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Article

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Effect of Exogenous Oil Revenue Shocks on Reallocation of Public and Private Investments in Iran

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ABSTRACT

Determining the mechanism of oil shock effects on macroeconomic variables of oil-producing countries and incorporating these effects into the models that predict such variables is of utmost importance for the fiscal policy makers attempting to adopt appropriate policies to counter the shock induced volatilities. In this study, a dynamic stochastic general equilibrium model based on the real business cycle theory is used to investigate the effect of oil revenue shocks on reallocation of private and public investment and the presence of resource curse in Iran's economy over the period 1974–2012. For this purpose, after estimating the model parameters and conducting a simulation, variables' impulse response to shocks are plotted and analyzed. The results demonstrate the negative effects of positive oil shock on private sector, a substitution relation between public and private investment, and the presence of resource curse during this period of Iran's economy.

Keywords: Real Business Cycle, Oil Shock, Substitution Relation, Resource Curse
JEL Classifications: F44, O13, Q13

1. INTRODUCTION

After the first oil price shocks in 1973, oil exporting countries started to show some signs of slower development or entrenchment of underdevelopment. Shocks in oil revenues have periodically caused major volatilities in macroeconomic variables of Iran's heavily oil dependent economy. Iran's economic structure is so intertwined with oil that oil shocks have major effects on Iran's economy not only directly through the exports, but also indirectly through other gross domestic product (GDP) components.

Increased oil revenues can have positive effects on private investment by boosting investment, especially public investment in infrastructure, and import of capital and intermediate goods and new technologies. It is notable that further increases in oil revenues cannot induce equally potent positive effects via additional investment, because, on one hand, the economy does not possess the institutional and structural capacity to attract additional investment, and on the other hand, the oil revenue windfall leads to low efficiency resource allocation in the public sector, low return investments, and increased number of unfinished projects, which all severely undermine the positive effects of further investments on the economy. In addition, the increased import of consumer goods during an oil revenue windfall undermines the competitiveness of domestic production and relative return of private investments, which discourages the private sector from investing in manufacture of tradable commodities.

Recession in the global economy then turned the attention of many researchers to the effects of oil shocks on macroeconomy. During and after this period, the effects of oil shocks on macroeconomy and in particular on production and economic growth of developed and developing countries were extensively researched. Notable works on this subject include the publications of Darby, 1982; Lee et al., 1995; Jiménez-Rodríguez and Sánchez, 2005; Reyes-Loya and Blanco, 2008; Aydın and Acar, 2011; Cologni and Manera, 2013; Cunado and de Gracia, 2015; Basnet and Upadhyaya, 2015; Nusair, 2016. The factors that may undercut the potentially positive effects of oil price shocks on the economy of oil exporting countries include the price uncertainty, inaccurate price estimation and thus increased decision-making risk, and ineffective use of revenue windfalls caused by sudden increase in oil prices (for example Benjamin et al., 1989; Lee et al., 1995; Gylfason, 2001; Sachs and Warner, 2001; Sáez and Puch, 2002; Sala-I-Martin and Subramanian, 2003; Alexeev and Conrad, 2009; Iwayemi and Fowowe, 2011; Cologni and Manera, 2013; Cologni and Manera, 2013).

The impact of public revenues and expenditures on the economic growth have been studied by several researchers (Lane, 2003; Afonso and Furceri, 2010). In general, oil exporting countries experience greater volatilities in their external balance and public sector. The countries where raw materials constitute a great portion of exports experience more significant volatilities. These volatilities could become a source of investment uncertainty and time inconsistency in government policies[1], and thereby undermine the growth performance of the country. Auty (2002) reports a relationship between volatilities in revenues due to export of natural resources and government's unbalanced policies in regard to management of social surpluses, reflected, for example, in adoption of pro-cyclical policies and inefficient use of savings funds.

Hausmann and Rigobon (2003) explain the resource curse by linking the revenue volatilities to investors' risk aversion. In other words, they argue that economic volatility discourages the risk-averse investors, thereby slowing the economic growth.

Next, we examine the share of oil revenues in Iran's state budget to demonstrate the implications of uncertainty in these revenues for Iranian economy. Given the low price elasticity of natural resources, their economic rents are very unstable (at least in the short term). For example, assuming that the standard deviation of oil price is about 30–35% per year, for a country where oil export revenue constitutes about 20 percent of its GDP, a price shock as large as standard deviation leads to a revenue shock as great as 6 percent of GDP. This volatility is significantly greater than the total GDP volatilities of developed countries (about 2 percent) or even developing countries (between 3% and 4%) (Hausmann and Rigobon, 2003).

Thus, oil revenue volatility, when channeled to the economy via the government's fiscal policies (such as subsidizing consumption, etc.) can lead to reduced investment and economic growth. Such volatility however can be managed by preparing adequate precautionary savings.

On the relationship between public and private investment, one should note that public investment may boost, crowd in, and supplement the private investment via the following processes:

A. External effects of public investment in infrastructure may lead to higher productivity and profitability and thus increased private investment.
B. Public investment may increase the private investment by boosting the demand for the products of private sector.
C. Public investment may improve GDP and national saving and thus provide the physical resources necessary for the growth of financial and private sector, thereby boosting the private investment.

On the other hand, public investment can also undermine, or in other words, crowd out the private investment by creating a competition between public and private sectors for attaining the scarce physical and financial resources or undercut the resources available to private sector and imperative for private investment by increasing the interest rates or rationing bank credits (Naqvi, 2002; Erden and Holcombe, 2006; Afonso and Avbyn, 2009; Hatano, 2010; Frimpong and Marbuah, 2010; Álvarez, 2012; Ifeakachukwu et al., 2013). Under such condition, public investment effectively sidelines and replaces the private investment.

In this study, we use a dynamic stochastic general equilibrium (DSGE) model based on real business cycle (RBC) theory and tailored to Iran's economy (as a typical example of an oil exporting economy) to study the effects of exogenous oil revenue shocks on reallocation of private and public investments.

2. MODEL

DSGE model utilized in this study is based on RBC theory, consists of four components: Households, firms, government, and oil sector. The model assumes that firms are owned by households and government incomes consist of oil revenues and taxes.

2.1. Household

Households seek to maximize their expected utility subject to budget constraint. It is assumed that household has an unlimited lifetime and partakes, in every period, in consumption and leisure to maximize its expected lifetime utility.

$$\text{Max } E_0 \sum_{t=0}^{\infty} \beta^t u_t\left(C_t, L_t\right) \tag{1}$$

In the above relationship, E_0 denotes the expectation operator, C_t denotes the consumption, L_t denotes the leisure, $\beta \in (0,1)$ is the subjective discount factor, and u_t is the momentary utility function. In the macroeconomics literature and intertemporal models, utility function is often expressed by two instantaneous utility functions: Constant relative risk aversion (CRRA) function, which is extensively used in intertemporal optimization models, and constant absolute risk aversion (CARA) function, which is in the form of $u(c)=\frac{1}{a}e^{-ac}$, where $a > 0$ is the absolute risk averseness factor. Fisher and Blanchard believe that CRRA provides a more reasonable description of risk-averseness than CARA, however CARA can sometimes be used for a simpler analysis (Blanchard and Fischer, 1989). Romer (2001) suggests that shape of the function has an essential effect on convergence of economy to a balanced formation. The model of this study is based on CRRA function, which is defined as follows:

$$u_t\left(C_t, L_t\right)=\frac{C_t^{1-\sigma} L_t^{1-J}}{1-\sigma} \tag{2}$$

1 This refers to a situation where preferences of economic policy makers is time variant, in the sense that economic preferences at a certain time are incompatible with preferences at another time. The change in preferences may be due to a change in condition or resources available to policy makers. For example, lower oil revenues may alter the preferences of fiscal policy makers from development projects to current expenditures.

In this function, σ and ϑ are preference parameters. $\sigma > 1$ is the inverse of elasticity of consumption substitution and ϑ is the inverse of elasticity of labor supply. This utility function has a positive relationship with both consumption and leisure. Function u is also a concave and increasing function of consumption, meaning that $u_c > 0$ and $u_{cc} < 0$. The time spent by household on work and leisure is normalized to one. Thus, time constraint of labor N_t and leisure L_t, is in the form of $L_t + N_t = 1$. Equation (3) expresses the household's budget constraint, according to which household income must be greater than its total expenses. In addition, each household owns a capital that it rents to the firm (Equation 4):

$$W_tN_t+R_tK_t^P-T_t\,{}^3C_t+I_t^P \tag{3}$$

$$K_{t+1}^P=\left(1-\delta^P\right)K_t^P+I_t^P \tag{4}$$

In these equations, W_t denotes the real wage rate, R_t is the real rental rate, I_t^P denotes the gross private investment, K_t^P is the capital that household rent to the firm (in each period), and T_t is the taxes paid to government. $\delta^P \in [0, 1]$ is the depreciation rate of private capital, and K_0 is assumed to be an exogenous value. Household maximizes it utility based on the sequence $\{C_t,N_t,K_{(t+1)}\}_{t=0}^{\infty}$, budget constraint (Equation 3), and Equation 4. Assuming that household earns an income for the labor and capital it rents to the firm, we have: $Y_t^P=W_tN_t+R_tK_t^P-T$.

Simplifying the household's first order condition gives the following equations:

$$\lambda_t=C_t^{-\sigma}(1-N_t)^{1-\vartheta} \tag{5}$$

$$\lambda_tW_t=\frac{1-\vartheta}{1-\sigma}C_t^{1-\sigma}(1-N_t)^{-\vartheta} \tag{6}$$

After solving the first order condition and simplifying the equations, Euler consumption function is obtained as follows:

$$C_t^{-\sigma}=\beta EC_{t+1}^{-\sigma}\left(\frac{1-N_{t+1}}{1-N_t}\right)^{\nu\text{-}1}\left(R_{t+1}-\delta+1\right) \tag{7}$$

And the last equation is the resource constraint:

$$K_{t+1}^P+C_t=Y_t^P+(1\text{-}\delta^P)K_t^P\text{-}T_t \tag{8}$$

2.2. Firm

Household owns a firm that seeks to maximize the profit gained according to a Cobb–Douglas production function with two inputs, capital stock per capita K_t^P and labor per capita N_t^P, and a constant returns-to-scale. It is assumed that firms produce homogeneous goods in a competitive environment. Prices are given and profit maximization problem is expressed as follows:

$$\max_{K_t^P,N_t^P}\Pi_t=Y_t^P-W_tN_t^P-R_tK_t^P \tag{9}$$

$$\text{s.t:}Y_t^P=f_t^P(N_t^P,K_t^P)=A_t(K_t^P)^{\theta}(N_t^P)^{(1\text{-}\theta)}\ \theta\in(0,1) \tag{10}$$

Where Y_t^P is the production of private firm, θ is the capital's share in production or the production elasticity with respect to capital input, and A_t denotes technological advancement. Here, economic growth is assumed to be independent from technological advancement, thus $A_t = 1$. When solving the firm's maximization problem, the marginal product of each input equals the input's cost. According to Equation 10:

$$\left(\frac{K_t^P}{N_t^P}\right)^{\theta}=\frac{Y_t^P}{N_t^P}\ \text{And}\ \left(\frac{K_t^P}{N_t^P}\right)^{\theta}=\frac{Y_t^P}{K_t^P}$$

2.3. Government

Government hires its required labor N_t^G from households and invests a part of its revenues in government production and allocates another part to purchase of goods from the market. In other words, government intervention in the economy consists of three procedures: Investments in productive activities, salary payments to government employees, and purchase of consumption goods. Government's sources of income are natural resource revenues (here, oil revenues), taxes, and other governmental revenues (from the government production), whose values in period t are expressed by Z_t, T_t, and Y_t^G respectively. Thus, government production function is given by:

$$Y_t^G=f_t^G\left(N_t^G,K_t^G\right)=A_t(K_t^G)^{\gamma}(N_t^G)^{1-\gamma}\ \gamma\in\left(0,1\right) \tag{11}$$

N_t^G,K_t^G Are the labor and capital stocks for government production. Production function has a constant returns-to-scale with respect to production factors. Government's investment increases subject to the following law of motion:

$$K_{t+1}^G=\left(1-\delta^G\right)K_t^G+I_t^G \tag{12}$$

In this function, I_t^G represents the gross public investment and is an exogenous value. $\delta^G\in[0,1]$ is the public capital depreciation rate. An additional equilibrium condition for this optimization is the equality of marginal product and cost of labor:

$$W_t=\left(1-\gamma\right)\left(\frac{K_t^G}{N_t^G}\right)^{\gamma} \tag{13}$$

According to the government production function:

$$\left(\frac{K_t^G}{N_t^G}\right)^{\gamma}=\frac{Y_t^G}{N_t^G}$$

In each period, the government faces the following budget constraint:

$$Z_t+T_t+Y_t^G=G_t+I_t^G \tag{14}$$

Where Gt is the government's current expenditures, T_T is the government's tax income, Z_t is the flow of government's exogenous oil revenues. According to Equation (14), sum of government's current expenditures and investments should not exceed its total revenue. In this formulation, differentiation of the expenditures due to purchase of consumer good from government investment allows the transmission mechanisms of different fiscal policies to be properly evaluated. These fiscal policies are in response to the world's economic situation, or more specifically changes in oil prices. In addition, due to its exogenous origin, government spending too serves as a source of real shocks.

The stochastic processes for exogenous variable (government's oil revenues and consumption expenditure) are expressed by the following first order autoregressive stochastic model:

$$Z_t = \rho + \rho_z Z_{t-1} + \mu_z \tag{15}$$

$$G_t = \rho + \rho_G G_{t-1} + \mu_G \tag{16}$$

Where μ_Z and μ_G are normally distributed random variables with zero mean and standard deviation of σ_z and σ_G. Both of these variables are random, and their shocks would disrupt the equality of budget constraint. With the shock applied to these variables, budget constraint will be as follows:

$$G_t \leq Z_t + T_t + Y_t^G - I_t^G$$

2.4. Total Balance of the Economy

Substituting $Y_t^P = W_t N_t^P + R_t K_t^P$ into the household's budget gives:

$$Y_t^P - T_t \geq C_t + I_t^P \tag{17}$$

After combining the government's budget constraint with equation 28, the function representing the total balance of the economy will be given by:

$$Y_t^P - T_t \geq C_t + I_t^P$$

$$Z_t + T_t + Y_t^G = G_t + I_t^G$$

$$I_t + C_t + G_t \text{£} Y_t + Z_t \tag{18}$$

Where $I_t = I_t^P + I_t^G ; Y_t = Y_t^P + Y_t^G ; K_t = K_t^G + K_t^P$ and $N_t = N_t^G + N_t^P$ [2]

3. MODEL ESTIMATION

Empirical evaluation of DSGE models is carried out in two steps: Preparing the models for analysis, and preparing the data required to adapt the model to reality. The first step, where the behavior of economic actors should be optimized, leads to a nonlinear system of equations that cannot be analyzed directly, but can be transformed to fit the purpose. In this transformation, nonlinear system should be subjected to a linear approximation, which here is carried out by Uhlig's method. In the next step, data should be prepared for use in model, or more specifically to be detrended. This is because to analyze a DSGE model designed to explain the cyclic behavior of a dataset that in reality contains both trends and cyclic information, data must first be detrended. Here, the Hodrick–Prescott filter is used for this purpose.

First, model is written in terms of steady-state values and log-linearized. The method used for this purpose is explained in Appendix 1. Next, the data, which here consists of annual data reported by Iran's central bank and Iran's statistics center for the period 1974–2012, was detrended to focus the analysis on its cyclic components. The Bayesian estimation is then used to derive the parameters and obtain the empirical model.

Once the model is log-linearized, DSGE model parameters can be determined in two ways. The first approach is the calibration (initialization) of all parameters. Calibration is one of the most important steps in the empirical evaluation of DSGE models in both RBC and new Keynesian schools, and often involves initialization of model parameters based on the existing literature on the subject. The second approach is the calibration of some model parameters and estimation of others by Bayesian techniques. The principal merits of this approach include better compliance of results to actual economic conditions and possibility of incorporating real economic data directly into parameter estimations. In view of mentioned merits, this study utilizes the second approach. Bayesian approach requires the prior information of parameters that must be estimated to be specified. This information can be obtained from -for example-the same resources that are used for calibration. This study too uses this source for this purpose. In other words, the prior information about the model parameters are gathered from the values observed in previous studies (calibrated values), which are presented in Table 2. To be more precise, prior information reflects the researcher's opinion before examining the information contained in the sample data. Prior information is expressed by a prior probability distribution function, and information contained in sample observations is expressed by a likelihood function. The product of these two distributions, according to Bayes' theorem, gives a new distribution called the posterior probability distribution, which constitutes the basis of all evaluations and decisions to be made. In the Bayesian approach, research combines their prior information about the model parameters with the information obtained from sample observations and ultimately obtains a posterior probability function and thus the Bayesian estimator of this probability distribution function. In this approach, problem parameters are considered to be not unknown constants but rather random variables, for which each particular value has a certain probability of occurrence (Shahmoradi and Ibrahim, 2010). The data used in this study are adjusted for the period 1974–2012. Data is detrended by the Hodrick-Prescott filter, and is then used to estimate model parameters. Coefficients and parameters are divided into two groups. The first group contains parameters such as plasticity, while the second group contains a series of macroeconomic variables. To estimate each parameter, mean and standard deviation of its prior distribution is determined. For some parameters such as the inverse of elasticity of labor

2 In these equations, private consumption, ${C_t}^p$, labor, Lt, private investment, ${I_t}^p$, private capital stock, ${I_t}^p$, private production, ${Y_t}^p$, private labor stock, N_t^P, wages, W_t, capital returns, R_t, government production, Y_t^G government labor, N_t^G, oil revenues, Z_t, government spending, Gt, government investment I_t^G, government capital stock, K_{t+1}^G, total investment I_t, total production and Y_t government tax revenue T_t are endogenous variables μ_Z, and oil revenue shock and government spending shock μ_G exogenous variables.

Table 1: Model parameters

Parameter	Description	Distribution	Prior mean
σ	Inverse of intertemporal elasticity of substitution consumption	Gamma	1.5
β	Subjective discount factor	Beta	0.96
ϑ	Inverse of elasticity of labor supply	normal	2.17
γ	Capital's share in government production	Beta	0.41
θ	Capital's share in private production	Beta	0.41
δ^{P}	Depreciation rate of government capital	Beta	0.042
δ^{G}	Depreciation rate of private capital	Beta	0.042
ρ_G	Autoregressive coefficient of government spending	Beta	0.48
ρ_Z	Autoregressive coefficient of oil revenue	Beta	0.49

supply and the inverse of elasticity of consumption substitution, for which no prior data specific to Iran's economy is available, we employ the standard values used in international literature. Some of other values are obtained by basic calculations. The values of model parameters and sources from which they have been derived are listed in Table 1.

The ratios of linear formulation are calculated using the annual data reported by Iran's central bank for the years 1974–2012. The values calculated for these ratios are presented in Table 2.

Values of exogenous shocks are obtained by using the least squares method on the figures reported by Iran's central bank and Iran's statistics center for the said period. Table 3 shows ρ_G and ρ_G estimated by this method.

The model is solved using the Dynare toolkit based on the Blanchard-Kahn conditions. After entering parameter specifications including the ranges of parameters to be calibrated, initial values, and prior mean and standard deviation of parameters to be estimated, data of the period 1974–2012 was subjected to 20,000 iterations of Metropolis-Hastings algorithm[3].

4. RESULTS OF MODEL ESTIMATION

Table 4 summarizes the prior values of parameters and final Bayesian estimates:

One of the important outputs of Dynare is MCMC plot, which is in fact the main reference for evaluating the integrity of solutions. As mentioned, Dynare runs multiple iterations of Metropolis-Hastings simulation, each starting at a different location. For the results of these chains to be acceptable, chains must behave similarly or converge toward each other. MCMC plot provided by Dynare also gives three measures called Interval, m2 and m3, which represent 80% confidence interval for the mean, variance and third moment, respectively. In the plots known as multivariate diagnostic chart, an aggregate measure is provided based on the eigenvalues of the variance-covariance matrix of each parameter. These plots can be used to provide evidence for convergence and relative stability in all moment measures of the parameters. In these plots, the horizontal axis represents the number of Metropolis-Hastings iterations and the vertical axis represents the parameter moments, starting from the initial value of the Metropolis-Hastings iterations. In case of no similarity between these plots, it can be concluded that prior distributions are inaccurate and estimation should be repeated by new prior distributions. Charts of prior and posterior distribution, the results of the first, second and third moment measures and multivariate diagnostic and mcmc plots are presented in the Appendix 2.

Success of DSGE studies based on RBC and new Keynesian theories is often gauged by comparing the moment measures obtained from the calibration against the moments of real world data. In other words, the estimated parameters and calculated ratios can be used to simulate the existing time series in the model and compare the moments of simulated series with their real counterparts. Naturally, a closer proximity between simulated and real values demonstrates the greater success of the model. In this study, the developed model is evaluated by comparing the standard deviations of primary variables such as non-oil production, private consumption and private investment in simulations against their real values.

In these results, volatility refers to the standard deviation of each variable's cyclic component, and relative volatility refers to the ratio of standard deviation of each variable to standard deviation of non-oil production. According to Table 5, comparison of the moments obtained from the model with their real world values yields the following results:

Sample data show that in the real world, changes in private investment has 2.91 times as much volatility as changes in non-oil production. The model results also show the ratio of this volatility to be 3.37, demonstrating the greater volatility of private investment when compared with non-oil production. Overall, these results show the success of the model in predicting private investment.

Cyclic fluctuations of non-oil production, which can represent the business cycles of Iran's economy, are measured by standard deviation of non-oil production. The results show the standard deviation of real non-oil production to be 0.0601 while the corresponding value obtained from the model is 0.0326. The standard deviation of the real value of private consumption is 0.069 and its corresponding value in the model is 0.0780, which reflects the model's success in predicting private consumption. Similarly, when compared against the real standard deviation of private investment, 0.175, prediction of standard deviation of 0.11 shows the model's relative success in explaining this parameter.

3 Represented in the software by the symbol mh_replice.

Table 2: Values of steady-state ratios

Parameter	Description	Value	Parameter	Description	Value
$\frac{\bar{C}}{\bar{Y}}$	Steady-state ratio of private consumption to non-oil production	0.60	$\frac{\bar{K}^G}{\bar{K}}$	Steady-state ratio of government capital stock to total capital stock	0.28
$\frac{\bar{G}}{\bar{Y}}$	Steady-state ratio of government's consumption expenditure to non-oil production	0.39	$\frac{\bar{N}^P}{\bar{N}}$	Steady-state ratio of private labor stock to total labor stock	0.72
$\frac{\bar{I}^P}{\bar{Y}}$	Steady-state ratio of private investment to non-oil production	0.31	$\frac{\bar{N}^G}{\bar{N}}$	Steady-state ratio of government labor stock to total labor stock	0.28
$\frac{\bar{I}^G}{\bar{Y}}$	Steady-state ratio of government investment to non-oil production	0.12	$\frac{\bar{I}^G}{\bar{Z}}$	Steady-state ratio of government investment to oil revenue	0.30
$\frac{\bar{Z}}{\bar{Y}}$	Steady-state ratio of oil revenue to non-oil production	0.25	$\frac{\bar{G}}{\bar{Z}}$	Steady-state ratio of government consumption expenditure to oil revenue	0.50
$\frac{\bar{I}^G}{\bar{K}^G}$	Steady-state ratio of government investment to government investment stock	0.13	$\frac{\bar{Y}^G}{\bar{Z}}$	Steady-state ratio of government production to oil revenue	0.07
$\frac{\bar{I}^P}{\bar{K}^P}$	Steady-state ratio of private investment to private investment stock	0.13	$\frac{\bar{T}}{\bar{Z}}$	Steady-state ratio of tax income to oil revenue	0.18
$\frac{\bar{Y}^G}{\bar{Y}}$	Steady-state ratio of government production to GDP	0.13	$\frac{\bar{C}}{\bar{Y}^P}$	Steady-state ratio of private consumption to private revenue	0.67
$\frac{\bar{Y}^P}{\bar{Y}}$	Steady-state ratio of private production to GDP	0.87	$\frac{\bar{T}}{\bar{Y}^P}$	Steady-state ratio of tax income to private sector revenue	0.096
$\frac{\bar{K}^P}{\bar{K}}$	Steady-state ratio of private capital stock to total capital stock	0.72	$\frac{\bar{K}^P}{\bar{Y}^P}$	Steady-state ratio of private capital stock to private sector revenue	2.54

Table 3: Estimated exogenous shocks

Parameter	Description	Value
ρ^G	Autoregressive coefficient of government spending	0.48
ρ_Z	Autoregressive coefficient of oil revenue	0.49
σ_G	Residual standard deviation of government spending regression	0.12
σ_Z	Residual standard deviation of oil revenue regression	0.14

Table 4: results of Bayesian estimation

Parameter	Prior mean	Estimation
σ	1.5	1.5005
β	0.96	0.9592
ϑ	2.17	2.17
γ	0.41	0.4109
θ	0.41	0.411
δ^P	0.042	0.0369
δ_G	0.042	0.0406
ρ^G	0.48	0.4808
ρ_Z	0.49	0.4895

Overall, comparing the moments obtained from models with the moments of real world data shows that the model can accurately simulate the key changes in private investment and consumption, but is not as much successful in predicting the changes in non-oil production.

5. ANALYSIS OF MODEL'S IMPULSE RESPONSES

This section presents the plots of impulse response of primary macroeconomic variables to the government's oil revenue and expenditure shocks. The shocks considered for analysis are equal to 1 residual standard deviation of variable regression. In these plots, the vertical axis is the percentage change in variables from their steady-state values and the horizontal axis represents the periods (here, each period is 10 years).

5.1. Effect of Oil Revenue Shock

According to Figures 1 and 2, a positive oil revenue shock leads to increased government investment, government construction expenditure, and investment in infrastructure, followed by an increase in government capital stock and public production before settling down to a steady state condition. As the plots show, positive oil revenue shock also leads to reduced private investment, which means private investment is substituted by public investment. In other words, such increase in public investment not only fail to supplement private investment and provide better conditions for private investors, but also leads to stagnation of investment climate for private sector, and thereby reduced private capital stock and private sector production. Increase in public investment also leads to improved labor condition, further employment, and higher wages in this sector.

Figure 1: Variables' impulse responses to oil shock

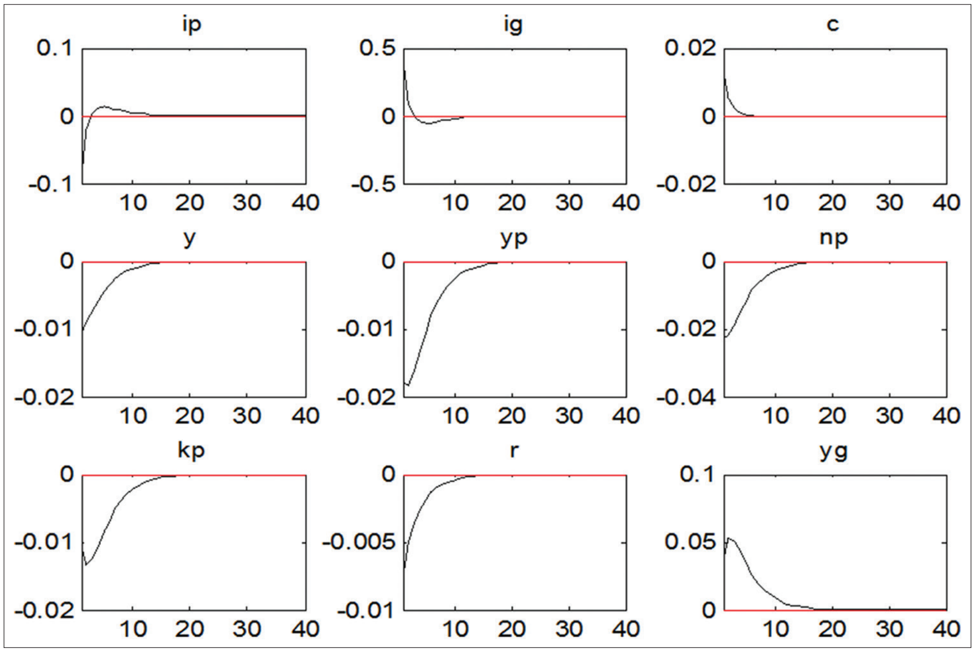


Figure 2: Variables' impulse responses to oil shock

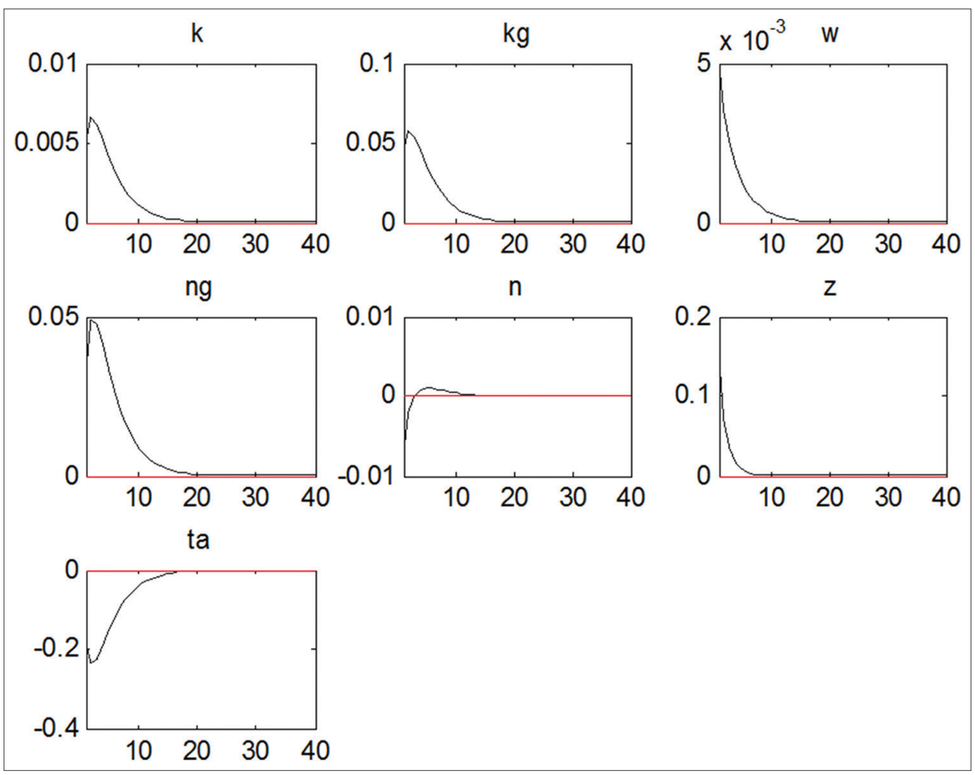


Table 5: Comparison of the moments obtained from real-world data and simulation

Variable	Volatility (standard deviation)		Relative volatility	
	Real value	Simulated value	Real value	Simulated value
Non-oil production	0.0601	0.0326	1	1
Private consumption	0.068	0.0780	1.13	2.42
Private investment	0.175	0.11	2.91	3.37

On the other hand, the reduced private investment leads to lower employment in this sector. Given the higher share of private sector in total employment, total employment first decreases, but as the effect of positive oil shock fades, it approaches a steady state value. With the reduced private investment, the consequent effect on interest rate decreases the demand for investment in this sector.

5.2. Effect of Government Spending Shock

Figure 3 shows the effect of positive government spending shock on non-oil production and private investment and consumption. The results generally indicate the crowd-out effect of such government spending shock. As can be seen, a government spending shock as large as 1 standard deviation initially increases the non-oil production, but with time, its crowd-out effect on private consumption and investment pushes the non-oil production down toward a steady state. Eventually, as the effect of expenditure shocks fades, non-oil production converges to a steady state condition.

6. CONCLUSION

In this study, a DSGE model based on the RBC theory was developed and adjusted to Iran's economy. This model consists of three components: Households, firms and governments. Household's objective is to maximize its utility subject to resource constraints, and firm and government's objective is to maximize their profit and production. Oil revenue and government spending were simulated independently by the first order auto regression, with their shocks defined as exogenous variables.

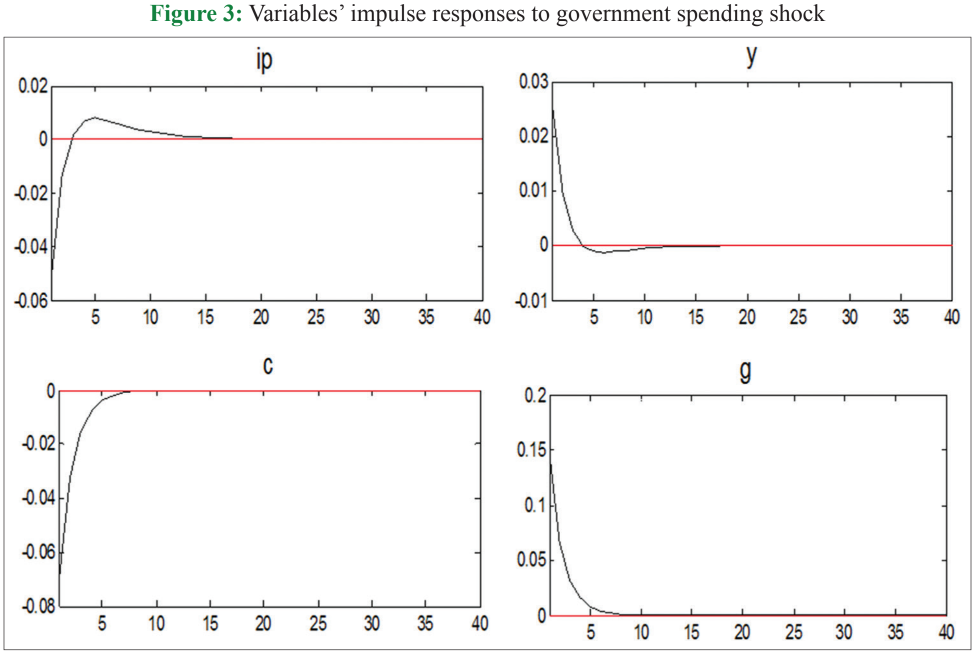
Next, all formulations were linearized by a log-linearization method, and then model parameters were estimated by Bayesian method and its ratios were adjusted according to Iran's economic data.

The results obtained using this model include prior and posterior distribution charts of variables, parameter values estimated by Bayesian method, and plots of variables' impulse response to shocks and standard deviations. The moment measures of model simulations were then compared against the moment measures of real world data. In other words, the estimated parameters and calculated ratios were used to reconstruct the existing time series and compare them with their real counterparts. Thus, to measure the model's success and accuracy, after detrending the data, volatilities of primary variables, namely non-oil production and private consumption and investment were determined and then compared with model outputs. Finally, the above said plots were used to analyze the impulse response of variables to oil revenue and government spending shocks.

The results obtained from the RBC-based DSGE model estimated to study the effect of oil revenue and government spending shocks on macroeconomic variables of Iran are as follows:

- Prior and posterior distributions of parameters, and mcmc and multivariate diagnostic plots show that estimations are reasonably satisfactory.
- Comparing the changes (standard deviation) and relative volatility of real and simulated values of primary variables showed that the model can simulate the changes and volatilities with reasonable accuracy.
- According to the results, non-oil production is less volatile than private investment, and the results derived from Iran's economic data also support this conclusion.
- Given that private investment constitutes a high percentage of GDP, reduced private investment induced by positive oil revenue shock leads to reduced production and thus slower economic growth. This result supports the resource curse hypothesis for the specific case of Iran.
- The increase in oil revenues leads to increased public investment and reduced private investment, which reflects a substitution relation between government and private investments when oil revenue experiences a positive shock.
- A shock to government consumption expenditure initially leads to increased production, but after several periods, its crowd-out effect undermines the private investment and consumption and consequently the production.

Figure 3: Variables' impulse responses to government spending shock



The results of this study indicate that in the case of Iran, every effort should be made to protect the economy from direct injection of higher oil revenues due to lifting of sanctions.

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APPENDICES

Appendix 1: Model linearization

The DSGE models are solved by Dynare toolkit (4.4.3) in MATLAB software environment. Having the equations derived from each component's first order conditions, the model is linearized around its equilibrium condition for Iran's economy. To incorporate the data, their logarithmic values are computed and then detrended by Hodrick–Prescott filter.

$$\hat{W}_t + 1 - \hat{N}_t = \hat{C}_t$$

$$-\sigma\hat{C}_t = -\sigma(1+\beta\left(1-\delta^P\right)\hat{C}_{t+1} + \left(1-J\right)[\hat{N}_t - (1+\beta\left(1-\delta^P\right)\hat{N}_{t+1}]$$
$$+\hat{R}_{t+1} + \beta\left(1-\delta^P\right)$$

$$\hat{K}_t^P = \frac{\overline{I}^P}{\overline{K}^P}\hat{I}_t^P + (1-\delta)\hat{K}_{t-1}^P$$

$$\hat{Y}_t^P = \frac{\bar{K}^P}{\bar{Y}^P}\hat{K}_t^P + \frac{\bar{C}}{\bar{Y}^P}\hat{C}_t + \frac{\bar{T}}{\bar{Y}^P}\hat{T}_t - (1-\delta^P)\frac{\bar{K}^P}{\bar{Y}^P}\hat{K}_{t+1}^P$$

$$\hat{N}_t^P = \hat{Y}_t^P - \hat{W}_t$$

$$\hat{K}_t^P = \hat{Y}_t^P - \hat{R}_t$$

$$\hat{Y}_t^G = \gamma\hat{K}_t^G + (1-\gamma)\hat{N}_t^G$$

$$\hat{N}_t^G = \hat{Y}_t^G - \hat{W}_t$$

$$\hat{Z}_t = \frac{\bar{I}^G}{\bar{Z}}\hat{I}_t^G + \frac{\bar{G}}{\bar{Z}} - \frac{\bar{T}}{\bar{Z}}\hat{T}_t - \frac{\bar{Y}^G}{\bar{Z}}\hat{Y}_t^G$$

$$\hat{K}_t^G = \frac{\bar{I}^G}{\bar{K}^G}\hat{I}_t^G + (1-\delta^G)\hat{K}_{t-1}^G$$

$$\hat{Y} = \frac{\bar{I}^G}{\bar{Y}}\hat{I}_t^G + \frac{\bar{I}^P}{\bar{Y}}\hat{I}_t^P + \frac{\bar{G}}{\bar{Y}}\hat{G}_t + \frac{\bar{C}}{\bar{Y}}\hat{C}_t - \frac{\bar{Z}}{\bar{Y}}\hat{Z}_t$$

$$\hat{Y}_t = \frac{\bar{Y}^G}{\bar{Y}}\hat{Y}_t^G + \frac{\bar{Y}^P}{\bar{Y}}\hat{Y}_t^P$$

$$\hat{K}_t = \frac{\bar{K}^G}{\bar{K}}\hat{K}_t^G + \frac{\bar{K}^P}{\bar{K}}\hat{K}_t^P$$

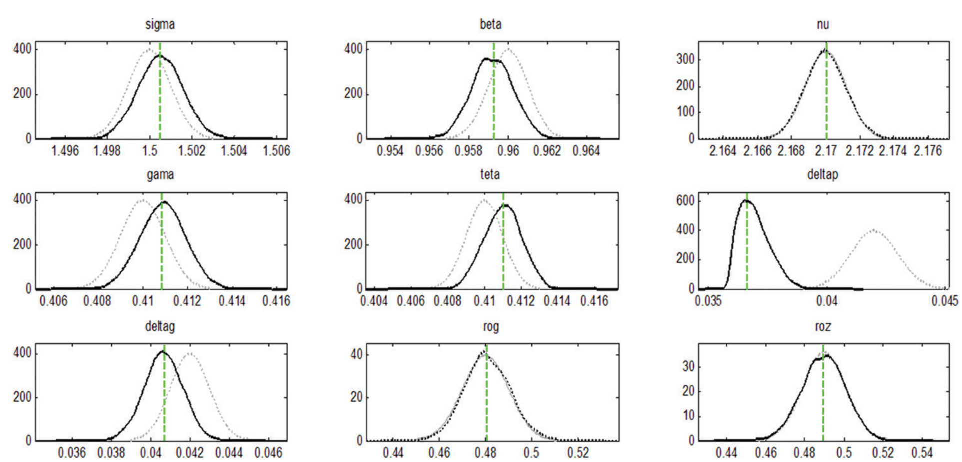
$$\hat{N}_t = \frac{\bar{N}^G}{\bar{N}}\hat{N}_t^G + \frac{\bar{N}^P}{\bar{N}}\hat{N}_t^P$$

$$\hat{Z}_t = \rho_z\hat{Z}_{t-1} + \mu_z$$

$$\hat{G}_t = \rho_G\hat{G}_{t-1} + \mu_G$$

Appendix 2: Prior and posterior distributions, mcmc, and multivariate diagnostic plots

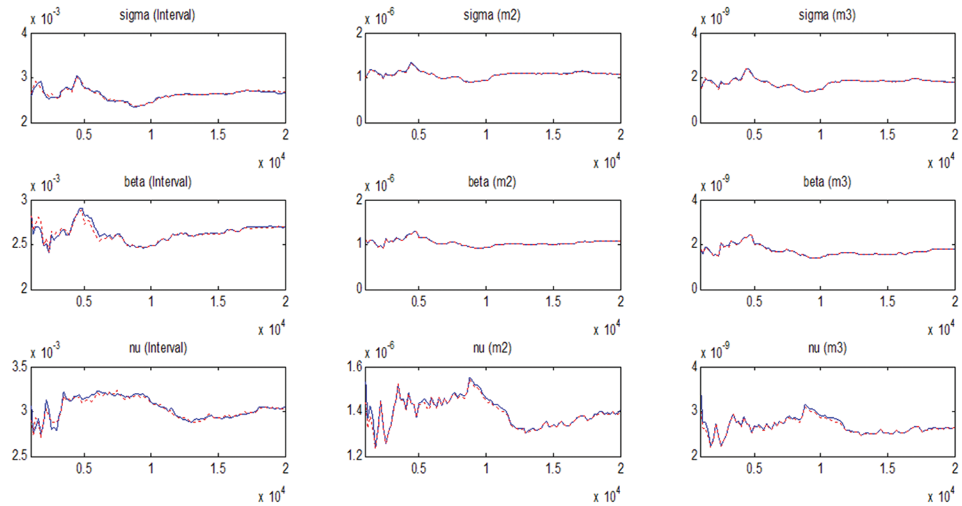
Prior and posterior distribution plots



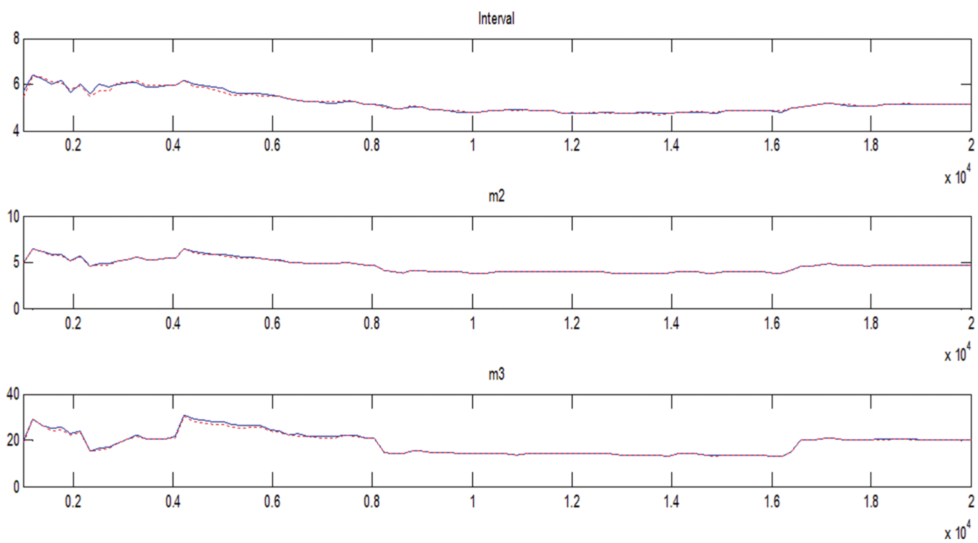
*Dashed curve: Prior distribution

Solid curve: Posterior distribution

mcmc plots



Multivariate diagnostic plots



*Solid curve: Moment measure for prior values

Dashed curve: Moment measure for posterior values