$P_{Y,t}Y_t = P_t C_t + P_{X,t}X_t - P_{M,t}M_t \quad (38)$$

where $P_{Y,t}$ denotes implicit GDP deflator.

The general equilibrium system for this economy consists of the first order conditions of the household, the first order conditions of the firms and the market clearing conditions. Additionally, the stochastic exogenous processes that are present in this model are $Z_t, A_t, i_t^*, C_t^*, O_t^*, \frac{P_{F,t}^*}{P_{F,t-1}^*}, \frac{P_t^*}{P_T}$.

9. Calibration and Estimation

Having set up the theoretical model with nominal rigidities, we calibrate the structural parameters that characterize the economy. The stochastic system of difference equations forms a linear rational expectation system that can be written in canonical form as:

$$\Omega_0(\vartheta)Z_t = \Omega_1(\vartheta)Z_{t-1} + \Omega_2(\vartheta)\varepsilon_t \quad (39)$$

where Z_t is the vector containing the variables of the model expressed as log-deviations from their steady state. Appendix (A) and (B) present the steady state and log-linearized version of the model developed in the previous section. ε_t is a vector containing white noise innovations to the structural shocks of the model. Matrices Ω_i are non-linear functions of the structural parameters contained in vector ϑ . The solution to this system of difference equation can be expressed after a Jacobian or Schur decomposition for the coefficient matrix as follows:

$$Z_t = \Omega_z(\vartheta)Z_{t-1} + \Omega_\varepsilon(\vartheta)\varepsilon_t \quad (40)$$

where $\Omega_z(\vartheta)$ and $\Omega_\varepsilon(\vartheta)$ are functions of the structural parameters. Therefore, it is necessary to determine the value of the parameters. Table (1)

depicts the calibrated values for the parameters considering the economy of Iran. This calibration is based on the quarterly data of the economy during 1990-2011. Some of the parameters are taken from other researcher's studies on the economy of Iran which are shown in the fourth column of Table (1) and the others are author's own calculations. The calibrated linear rational expectation model is solved using the software Dynare¹.

Table 1: Calibration of structural parameters

Parameter	Definition	Value	Source
θ	Elasticity of substitutions. Domestic and foreign goods	1	Elekdag, Justiniano and Tchakarov (2006)
γ	Share of foreign imported goods in the home consumption basket	0.25	Fakhr Hosseini (2010)
θ_H	Price elasticity of demand for consumption goods	4.33	Shahmorsdi (2008)
β	Discount factor	0.985	Jalali-Naeini (2012)
σ	Inter-temporal elasticity of substitution	0.46	Jalali-Naeini (2012)
φ	Frisch elasticity of labor supply	0.48	Taei (2006)
ϕ	Probability of price reset	0.75	Zangane (2009)
α	Share of oil in non-oil production function	0.15	Shahmoradi (2008)
$\frac{O_H^*}{X}$	Share of oil export in total export	0.85	Author Calculation
$\frac{C_H}{Y_H}$	Share of home good consumption in total home good production	0.8	Author Calculation
$\frac{O_H^*}{O^s}$	Share of oil exports to oil production	0.5	Author Calculation
$\frac{X - M}{Y}$	Share of net export in GDP	0.4	Author Calculation
η	Habit persistence coefficient	0.6	Romero (2008)
ρ_i	Smoothing coefficient	0.5	Author Calculation
ϕ_y	Coefficient of output	0.5	Author Calculation
ϕ_{π_H}	Coefficient on domestic inflation	1.5	Author Calculation
ϕ_{π}	Coefficient of CPI inflation	1.5	Author Calculation
ϕ_{ε}	Coefficient of exchange rate	0.75	Author Calculation
ω	Risk premium coefficient	-0.008	Romero (2008)

Source: Author's calculations

1. The Dynare file is available at request.

10. Optimal Monetary Policy

In this section we characterize the optimal monetary policy for our small open economy, as well as its implications for a number of macroeconomic variables. As discussed in Rotemberg and Woodford (1999) in a closed economy with staggered price-setting of Calvo, under the assumption of a constant Pigovian employment subsidy that neutralize the distortion associated with firm's market power, it can be shown that the optimal monetary policy is the one that replicates the flexible price equilibrium allocation. That policy is required to stabilize the real marginal costs (thus mark-ups) at their steady-state level, which in turn implies that domestic prices be fully stabilized. With the subsidies in place, there is only one effective distortion left in economy, namely, sticky prices. By stabilizing mark-ups at their friction-less level, nominal rigidities cease to be binding, since firms do not feel any desire to adjust prices. However, in an open economy-and as noted among others, by Corsetti and Pesenti (2001), there is an additional factor that distorts the incentives of monetary authority (beyond the presence of market power) which is the possibility of influencing the terms of trade in a way beneficial to domestic consumers. This possibility is a consequence of the imperfect substitutability between domestic and foreign goods, combined with sticky prices that make the monetary policy non-neutral. Therefore, the closed-form monetary prescription is not valid and some other forms of optimal monetary policy both with discretionary and commitment approaches must be explored. It must be noted that unlike closed-form models there are two sources of rigidities in this open economy: nominal price rigidity and nominal export price rigidity. These rigidities in the environment of open economy bring about some different distortions that the monetary authority must accommodate. In this paper, we assume that the optimizing monetary authority maximizes the inter-temporal utility function of the household subject to the optimal behavior chosen by the private sector and the

economy's resource constraints. Furthermore, we assume that the policymaker can credibly commit to the chosen path of action and does not re-optimize along the way. We consider two cases: For our benchmark, we assume that the monetary authority implements the Ramsey-optimal policy¹. We then contrast the Ramsey policy with an optimal policy that is chosen considering its implementation constraints known as optimal simple rules:

i) Ramsey optimal monetary policy

Recently, researchers are interested in finding Ramsey Optimal monetary policy in models with nominal rigidity. For example, Levin, Ontaski, Williams and Williams (2005) investigate the design of monetary policy when central bank faces uncertainty about the true structure of the economy. They find an optimal policy regime that maximizes household welfare using Ramsey approach and then evaluate the performance of alternative simple policy rules relative to this benchmark.

The Ramsey Optimal policy under commitment can be computed by formulating an infinite horizon of Lagrangian problem. In terms of setting the policy, the social planner want to maximize the welfare given the decision of the private sector without relying on a particular form of policy rule such as (32). The welfare of the economy which is the planner's objective is given as the same form as the lifetime utility of the representative agent, that is, a recursive utility function given by:

$$V_t = \left[\frac{(C_t - \eta C_{t-1})^{1-\frac{1}{\sigma}}}{1 - \frac{1}{\sigma}} - \frac{(N_t^S)^{1+\frac{1}{\varphi}}}{1 + \frac{1}{\varphi}} \right] + \beta E_t(V_{t+1}) \quad (41)$$

1. Please see Khan, King and Wolman (2003), Levin et al. (2006), and Schmitt-Grohe and Uribe (2007) for detailed discussions in New-Keynesian models.

where V_t is the Bellman value function and denotes the dynamic social welfare arising from the planner's choice of policy¹. Thus, the policy maker seeks to maximize the following objective function:

$$W_0 = E_0 \sum_{t=0}^{\infty} \beta^t V_t \quad (42)$$

where, W_0 is the net present value of utility function with infinite horizon. This maximization is subject to private sector decisions, market equilibrium conditions and appropriate initial values for forward-looking variables and Lagrange multipliers. In other words, the constrained optimization is subject to the equilibrium characterization for endogenous variables, given in Appendix B. The optimality condition of this Ramsey policy issue can then be obtained by differentiating the Lagrangian Equation with respect to each of the endogenous variables and setting the derivatives to zero. This is done numerically by using Dynare software.

It must be considered that Romero (2008) has derived the second ordered Taylor expansion for the above utility function which yields the following loss function with consumption instead of output in the final specification²:

$$L_t = \lambda_1 \pi_t^2 + \lambda_2 (C_t - C_t^n)^2 \quad (43)$$

Using this loss function instead of the above objective function and doing the constrained optimization, we can see that 32 endogenous variables are included in 31 equations. Hence, the planner's optimization procedure would pin down the variable with extra degree of freedom, namely the

-
1. V_t is the dynamic social welfare of the social planner expressed in the form of a Bellman value function.
 2. In the standard New-Keynesian models output gap is a proxy for the marginal production cost and consumption which equals domestic production in steady-state condition. Therefore, this variable emerges in the standard loss function as a proxy for consumption. Since inflation dynamics in the oil exporting countries has a wealth effect demand side driver as well and consumption does not equal domestic production in steady state, loss function specification in this model is based on consumption gap rather than output gap.

nominal interest rate schedule. So, the solution of the problem gives the policy instrument as a function of state variables and shocks that can be obtained using numerical methods.

The limitation of this Ramsey approach is that we cannot solve for the closed-form policy reaction function. However, the optimal response of the policy variable to various shocks can be revealed in impulse response functions (IRF).

ii) Optimal simple rules

Ramsey optimal policy provides a convenient benchmark for welfare analysis in economic models. However, from the point of view of a policy maker, pursuing a Ramsey Policy may be difficult to communicate to public. It may also not be operational in the sense that the instruments used to implement the Ramsey policy may not be available to the policy maker. The literature has therefore focused on finding simple and implementable rules that come close to the welfare outcomes implied by Ramsey Policy (Schmitt-Grohe and Uribe 2007).

Following Taylor (1993), numerous researches have been done to estimate or evaluate all kinds of simple monetary policy rules. The policies are simple in the sense that they involve only a few observable macroeconomic variables. In terms of maximizing agent's welfare, the performances of simple rules are inferior to that of Ramsey optimal policy. Ramsey policy can react to all endogenous variables while simple rules only react to several observable variables. However, usually we cannot find a closed solution for Ramsey policy. What we can do is to find a simple policy rule that corresponds to shocks in the similar way that Ramsey policy does. This simple rule can tell central bank how to respond to a specific shock.

From the literature on optimal monetary policy we know that monetary policy should ideally seek to eliminate distortions generated by nominal rigidities. There are two sources of such microeconomic distortions as

stickiness in domestic and export price setting in the model. Thus, monetary policy should try to close these two inefficiency wedges. Intuitively, optimal simple rules should target variables that are intimately related to the wedges. Domestic inflation, CPI inflation and the exchange rate are natural candidates for such target variables.

In this paper we study four different series of simple policy rules:

The estimated empirical rule (EMP rule):

$$\frac{1+i_t}{1+i} = \left(\frac{1+i_{t-1}}{1+i}\right)^{\rho_i} \left(\frac{Y_t}{Y}\right)^{(1-\rho_i)\phi_y} \left(\frac{P_{H,t}}{P_{H,t-1}}\right)^{(1-\rho_i)\phi_{\pi_H}} \left(\frac{P_t}{P_{t-1}}\right)^{(1-\rho_i)\phi_{\pi}} \left(\frac{\varepsilon_t}{\varepsilon_{t-1}}\right)^{(1-\rho_i)\phi_{\varepsilon}} \quad (44)$$

The simple rule with CPI inflation targeting:

$$\frac{1+i_t}{1+i} = \left(\frac{1+i_{t-1}}{1+i}\right)^{\rho_i} \left(\frac{Y_t}{Y}\right)^{(1-\rho_i)\phi_y} \left(\frac{P_t}{P_{t-1}}\right)^{(1-\rho_i)\phi_{\pi}} \quad (45)$$

The simple rule with the domestic inflation targeting:

$$\frac{1+i_t}{1+i} = \left(\frac{1+i_{t-1}}{1+i}\right)^{\rho_i} \left(\frac{Y_t}{Y}\right)^{(1-\rho_i)\phi_y} \left(\frac{P_{H,t}}{P_{H,t-1}}\right)^{(1-\rho_i)\phi_{\pi_H}} \quad (46)$$

The simple rule with the domestic inflation and exchange rate targeting:

$$\frac{1+i_t}{1+i} = \left(\frac{1+i_{t-1}}{1+i}\right)^{\rho_i} \left(\frac{Y_t}{Y}\right)^{(1-\rho_i)\phi_y} \left(\frac{P_{H,t}}{P_{H,t-1}}\right)^{(1-\rho_i)\phi_{\pi_H}} \left(\frac{\varepsilon_t}{\varepsilon_{t-1}}\right)^{(1-\rho_i)\phi_{\varepsilon}} \quad (47)$$

In this setting we search for the optimized feedback coefficients and solve for $[\rho_i, \phi_y, \phi_{\pi_H}, \phi_{\pi}, \phi_{\varepsilon}]$. Therefore, we will explore among six different simple rules to identify the optimal implementable monetary policy.

11. Comparative Analysis of Monetary Policy Rules

Our comparative study on different monetary policy is implemented according to the following procedure:

First, we explore the performance of the fully optimal Ramsey Rule (LQ) and compare it to the estimated one. By doing so, we seek for systematic differences in stabilization properties. Stabilization is captured by the implied volatility of selected nominal and real variables. The impulse response to different types of shocks under the different policy rules can help us to understand the mechanisms at work.

Next, we include the optimal simple rules into the comparative exercise. We examine, on the one hand, how successful the simple rules are in replicating the performance of the fully optimal one, and, on the other hand, the systematic differences from the empirical rule. The overall performance of the rules is reflected in the value of the policymaker's objective (W_0) in (1). The potential utility gain of including the exchange rate, domestic inflation or CPI inflation into the simple rules allows us to assess the relative welfare costs of different types of nominal rigidities.

Finally, we compare optimized simple policy rules with different specifications. The comparative analysis of simple rules allow us to judge the stabilization properties of different policy rules when monetary policy responds to variables other than output and domestic inflation. Moreover, the optimized relative weights on the feedback parameters are interesting in themselves.

12. Comparing Ramsey Optimal Policy with the Empirical Rule

Our first exercise consists of comparing the Ramsey optimal policy to the estimated rule. First, volatilities of selected variables provide an indication of their stabilization performance. These are reported in Table (2). The

figures in the table show that commitment policy in the form of Ramsey rule reduces the volatility in the nominal variables. It must be mentioned that commitment policy with the consumption gap in the objective function has relatively better performance in terms of nominal variables stabilization. In Appendix C, the impulse responses for selected variables have been plotted for the real oil price shock. These simulated impulse response functions show that nominal variables return to their steady state values more rapidly compared to the empirical estimated condition. This finding is in line with the elimination or mitigation of market failure due to relative price distortions arising from nominal rigidities. As it is indicated in the literature, stabilizing nominal variables using optimal monetary policy can act in terms of reducing or eliminating the effect of nominal rigidities. The reason behind this statement is the elimination of price adjustment incentives by monopolistically competitive firms via closing inefficiency wedges. Table (2) shows that stabilization performance of output gap and consumption based commitment optimal monetary policy is most pronounced in real exchange rate standard deviation. It shows that controlling real exchange rate channel of oil price shock transmission is controlled to reduce the welfare costs in Ramsey rules. The other important finding in this part is continuous welfare cost rise for higher relative weight for inflation in loss function relative to consumption or output gap. It shows that inflation stability has higher welfare costs in this model relative to consumption or output gap stability. It seems that this result is owing to the lower elasticity of labor supply to real wages and the lower inter-temporal elasticity of substitution.

Table 2: Volatility of selected variables under optimal monetary policy and the empirical rule

Variables	LQC (consumption)	LQY (Output gap)	EMP
CPI inflation	1.42	1.40	1.60
Domestic inflation	1.34	1.29	1.61
Real exchange rate	0.28	0.30	0.75
Output	0.8	0.68	3.29
Domestic output	2.32	2.41	4.65
Export	2.82	2.80	2.54
Import	6.72	6.05	5.39
Consumption	0.68	0.80	4.09
Domestic consumption	3.57	3.68	6.15

Source: Author's findings

Notes: LQC: Ramsey rule based on Linear - Quadratic with consumption.

LQY: Ramsey rule based Linear - Quadratic with output gap.

EMP: Empirical rule.

13. Comparing Ramsey Optimal Policy and Optimal Simple Rules

First we would like to know how close the simple rules can get to the fully optimal one both in consumption and output gap based optimal Ramsey rules. The first row of the table (3) shows that the welfare consequences of following optimal simple rules are significant. Shifting to the Ramsey rules from the optimal simple rules generates welfare loss of at least 0.41 points for consumption based objective function and 0.36 points in output gap based objective function. Another interesting implication of the analysis is

that including the nominal exchange rate in to the domestic inflation targeting rule does not have a significant effect. However, targeting domestic inflation does imply sizable welfare gains comparing CPI inflation targeting. It is in line with our prior belief that nominal rigidities in price setting causes severe inefficiencies in the goods market that cannot be accommodated with the Pigovian tax as in closed-form models.

Table 3: Welfare gain from following different policy rules

Welfare gain relative	LQ	OSR1	OSR2	OSR3
LQ policy (Consumption)	0 (-0.661)	-0.51	-0.42	-0.41
LQ policy (Output gap)	0 (-0.678)	-0.42	-0.38	-0.36

Source: Author's findings

A more easily interpretable measure of the relative performance of different policy rules is the amount of volatility they imply for selected variables in percent of the implied volatility under the empirical rule. Table (4) and (5) show the volatility of selected variables under different monetary policy both in consumption and output based objective function approach. As it can be inferred from Table (4) and (5), the performance of Ramsey and implementable simple rules are considerable in terms of nominal variable stabilization. Comparing the consumption and output based objective functions shows that the latter is more effective in terms of variables such as CPI inflation, real exchange rate, consumption and non-oil goods consumption while the former shows its effectiveness in output and non-oil output.

Table 4: Volatility of selected variables under different monetary policy rules (percent)

Variables (Real)	LQC	OSR1	OSR2	OSR3
CPI inflation	88.74	95.02	93.98	92.08
Domestic inflation	115.24	122.74	122.31	121.30
Real exchange rate	37.26	36.9	37.44	36.44
Output	24.53	15.07	18.77	18.80
Domestic output	49.9	49.63	50.6	50.07
Export	110.8	110.24	110.14	110.01
Import	124.65	120.28	126.47	126.50
Consumption	16.84	2.62	4.93	4.09
Domestic consumption	58.14	59.73	60.01	58.01

Source: Author's findings

Table 5: Volatility of selected variables under different monetary policy rules (percent)

Variables	LQY	OSR1	OSR2	OSR3
CPI inflation	87.49	95.25	64.76	94.79
Domestic inflation	111.55	121.46	121.16	121.19
Real exchange rate	40.00	40.11	40.61	40.55
Output	20.77	8.57	9.45	9.22
Domestic output	51.84	52.11	52.43	52.40
Export	110.31	109.35	109.23	109.25
Import	112.32	112.14	113.02	112.86
Consumption	19.75	6.10	7.08	7.10
Domestic consumption	59.88	61.05	61.39	61.35

Source: Author's findings

14. Comparing Different Optimal Simple Rules

The difference in terms of welfare gains and stabilization performance between the optimal simple rules is reflected in the optimized feedback coefficients, too. These are reported in Table (6).

Table 6: Optimized feedback coefficients in the empirical and different optimal simple rules

Optimized feedback parameter to	EMP	OSR1	OSR2	OSR3
Inflation	1.5	0.56	2.05	2.02
Output gap	0.5	2.41	2.30	2.29
Domestic inflation	1.5		2.63	2.62
Exchange rate	0.25			0.021

Source: Author's findings

Consider first, that all the optimal simple rules give a much higher feedback coefficient to domestic inflation. This also implies that all the optimal simple rules involve much more variations in the domestic real interest rate, and thus a more volatile consumption path. Second, if the nominal exchange rate is included in the policy rule, it gets much lower optimized coefficients than CPI inflation. Third, the policy rule reacting also to domestic inflation gives a relatively higher weight on the measure of domestic inflation than on CPI inflation. This is in line with our intuition that monetary policy should ideally care more about the stickier sector and attach higher weights to reacting to inflation that is supposed to generate more inefficiency.

Table 7: Optimized feedback coefficients in the empirical and different optimal simple rules

Optimized feedback parameter to	EMP	OSR1	OSR2	OSR3
Inflation	1.5	0.9	0.24	0.075
Output gap	0.5	0.67	0.69	0.727
Domestic Inflation	1.5	--	0.66	0.692
Exchange rate	0.25	--	--	0.134

Source: Author's findings

15. Conclusion

In this paper a dynamic stochastic general equilibrium model is built based on Romero (2008) for an oil exporting country calibrated to the economy of Iran. The model takes into account two main effects transmitted by an oil price shock. One of them is the positive implication of increased oil exports and oil revenues. The other one is the negative effect of higher input costs on the production process of the economy. In order to capture these two effects, the model includes both endogenous oil sector and a final goods sector that is inherently dependent on oil for its production process. In this way, an oil price shock is able to bifurcate into the economy by increasing oil revenues and promoting oil exports, on the one hand, and, on the other hand, by generating contractionary effects due to the higher costs of production driven by the oil price increase. Under the Empirical monetary rule (EMP) when there is an increase in the price of oil, we observe an improvement in the current account due to higher oil exports. The higher oil price contracts production and consumption of home goods and depreciates the real exchange rate. Moreover, the rise in the real exchange rate implies a fall in consumption of foreign goods. Overall consumption level in the economy

decreases. There is also an increase in domestic inflation due to higher oil prices which in turn raises the CPI inflation level in the economy. The effect on GDP is positive in short term due to sharp reduction in imports but negative afterwards since the increase in exports is not able to compensate the combined effect of higher imports and lower consumption. Additionally, we find that the response of monetary authority to these conditions is contractionary. However compared to the scenario where the monetary authority reacts to domestic inflation, we conclude that the overall effect of the policy is relatively less contractionary. Given the above channel of transmission for the oil price shock and the monetary policy effect, we have tried to shed some light on the optimal monetary policy rule for the economy of Iran. Therefore, we compared different monetary policy rules. The welfare cost and stabilization performance associated with each monetary rule has been considered. The comparative study on the monetary policy rules results in the following points:

- *Compared to the optimal policy, the empirical rule implies excess smoothing of real domestic variables, and excess volatility of nominal variables.* The best monetary policy can achieve is to reduce inefficiencies generated by nominal rigidities. Stabilizing nominal variables has exactly this effect, as it indicates that monetary policy has successfully eliminated all incentives for adjusted prices that close the inefficiency wedges. The excess smoothness in real variables, particularly in export and import is a natural consequence of the estimated policy rule.
- *Simple optimal rules can approximate the fully optimal rules relatively well.* Sizable welfare gains can be achieved with the optimized feedback coefficients. Simple policy rules with the higher coefficients on inflation relative to the estimated one imply more variable real interest rates and, consequently, more volatility in real variables. On the other hand, this also means that they reduce the variability of nominal variables.

- *Adding nominal exchange rate to the policy rule does not improve significantly welfare or the stabilization properties of the simple rules.* This result suggests that optimal monetary policy should not target the wedge related to price stickiness of the export sector separately. The reason behind it is that fluctuation in the nominal exchange rate causing unintended variations in exporter's markup and already corrected for when the monetary authority aims to eliminate the inefficiency wedge of domestic inflation. Moreover, responding to the exchange rate creates additional variance for domestic producers through the marginal cost channel, while responding to inflation has no such externality for export sector.
- *Including domestic inflation into the policy rule implies significant improvement in welfare.* After the oil price shock, inflation in the import sector exhibits the strongest response under the inflation targeting rule. Such result confirms findings in the previous literature on strict inflation targeting. This monetary rule induces wide fluctuations of the macroeconomic variables. In terms of speed of return to steady-state, this monetary rule does not allow a rapid adjustment of inflation in imported sector. But, we find the relatively opposite for domestic inflation rule.
- *Inflation stability relative to output or consumption gap stability has always more welfare cost.* As the relative weight on inflation stability in the loss function increases, the welfare cost rises. It seems that the lower labor supply elasticity and lower inter-temporal elasticity of substitution for the economy of Iran provides such a condition.

To sum up, the current monetary policy-corresponding to our baseline model- followed by Iran is not well suited to face oil shocks. We see that adding exchange rate to the monetary rule is especially inefficient to respond to oil price shocks and unable to stabilize inflation. From this perspective, if

we consider the trade-off between macroeconomic stabilization and low inflation environment, we find that the domestic inflation targeting rule is superior to CPI inflation targeting rule.

Reference

- Altissimo, F., V. Curdia & D. R. Palenzuela, (2005). "Linear Quadratic Approximation to Optimal Policy: An Algorithm and Two Applications", *Working Paper* 803, ECB.
- Barsky, R.B. and L. Kilian, (2001). "Do we really know that oil caused the Great Stagnation? A monetary alternative" in: B. Bernanke and K. Rogoff, eds., *NBER Macroeconomics Annual* No.16.
- Barrell, B. O. Pomerantz, (2004). "Oil Prices and World Inflation", *Journal of the national institute of economic and social research*.
- Benigno, P. & M. Woodford, (2007). "Linear-Quadratic Approximation of Optimal Policy Problems", Columbia University.
- Calvo, G., (1983). "Staggered prices in a utility-maximizing framework", *Journal of Monetary Economics*, 12 (3), 383-398.
- Chang, J., (2005). "Optimal Monetary Policy and Oil Supply Shocks- a New Keynesian Perspective", mimeo, *Georgetown University*.
- Clarida, R., J. Gali and M. Gertler, (2000). "Monetary policy rules and macroeconomic stability: evidence and some theory", *Quarterly Journal of Economics* 115, 147-180.
- DeLong, J. Bradford, (1997). "America's Peacetime Inflation: The 1970s". In *Reducing Inflation: Motivation and Strategy*, edited by Christina D. Romer and David H. Romer, pp. 247-276. Chicago: *University of Chicago Press*.

Devereux, M., P. Lane and J. Xu, (2005). "Exchange Rate Regime and Monetary Policy Rules for Emerging Markets", *Economic Journal*.

Gali, J., & T. Monacelli, (2005). "Optimal monetary policy and exchange rate volatility in a small open economy". *Review of Economic Studies* 72, 707-734.

Hooker, Mark A., (1999). "Are Oil Shocks Inflationary? Asymmetric and Nonlinear Specifications Versus Changes in Regime", *Board of Governors of the Federal Reserve System Working Paper*.

Hunt, Benjamin, Peter Isard, and Doug Laxton, (2001). "The Macroeconomic Effects of Higher Oil Prices", *IMF Working Paper* 01/14.

Jalali-Naini, A.R and M.A., Naderian, (2011). "Inflation and Output in a Cash-Constraint Economy." *Journal of Money and Economy*, 6, 1-28.

Kamps, C. and C. Pierdzioch, (2002), "Monetary Policy Rules and Oil Price Shocks", *Kiel Working Paper* No. 1090.

Leduc, S. and K. Sill, (2004). "A quantitative analysis of oil-price shocks, systematic monetary policy, and economic downturns", *Journal of Monetary Economics*, 51, 781- 808.

Medina, J. P., and C. Soto, (2005). "Oil Shocks and Monetary Policy in an Estimated DSGE model for a Small Open Economy", *Central Bank of Chile Working Paper* No. 353.

Romero, R., (2006). "Monetary Policy in Oil-Producing Economies", mimeo, *Princeton University*.

Schmitt- Grohe, S. and M. Uribe (2003). "Closing Small Open Economy Models", *Journal of International Economics* 61: 163-85.

Schmitt-Grohe, Stephanie, and Martin Uribe, (2007). "Optimal, Simple and Implementable Monetary and Fiscal Rules." *Journal of Monetary Economics* 54: 1,702–25.

Shahmoradi, A. et al. (2010). "Natural Interest Rate Estimation in Iran Based on DSGE", *Journal of Economic Research*, 90, 19-41.

Taei, Hasan (2006). Labor supply function: analysis based on Micro data, *Iranian Economic Research Quarterly*, 29, 93-112.

Appendix A

The steady state of the economy is implicitly defined by the following non-linear system of equations.

$$Y = C + X - M$$

$$C_H = (1 - \gamma)C$$

$$C_F = \gamma C$$

$$\frac{W}{P} = (N^s)^{1/\varphi} C^{1/\sigma} (1 - \eta)^{1/\sigma}$$

$$N = \left(\frac{\theta_{H-1}}{\theta_H} \right) \alpha \frac{Y_H}{\left(\frac{W}{P} \right)}$$

$$O = \left(\frac{\theta_{H-1}}{\theta_H} \right) (1 - \alpha) \frac{Y_H}{\left(\frac{P^o}{P} \right)}$$

$$\left(\frac{\theta_{H-1}}{\theta_H} \right) = \frac{\left(\frac{W}{P} \right)^\alpha \left(\frac{P^o}{P} \right)^{1-\alpha}}{\alpha^\alpha (1 - \alpha)^{1-\alpha}}$$

$$O^s = (N^o)^\nu$$

$$\nu \frac{P^o}{P} (N^o)^{\nu-1} = \frac{W}{P}$$

$$C_H^* = \gamma^* C^*$$

$$\frac{P^o}{P} = \frac{P^{*o}}{P}$$

$$O_H^* = \gamma_o^* \left(\frac{P_o^*}{P} \right)^{-\theta_o^*}$$

$$Y_H = C_H + C_H^*$$

$$O^s = O + O_H^*$$

$$N^s = N + N^o$$

$$M = C_F$$

$$X = C_H^* + \frac{P^o}{P} O_H^*$$

$$1 = (1 + i^*) \beta e^{\left(\frac{B^*/P}{X} \right)}$$

$$X - M = \frac{B^*/P}{(1 + i^*) e^{\left(\frac{B^*/P}{X} \right)}} - \frac{B^*}{P}$$

Appendix B

The log-linearized equations of the model:

$$c_{H,t} = -\theta(1 - \gamma)(p_{H,t} - p_t) + \theta(1 - \gamma)s_t + c_t$$

$$c_{F,t} = \theta_y(p_{H,t} - p_t) - \theta_y s_t + c_t$$

$$p_{F,t} - p_t = e_t + p_{F,t}^* - p_t$$

$$p_{H,t} - p_t = e_t + p_{H,t}^* - p_t$$

$$o = \gamma(p_{H,t} - p_t) + (1 - \gamma)s_t$$

$$c_t = \frac{\eta}{(1+\eta)} c_{t-1} - \frac{\sigma(1-\eta)}{(1+\eta)} (i_t - E_t \pi_{t+1}) + \frac{E_t c_{t+1}}{(1+\eta)}$$

$$i_t = i_t^* + E_t \Delta e_{t+1} + \rho b_t^*$$

$$\begin{aligned} \pi_{H,t} = & \beta E_t \pi_{H,t+1} + \frac{(1-\phi)(1-\beta\phi)}{\phi} [\alpha(w_t - p_t) + (1-\alpha)(p_t^o - p_t)] \\ & - \frac{(1-\phi)(1-\beta\phi)}{\phi} [(p_{H,t} - p_t) + a_t] \end{aligned}$$

$$n_t - o_t = (p_t^o - p_t) - (w_t - p_t)$$

$$y_{H,t} = a_t + \alpha n_t + (1-\alpha)o_t$$

$$w_t - p_t = \frac{1}{\phi} n_t^s + \frac{1}{\sigma(1-\eta)} c_t - \frac{\eta}{\sigma(1-\eta)} c_{t-1}$$

$$p_{H,t} - p_t = (p_{H,t-1} - p_{t-1}) + \pi_{H,t} - \pi_t$$

$$p_t^o - p_t = \nu s_t + \nu(p_t^{*o} - p_t) + (1-\nu)p_{t-1}^o - \nu p_t$$

$$y_{H,t} = \frac{c_H}{y_H} c_{H,t} + \frac{y_H - c_H}{y_H} c_t^* - \theta^* \frac{y_H - c_H}{y_H} [(p_H - p_t) - s_t]$$

$$y_t = \frac{C c_t + X \ln\left(\frac{p_{X,t} x_t}{p_t}\right) - M \ln\left(\frac{p_{M,t} m_t}{p_t}\right)}{C + X - M}$$

$$\begin{aligned} \ln\left(\frac{p_{X,t} x_t}{p_t}\right) = & \frac{c_H^*}{X} (\tilde{p}_{H,t} - \tilde{p}_t) - \theta_o^* \frac{c_H^*}{X} (\tilde{p}_{H,t} - \tilde{p}_t - s_t) + \frac{c_H^*}{X} c_t^* \\ & + \frac{p_t^o}{p} \frac{o_H^*}{X} (\tilde{p}_t^o - \tilde{p}_t) - \frac{p^o}{p} \frac{o_H^*}{X} \theta_o^* (\tilde{p}_t^o - \tilde{p}_t - \tilde{s}_t) + \frac{p^o}{p} \frac{o_H^*}{X} \tilde{o}_t \end{aligned}$$

$$o_t^s = \frac{o}{o^s} \tilde{o}_t + \frac{o_H^*}{o^s} \tilde{o}_t^* - \theta_o^* \frac{o_H^*}{o^s} (p_t^o - p_t - s_t)$$

$$\ln\left(\frac{p_{M,t}m_t}{p_t}\right) = p_{F,t} - p_t + c_{F,t}$$

$$i_t = p_i i_{t-1} + (1 - p_i)[\phi_\pi \pi_t + \phi_{\pi_H} \pi_{H,t} + \phi_y y_t + \phi_\varepsilon \Delta e_t]$$

$$o_t^s = z_t + v n_t^o$$

$$(1 - \rho)\beta b_t^* = \beta i_t^* + b_{i-1}^* \ln\left(\frac{p_{X,t-1}x_{t-1}}{p_{t-1}}\right) \\ + \left(\frac{X}{B^*/p} - \beta\right) \ln\left(\frac{p_{X,t}x_t}{p_t}\right) \\ - M \ln\left(\frac{p_{m,t}m_t}{p_t}\right) + s_t - s_{t-1} - \tilde{\pi}_t, \quad \rho = \omega \frac{B^*/p}{X}$$

$$n_t^s = \frac{N}{N^s} n_t + \left(1 - \frac{N}{N^s}\right) n_t^o$$

$$w_t - p_t = z_t + p_t^o - p_t + (v - 1)h_t^o$$

$$s_t - s_{t-1} = e_t - e_{t-1} - \tilde{\pi}_t$$

$$p_t^o - p_t = \rho p_{o^*} (p_{t-1}^{o^*} - p_{t-1}) + \varepsilon_{\rho p_{o^*},t}$$

$$\pi_t^* = \rho_{\pi^*} \pi_{t-1}^* + \varepsilon_{\pi^*,t}$$

$$o_t^* = \rho_{o^*} o_{t-1}^* + \varepsilon_{o^*,t}$$

$$c_t^* = \rho_{c^*} c_{t-1}^* + \varepsilon_{c^*,t}$$

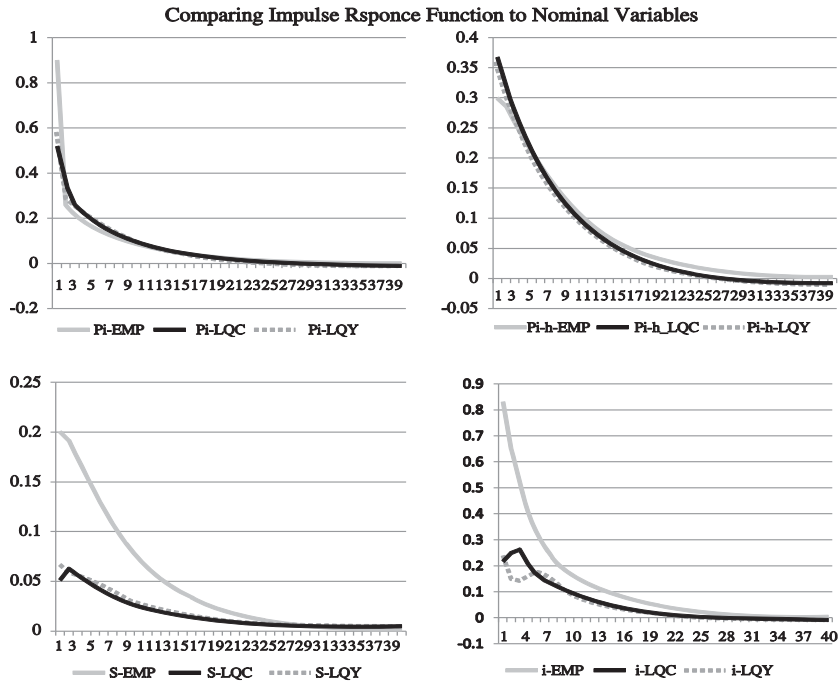
$$i_t^* = \rho_{i^*} i_{t-1}^* + \varepsilon_{i^*,t}$$

$$a_t = \rho_a a_{t-1} + \varepsilon_{a,t}$$

$$z_t = \rho_z z_{t-1} + \varepsilon_{z,t}$$

Appendix C

Comparing the fully optimal rules (Ramsey Rule) with the empirical one



Comparing Impulse Responce Function to Real Variables

