Effects of Oil Price Shocks on Agricultural Sector Using Dynamic Stochastic General Equilibrium Model

Z. Permeh¹, M. Ghorbani²*, H. Tavakolian³, and N. Shahnoshi²

ABSTRACT

This study aimed to develop a multi-sector Dynamic Stochastic General Equilibrium (Large DSGE) model for Iran's economy. In this model, economy was divided into three sectors: Agriculture, non-agriculture, and oil. Imports and exports were also included in the model. In order to adapt the model with Iran's economic conditions, price stickiness in agriculture and non-agriculture were included. Then, the impact of rising oil prices on agricultural sector was examined. To calculate the required coefficients, 1971-2012 data was gathered and Bayesian method was used. The results showed the negative impacts of rising oil prices on agriculture as well as the negative effects of Dutch Disease.

Keywords: Agriculture, Bayesian, DSGE, Multi-sector, Oil prices, Stickiness.

INTRODUCTION

Agriculture is very critical because it provides food security, creates jobs, increases non-oil exports, prevents rural immigration, etc. On the other hand, due to high oil share in Iran’s economy, the effects of turbulent oil revenues on real sectors have always been significant. In this context, oil boom (higher oil prices) has different effects on the growth of tradeables and non-tradeables. In this situation, a significant gap is created between the factors’ prices and price indices in different sectors, so that tradeables (such as agriculture and industry) are weakened and non-tradeables (such as construction) are strengthened. This is called de-agriculturalization. Meanwhile, the effects of higher oil prices on the growth of tradeables, including agriculture, have been analyzed in various patterns and models (econometric models and computable general equilibrium models). Since 1970s, econometric models have faced Lucas critique. In his critique of econometric models, Lucas (1976) says that if a certain relationship between two economic variables has been estimated econometrically, policy-makers, in formulating a policy for the future, cannot rely on that relationship to persist once a policy aiming to exploit the relationship is adopted (Ericsson and Irons, 1995). On the other hand, computable general equilibrium models are not so compatible with Iran’s economic conditions due to lack of stickiness of prices and wages, as well as neutrality of money.

There are numerous studies on the effects of higher oil prices on agriculture such as Pasban (2004), Bakhtiari and Haghi (2001), Bahrami and Farshchi (2011), and Yazdani and Sherafatmand (2011). These studies show that higher oil prices have negative effects on agriculture. Manzoor et al. (2011)

¹ Institute of Trade Studies and Research, Ferdowsi University of Mashhad, Mashhad, Islamic Republic of Iran.
² Department of Agricultural Economics, Faculty of Agriculture, Ferdowsi University of Mashhad, Mashhad, Islamic Republic of Iran.
* Corresponding author; email: ghorbani@um.ac.ir
³ Faculty of Economic, Allameh Tabataba'i University, Tehran, Islamic Republic of Iran.
use the computable general equilibrium model to simulate the effects of higher oil revenues on Iran’s economy. The results show that this shock increases activities in non-tradeables and decreases activities in tradeables (including agriculture). According to Stijns (2003), Dutch disease in developing countries leads to de-agrarianization. Olusi and Olagunju (2005) show that Dutch disease shifts the labor force in agriculture to non-tradeables.

Domestic and foreign studies have used DSGE model but they have not considered agriculture specifically and have not addressed the effects of oil revenues on the sector. Walker (2013) formulates the DSGE model for low-income countries in which agriculture plays a dominant role; but is only theoretical, aiming to analyze the shocks of climate and import prices of fertilizers. This study aimed to use the Dynamic Stochastic General Equilibrium (DSGE) model to address the effects of higher oil prices on agricultural variables (production, imports, exports, inflation, and consumption), by using time series data for 1971-2012.

MATERIALS AND METHODS

The primary structure of this model is based on Resende et al. (2010) and Balke et al. (2010). The following changes, however, are made: Households are divided into two groups (urban and rural); agriculture and oil sectors, as well as the Government and the Central Bank are introduced into the model; imported agricultural commodity subsidies are included, energy is introduced into the agricultural and non-agricultural production function, fertilizer and subsidies for fertilizer are included in the agricultural production function.

The DSGE model is the result of interactions among three blocks: Demand (households), supply (firms), and monetary authorities (the Government and the Central Bank). The equations of these blocks originate from microeconomic principles. These interactions lead to a clearing among the said blocks in each period, and ultimately to a general equilibrium. What follows is a description of these three blocks.

Households

Each household maximizes its lifetime utility through choosing Consumption (Ct), Investment (It), public Bonds (Bt), capital stack (Kt), real money holdings, using the following utility function:

$$\max E, \sum_{t=0}^{\infty} \beta^t \left[ \frac{(C_{ut+i}^{1-\sigma_c})}{1-\sigma_c} + \frac{\gamma (M_{ut+i}^{1-b})}{1-b M_{ut+i}} - \frac{1}{1+\sigma_{lw}} (L_{ut+i}^{1+\sigma_l}) \right]$$

(1)

where

$$\beta$$ stands for the discount factor, \(\sigma_c\) for the inverse of intertemporal elasticity of substitution, \(\sigma_l\) for the inverse of elasticity of work effort with respect to the real wage, \(b\) for the inverse of elasticity of money holdings with respect to the interest rate, \(L_{t+i}\) for Labor force, \(C_{t+i}\) for total household Consumption, and \(M_t\) for the Monetary base. This optimization will be achieved with an eye to two limitations: Budget line and capital accumulation. Where

$$C_{ut} + I_{ut} + \frac{M_{ut}}{P_t} + B_{ut} + T_{ut} + \frac{W_{ut} L_{ut}}{P_t} + R_{ut} K_{ut-1} + \frac{D_{ot}}{P_t} + \frac{M_{ut-1}}{P_t} + (1 + r_{t-1}) \frac{B_{ut-1}}{P_t}$$

(2)

$$K_{ut+i} = L_{ut} + (1 - \delta) K_{ut}$$

(3)
\( D_{at} \) is the Distributed profit of firms, \( P \) is the aggregate Price index, \( B_{at} \) is the quantity of one-period nominally riskless discount Bonds, \( r_t \) is the net actual return of bonds, \( T_{at} \) is the households’ Tax, \( \nu_{at} \) is the nominal Wage, \( R \) is the real Rate of capital, and \( \delta_a \) is the capital depreciation.

Consumer utility optimization results in the following equations:

\[
C_{at}^{\sigma} = \left(1 + r_t\right) \beta \left( E_{at} C_{at+1}^{\sigma_{t+1}} \right) \left( \frac{P_{1+\gamma_{t+1}}}{P_{1+\gamma_t}} \right) \left( \frac{r_{t+1}}{1+r_{t+1}} \right) C_{at}^{\sigma_t} \]

The above equation shows the allocation of consumption between periods. In addition, it shows the relationship between consumption, discount rate, and interest rate.

\[
m_{at}^b = \left( \frac{r_t}{1+r_t} \right) \left( \frac{1+\gamma_t}{1+\gamma_{t+1}} \right) C_{at}^{\sigma_t} \]

Equation (5) shows the positive relation between wage and consumption.

\[
-\lambda_t + \beta E_{at} \lambda_{t+1} \left( \frac{P_{1+\gamma_{t+1}}}{P_{1+\gamma_t}} \right) = 0 \]

Equation (7) shows that real interest rate gap will depend on inflation and nominal interest rates (Fisher Equation).

Utility function of rural households is the same as urban ones, but rural households do not participate in capital and asset markets. So, their budget constraints will be different. Like urban households, rural ones keep money. Their utility function, budget line, and capital stock are as follows:

\[
\max E \sum_{t=0}^{\infty} \beta^t \left[ \frac{C_{at}^{\sigma_t}}{1-\sigma_t} + \frac{1}{1-\beta} \left( \frac{M_{at}^{\gamma_t}}{P_t} \right)^{\frac{1}{\gamma_t}} \right] \]

\[
K_{at+1} = I_{at} + \left(1 - \delta_a \right) K_{at} \]

Optimizing the utility function of rural household yields:

\[
C_{at}^{\sigma_t} = \left(1 + r_t\right) E_{at} C_{at+1}^{\sigma_{t+1}} \left( \frac{P_{1+\gamma_{t+1}}}{P_{1+\gamma_t}} \right) \left( \frac{r_{t+1}}{1+r_{t+1}} \right) C_{at}^{\sigma_t} \]

Where:

\[
\eta > 0 \]

is the elasticity of substitution between goods, \( C_{at} \) is the agricultural goods, and \( C_{at}^{m} \) is the non-agricultural goods.

Agricultural and non-agricultural goods are also a combination of domestic and imported goods:

\[
C_{at} = \left(1 - \nu_a \right) \left( C_{at}^{-\sigma_{at}} \right)^{\nu_a \sigma_{at}} + \left( \nu_a \right)^{\frac{\sigma_{at}}{\sigma_{at}}} \left( C_{at}^{m \sigma_{at}} \right)^{\frac{\sigma_{at}}{\nu_a \sigma_{at}}} \]

\[
C_{at} = \left(1 - \nu_a \right) \left( C_{at}^{o \sigma_{at}} \right)^{\nu_a \sigma_{at}} + \left( \nu_a \right)^{\frac{\sigma_{at}}{\sigma_{at}}} \left( C_{at}^{m \sigma_{at}} \right)^{\frac{\sigma_{at}}{\nu_a \sigma_{at}}} \]

Where, \( C_{at}^{o} \) and \( C_{at}^{m} \) stand for the domestic and imported non-agricultural goods, \( C_{at}^{\sigma_{at}} \) and \( C_{at}^{m} \) indicate the domestic and
imported agricultural goods. Consumers choose agricultural and non-agricultural commodities in such a way as to minimize the costs. So, at this stage, the target is also to set a proper combination of agricultural and non-agricultural goods and then an optimal mix of the domestic and imported goods. Considering this optimization, we will have:

\[ C_{a,t} = \left(1 - \gamma\right) \left( \frac{P_{a,t}}{P_{t}} \right)^{\eta} C_{t} \] (17)

\[ C_{o,t} = \gamma \left( \frac{P_{o,t}}{P_{t}} \right)^{\eta} C_{t} \] (18)

If Equations (17) and (18) are used in Equation (14), the consumer price index will be:

\[ P_{t}^{c} = \left[ \left(1 - \gamma\right) \left( \frac{P_{a,t}}{P_{t}} \right)^{\eta} + \gamma \left( \frac{P_{o,t}}{P_{t}} \right)^{\eta} \right]^{\frac{1}{\gamma}} \] (19)

Non-agriculturals are a combination of domestic and imported goods and demand for them should be calculated. Hence, a mix of domestic and imported non-agricultural will be:

\[ C_{o,t}^{d} = \left(1 - \gamma_{o}\right) \left( \frac{P_{o,t}^{d}}{P_{t}^{d}} \right)^{\eta_{o}} C_{o,t} \] (20)

\[ C_{o,t}^{m} = \gamma \left( \frac{P_{o,t}^{m}}{P_{t}^{m}} \right)^{\eta_{o}} C_{o,t} \] (21)

Since we have imports and exports in the model (and in turn, the exchange rate), DSGE model will be open and the prices of imported goods will be:

\[ P_{o,t}^{m} = P_{o,t}^{m} * \text{ex}_t \] (22)

Where, \( P_{o,t}^{m} \) stands for the Prices of imported goods in local currency (Rials), \( P_{o,t}^{m} \) indicates the Prices of imported goods in dollar, and \( \text{ex}_t \) denotes the nominal exchange rate. The import price can be defined as the [AR(1)]:

\[ \log(P_{o,t}^{m}) = \rho_{o,m} \log(P_{o,t-1}^{m}) + (1 - \rho_{o,m}) \log(P_{o,t}^{m}) + \varepsilon_{o,t}^{m} \] (23)

Where, \( \rho_{o,m} \) is the coefficient of auto regression process for import prices.

The next step is to set the non-agricultural prices. To do so, we enter (20) and (21) in (14).

\[ P_{o,t}^{d} = \left[ \left(1 - \gamma_{o}\right) \left( \frac{P_{o,t}^{d}}{P_{t}^{d}} \right)^{\eta_{o}} + \gamma_{o} \left( \frac{P_{o,t}^{m}}{P_{t}^{m}} \right)^{\eta_{o}} \right]^{\frac{1}{\gamma_{o}}} \] (24)

If the same process is used for agriculturals (domestic and imported), domestic demand, import demand and the price combination of agriculturals will be:

\[ C_{a,t}^{d} = \left(1 - \gamma_{a}\right) \left( \frac{P_{a,t}^{d}}{P_{t}^{d}} \right)^{\eta_{a}} C_{a,t} \] (25)

\[ C_{a,t}^{m} = \gamma \left( \frac{P_{a,t}^{m}}{P_{t}^{m}} \right)^{\eta_{a}} C_{a,t} \] (26)

\[ P_{a,t}^{d} = \left[ \left(1 - \gamma_{a}\right) \left( \frac{P_{a,t}^{d}}{P_{t}^{d}} \right)^{\eta_{a}} + \gamma_{a} \left( \frac{P_{a,t}^{m}}{P_{t}^{m}} \right)^{\eta_{a}} \right]^{\frac{1}{\gamma_{a}}} \] (27)

Now it’s time to set the domestic prices of imported agriculturals. Since imported agriculturals receive subsidies, \( \left( \gamma_{m} \right) \) in the below function indicates the subsidy rate:

\[ P_{o,t}^{m} = (P_{o,t}^{m} * \text{ex}_t)^{\frac{1}{1 - \gamma_{m}}} \text{ and } 0 < \gamma_{m} < 1 \] (28)

Meanwhile, \( P_{o,t}^{m} \) can be defined as AR(1) process:

\[ \log(P_{o,t}^{m}) = \rho_{o,m} \log(P_{o,t-1}^{m}) + (1 - \rho_{o,m}) \log(P_{o,t}^{m}) + \varepsilon_{o,t}^{m} \]

Where, \( \rho_{o,m} \) is the coefficient of AR(1) for prices of imported agriculturals.

Firms

The production block in this paper is similar to that in new Keynesian literature. Production is created by two sectors: agriculture and non-agriculture.
Final Good Firms

There is a chain of firms which produce various goods in monopolistic manner and have market power for price-setting. Agricultural and non-agricultural production builds total production ($Y_t$) whose constituents are determined by CES function:

$$ Y_t = \left[ (1 - \omega_n)^{\frac{1}{\nu}} Y_{a,t}^{\frac{1}{\nu}} + \omega_n Y_{o,t}^{\frac{1}{\nu}} \right]^{\frac{\nu}{1}} $$  \hspace{1cm} (30)

Where,

$\omega_n$ stands for the share of non-agriculturals in final goods and $\nu$ indicates the elasticity of substitution of agriculturals and non-agriculturals. If $P_t$ is the final products’ Prices, producers choose the final products $Y_{a,t}$ and $Y_{o,t}$ in a way that maximizes the profit function. So demand for agriculturals and non-agriculturals will be obtained:

$$ Y_{a,t} = (1 - \omega_n) \left( \frac{P_o}{P_t} \right)^{\frac{1}{\nu}} Y_t $$  \hspace{1cm} (31)

$$ Y_{o,t} = \omega_n \left( \frac{P_o}{P_t} \right)^{-\frac{1}{\nu}} Y_t $$  \hspace{1cm} (32)

Meanwhile, if (31) and (32) are used, the final product prices, i.e. producer price index, will be:

$$ P_t = \left[ (1 - \omega_n) \left( \frac{P_o}{P_t} \right)^{\frac{1}{\nu}} + \omega_n \left( \frac{P_o}{P_t} \right)^{-\frac{1}{\nu}} \right]^{\frac{1}{\nu}} $$  \hspace{1cm} (33)

Non-Agricultural Firms

It is assumed that there is a final good producing firm which purchases $Y_{o,t}$ units of intermediate goods at the nominal price $P_{o,t}$ from monopolistic competitive firms, in order to produce $Y_{o,t}$ units of the final good using a technology with constant return to scale:

$$ Y_{o,t} = \left[ \int_{0}^{1} \left( Y_{o,t} \right)^{\frac{1}{\nu}} \, df \right]^{\frac{1}{\nu - 1}} $$  \hspace{1cm} (34)

Where, $\theta_o \in (1, \infty)$ stands for the elasticity of substitution of intermediate goods. The demand for intermediate inputs of sector $j$ will be obtained through optimizing the producers’ profit:

$$ Y_{o,j} = \left[ \frac{P_{o,j}}{P_{o,t}} \right]^{-\theta_o} Y_{o,t} $$  \hspace{1cm} (35)

Non-agricultural producer price will be obtained by:

$$ P_{o,j} = \left( \int_{0}^{1} \left( P_{o,j} \right)^{-\theta_o} \, df \right)^{-\theta_o} $$  \hspace{1cm} (36)

Here, it is assumed that $Y_{o,j}$ is a combination of imported ($Y_{m,t}$) and domestic ($Y_{d,t}$) goods. The constituents of which are determined by CES function:

$$ Y_{o,t} = \left[ (1 - \omega_o) \left( Y_{o,t} \right)^{\frac{1}{q_o}} + \omega_o \left( Y_{m,t} \right)^{\frac{1}{q_o}} + \omega_o \left( Y_{d,t} \right)^{\frac{1}{q_o}} \right]^{\frac{1}{q_o}} $$  \hspace{1cm} (37)

Where, $\eta_o$ stands for the elasticity of substitution of domestic and imported goods and $\omega_o$ indicates the import share in non-agricultural sector supply.

If $P_{o,t}^{im}$, $P_{o,t}^{pd}$ and $P_{o,t}^{op}$ are the Prices of imported goods, domestic goods and non-agricultural goods respectively, the firm chooses $Y_{m,t}$, $Y_{d,t}$ and $Y_{o,t}$ in a way which maximizes its profit. This maximization yields the below function for domestic and imported goods:

$$ Y_{o,t} = \left( 1 - \omega_o \right) \left( \frac{P_{o,t}^{op}}{P_{o,t}^{op}} \right)^{\frac{1}{q_o}} Y_{o,t} $$  \hspace{1cm} (38)
Now, if (τν) and (τλ) replace (τν), the equation of non-agricultural producer price will be obtained.

\[ P^{\nu}_{o,t} = \left[ 1 - \omega_o \right] \left( \frac{1}{\mu_o} \right) + \left( \omega_o \left( P^{\nu}_{o,t} \right) \right)^{\frac{1}{\mu_o}} \quad (40) \]

In the next step, the intermediate good \( Y_{o,j,t} \) will be produced using Cobb-Douglas function. The firm \( j \) produces the intermediate good \( Y_{o,j,t} \) using capital \( K_{o,t} \), labor \( L_{o,t} \) and energy \( E_{o,t} \). That is:

\[ Y_{o,j,t} = A_{o,j} \left( K_{o,j} \right)^{\alpha_o} \left( L_{o,j} \right)^{\alpha_l} \left( E_{o,j} \right)^{\alpha_e} \quad (41) \]

\( \alpha_o, \alpha_l \) and \( \alpha_e \) are the elasticity of non-agricultural production to capital, labor and energy. \( A_{o,j} \) stands for the technological impulse which follows the AR(1):

\[ \log A_{o,j} = \rho_{A_o} \log \left( A_{o,j-1} \right) + \left( 1 - \rho_{A_o} \right) \log \left( A_o \right) + e_{o,j} \quad (42) \]

Where, \( A_o \) is greater than zero and \( \rho_{A_o} \) stands for the technological coefficient.

Here, producers perform two tasks. Firstly, they minimize the costs by choosing optimal amounts of inputs. If the cost function is minimized, the following equation will be obtained (marginal cost function):

\[ \phi_{o,t} = \left( \frac{W_{o,j}^{\nu}}{L_{o,t}} \right)^{\alpha_o} \left( \frac{K_{o,t}^{\alpha_o}}{A_o^{\alpha_o}} \right) \left( \frac{P_{o,t}}{\alpha_l} \right) \quad (43) \]

Secondly, they maximize their profit by choosing the commodity prices. Here the price stickiness (Calvó price-setting) enters the model. \( \omega \) percent of firms do not adjust their prices (they add a given percent of previous inflation to the current price \( P_{o,j,t}^{\nu} = \pi_{o,j-1} P_{o,j-1}^{\nu} \)) and \( 1 - \omega \) percent of firms adjust their prices \( P_{o,j,t}^{\nu} \).

Mathematically, one can express this profit maximization problem as:

\[ D_{o,t} = E_t \sum_{j=1}^{n} \phi_{o,j} \left( A_{o,j,t} \right)^{\nu} \left( \frac{P_{o,d}^{\nu}}{P_{o,j,t}^{\nu}} \right) Y_{o,j,t}^{\nu} \left( \phi_{o,j,t} - \phi_{o,j,t} \right) \quad (44) \]

s.t.

\[ Y_{o,j,t}^{d} = \left( \frac{P_{o,j,t}^{\nu}}{P_{o,j,t}^{\nu}} \right)^{\nu} \quad (45) \]

Note that the appropriate discount factor in \( \phi_{o,j,t} \) is given by

\[ \left( \Delta_{t,t+1} \right)^{s_o} = \beta^{s_o} \left( Y_{o,j,t}^{d} \right)^{s_o} \quad (46) \]

According to Equation (45) inflation is a function of marginal cost, inflation of past and expected inflation:

**Agricultural Firms**

Agricultural products are either domestically consumed or exported. In addition, part of country’s annual need will be met through imports. Hence, the mixed goods of this sector encompass domestic production \( Y_{a,d}^{d} \), imports \( Y_{a,t}^{m} \) and exports \( Y_{a,t}^{e} \).

\[ Y_{a,t} = \left[ \left( 1 - \omega_1 \right) \frac{1}{\beta} \left( Y_{a,t}^{d} \right)^{\mu_1} + \left( \omega_1 \right) \frac{1}{\beta} \left( Y_{a,t}^{m} \right)^{\mu_1} \right]^{\frac{1}{\mu_1}} \quad (47) \]

Where,

- \( \mu_1 \) stands for the elasticity of substitution of imported and domestic goods. \( \omega_1 \)
indicates the import share in supply. If $P_{a,t}^d$, $P_{a,t}^{nd}$, and $P_{a,t}^p$ are the import, domestic, and producer prices of agricultural inputs, respectively, the firm chooses $Y_{a,t}^d$ and $Y_{a,t}^m$ in a way which maximizes its profit. This maximization yields the below function for domestic and imported goods:

$$Y_{a,t}^d = \left(1 - \omega_e \right) \left( \frac{p_{a,t}^d}{p_{a,t}^m} \right)^{-\alpha_e} Y_{a,t}^m$$

(47)

$$Y_{a,t}^m = \left( \omega_e \right)^{\frac{1}{\gamma_e}} \left( \frac{p_{a,t}^m}{p_{a,t}^p} \right)^{-\alpha_e} Y_{a,t}^d$$

(48)

Now if (47) and (48) are put in (45) prices of agricultural inputs will be:

$$P_{a,t}^d = \left[ \left( 1 - \omega_e \right) \left( \frac{p_{a,t}^d}{p_{a,t}^m} \right)^{-\alpha_e} + \left( \omega_e \right) \left( \frac{p_{a,t}^m}{p_{a,t}^p} \right)^{-\alpha_e} \right]^{-\frac{1}{\gamma_e}}$$

(49)

The firm combines distinct domestic and foreign goods using technology constant return to scale:

$$Y_{a,t}^d = \left( \int Y_{a,t}^d \frac{a_{t,j}^e}{a_{t,j}^d} \right)^{\frac{a_{t,j}^d}{a_{t,j}^e}}$$

(50)

Where,

$\theta_{a}$ stands for the elasticity of substitution of intermediate goods. The demand for intermediate inputs of sector $j$ will be obtained through optimizing the producers’ profit:

$$Y_{a,t}^d = \left( \frac{p_{a,t}^d}{p_{a,t}^{nd}} \right)^{-\theta_e} Y_{a,t}^{nd}$$

(51)

Agricultural producer price will be obtained by:

$$p_{a,t}^{nd} = \left[ \left( \frac{p_{a,t}^d}{p_{a,t}^{nd}} \right)^{\theta_e^{-1}} \right]^{\frac{1}{1-\theta_e}}$$

(52)

Now, the next problem arises: How $Y_{a,t}^d$, will be produced? Following the literature in this paper, we use Cobb-Douglas function:

$$Y_{a,t}^d = A_{a,t} \left( K_{a,t} \right)^{\alpha_d} \left( L_{a,t} \right)^{\beta_d} \left( E_{a,t} \right)^{\gamma_d} \left( \varepsilon_{a,t} \right)^{\delta_d}$$

(53)

Where,

$L_{a,t}$ stands for Labor, $K_{a,t}$ for capital stock, and $E_{a,t}$ for Energy. $\alpha_d$, $\gamma_d$ and $\beta_d$ indicate the capital, labor, and energy elasticity, respectively.

Energy in agricultural production is different from that in non-agricultural production. In the above function, the energy used in agriculture consists of energy of oil products and that of chemical and fertilizers and pesticides/herbicides which will be addressed later. $A_{a,t}$ indicates productivity impulse which is determined exogenously and follows the AR(1):

$$\log A_{a,t} = \rho_a \log (A_{a,t-1}) + (1-\rho_a) \log (A_a) + \varepsilon_{a,t}$$

(54)

Here, producers perform two tasks. Firstly, they minimize the costs by choosing optimal amounts of inputs. If the cost function is minimized, the following equation will be obtained (marginal cost function):

$$\phi_{a,t} = \left( \frac{w_{a,t}}{\gamma_{a,t}} \right)^{\frac{\alpha_d}{\gamma_{a,t}}} \left( \frac{R_{a,t}}{\alpha_d} \right)^{\frac{\beta_d}{\gamma_{a,t}}} \left( \frac{E_{a,t}}{\alpha_d} \right)^{\frac{\gamma_d}{\gamma_{a,t}}} \left( \frac{\varepsilon_{a,t}}{\delta_d} \right)^{\frac{\delta_d}{\gamma_{a,t}}}$$

(55)

Secondly, they maximize the profit by choosing the commodity prices. Calvo price stickiness is also introduced here. New KeynesianPhillips curve is as follows:

$$\pi_{a,t} = \pi_{a,t-1} + \beta \pi_{a,t} + \frac{1}{1-\beta} \pi_{a,t-1}$$

(56)

**Energy Combination in Agriculture**

The CES function combines the energy of oil products and that of chemical fertilizer:

$$E_{a,t} = \left( 1 - \alpha_e \right)^{\frac{1}{\gamma_e}} \left( E_{a,t}^p \right)^{\frac{\alpha_e}{\gamma_e}} + \left( \alpha_e \right)^{\frac{1}{\gamma_e}} \left( E_{a,t}^f \right)^{\frac{\gamma_e}{\gamma_e}}$$

(57)

Where,

$E_{a,t}^p$ stands for the Energy used in agriculture, $E_{a,t}^d$ for the Energy obtained
from oil products, \( E'_{a,t} \) for the Energy obtained from chemical fertilizers and pesticides/herbicides, and \( \alpha_e \) for \( E'_{a,t} \) share in total energy. Since chemical fertilizers and pesticides/herbicides are supplied both domestically and through importation, their CES function can be written as:

\[
E'_{a,t} = \left[ (1-\alpha_e) \left( \frac{1}{E'_{a,t}} \right) \frac{1}{\theta_e} + \left( \alpha_e \right) \left( \frac{1}{E'_{a,t}} \right) \frac{1}{\theta_e} \right]^{-\theta_e} 
\]

Where,

\( E'_{a,t} \) and \( E'_{a,t} \) stand for the domestic and imported fertilizers and pesticides/herbicides, and \( \theta_e \) for substitution elasticity between them. Meanwhile, agricultural firms choose the energy obtained from oil products and chemical fertilizers in a way which minimizes their costs. The consumption of domestic energy and chemical fertilizers will be as follows:

\[
E_{d,t} = (1-\alpha_e) \left( \frac{P_{a,t}}{P_{e,t}} \right)^{-\theta_e} E_{a,t} 
\]

\[
E_{f,t} = \alpha_e \left( \frac{P_{f,t}}{P_{e,t}} \right)^{-\theta_e} E_{a,t} 
\]

Where,

\( P_{e,t} \) stands for the chemical fertilizers’ Prices and \( P_{a,t} \) for the domestic energy Prices.

The energy prices should be set. Since oil prices are considered to be exogenous, the relevant formula can be written as:

\[
P_{e,t} = \alpha_e P_{e,t} 
\]

Where,

\( P_{e,t} \) indicates oil Prices which follows the AR(1):

\[
\log(pp_{a,t}) = \rho_{pp} \log(pp_{a,t-1}) + (1-\rho_{pp}) \log(pp_{e,t}) + \epsilon_{t}^{pp}
\]

Agricultural producers minimize

\[
E'_{a,t} = \left[ (1-\alpha_f) \left( \frac{1}{E_{a,t}} \right) \frac{1}{\theta_f} + \left( \alpha_f \right) \left( \frac{1}{E_{a,t}} \right) \frac{1}{\theta_f} \right]^{-\theta_f} 
\]

subject to budget constraint \( P_{a,t} E_{a,t} + P_{f,t} E_{f,t} = P'_{a,t} E'_{a,t} \). The results provide domestic and import demands:

\[
E_{d,t} = (1-\alpha_f) \left( \frac{P_{d,t}}{P_{f,t}} \right)^{-\theta_f} E_{a,t} 
\]

\[
E_{f,t} = \alpha_f \left( \frac{P_{f,t}}{P_{f,t}} \right)^{-\theta_f} E_{a,t} 
\]

Now, the domestic prices of imported chemical fertilizers and pesticides/herbicides should be set. Since chemical fertilizers receive subsidies, the import price in local currency can be written as:

\[
P_{a,t} = (P_{pe,t} * ex) ^{\gamma_f} \text{ and } 0<\gamma_f<1
\]

Where,

\( P_{pe,t} \) for oil Prices, and \( \gamma_f \) for the subsidy.

Agricultural Exporting Firm

All firms follow the unit prices in domestic and foreign markets (Obstfeld and Rogoff, 1995). Therefore, in accordance with the law of one price, exchange rate fluctuations will be transferred through export prices. Foreign demand for export is written as:

\[
Y_{a,t} = \left( \frac{P_{a,t}}{P'_{a,t}} \right) Y_{a,t}^{wa}
\]

Where,

\( P'_{a,t} \) stands for export Price in Rials, \( Y_{a,t}^{wa} \) for foreign production, and \( V_{a,t} \) for export elasticity. \( Y_{a,t}^{wa} \) follows the AR(1):

\[
\log(Y_{a,t}^{wa}) = (1-\rho_{v}^{*}) \log(Y_{a,t-1}^{wa}) + (\rho_{v}^{*}) \log(Y_{a,t-1}^{wa})
\]

Oil sector
In this paper, we follow Balke et al. (2010) and assume that oil-producing firm produces crude oil using technology \( Z_{p,t} \), Labor \( (L_{p,t}) \) and oil reserves \( (X_{p,t}) \):

\[
Y_{p,t} = Z_{p,t} \left[ \omega_p X_{p,t}^{1-\rho_p} + (1-\omega_p) L_{p,t}^{1-\rho_p} \right]^{1-\rho_p}
\]

(68)

The evolution of oil reserves reflects both additions to reserves and the depletion due to production:

\[
X_{p,t+1} = X_{p,t} + \Phi_g \left( I_{op,t} / X_{p,t} \right) X_{p,t} - Y_{p,t}
\]

(69)

The exploration of oil reserves follows the following formula:

\[
G_{p,t} = \Phi_p \left( \frac{I_{op,t}}{X_{p,t}} \right) X_{p,t}
\]

(70)

Where,

\[
I_{op,t}\text{ indicates Investment which is assumed to be a combination of public (} I_{p,t} \text{) and private investments (} I_{op,t} \text{)}:
\]

\[
I_{p,t} = A_{it} \left[ \omega_{it} I_{p,t}^{1-\rho_l} + (1-\omega_{it}) I_{op,t}^{1-\rho_l} \right]^{1-\rho_l}
\]

(71)

Where, \( \Phi_g (.) > 0 \) and \( \Phi_g (.) < 0 \). Note that in the steady state, \( G_{p,t} = Y_{p,t} \).

\[
\Phi_g (\frac{G}{X}) = \frac{G}{X} \text{ and } \Phi_g (\frac{G}{X}) = 1.
\]

One can view reserves in our model as representing total capital in the oil producing sector, which reflects oil-production infrastructure (capital), as well as oil in the ground. The depletion of reserves, i.e. the depreciation of oil-producing capital, depends on how much oil is produced (Balke et al. 2010).

It is assumed that private and public investment follows the AR(1):

\[
\log l_{op,t} = \rho_{op} \log l_{op,t-1} + (1-\rho_{op}) \log I_{op,t} + e_{op,t}
\]

(72)

\[
\log l_{s,t} = \rho_t \log l_{s,t-1} + (1-\rho_t) \log I_{s,t} + e_{st}
\]

(73)

The amount of oil production and reserves is determined through the optimization of the representative agent’s utility function in the oil-producing country, taking prices as given. Therefore, we have:

\[
p_{p,t} = p_{p,t} + mc_{p,t}
\]

(74)

\[
m_{c,p,t} = \frac{w_{x,t}}{w_{p,t}} \left( 1-\omega_p \right) \left( \frac{L_{p,t}}{Y_{p,t}} \right)^{\rho_p}
\]

(75)

Where, \( p_{p,t} \) stands for oil Price, \( m_{c,p,t} \) for cost of oil production in time \( t \), \( w_{p,t} \) wage in oil sector and \( mp_{p,t} \) marginal product of labor.

The Government and the Central Bank

Since the Central Bank in Iran is not independent, the Government and the Central Bank should be modeled together. It is assumed that the Government’s objective is to achieve a balanced budget. Thus, the Central Bank does its best to help the Government. The Central Bank also aims to stabilize prices and enhance economic growth (Komijani and Tavakolian, 2010). The Government budget constraint is as follows:

\[
g_t + (1+i_{t-1}) \frac{b_{t-1}}{n_r} + T_t = b_{t} + \left( DC_t - DC_{t-1} \right) / P_t
\]

(76)

Where \( g_t \) stands for the government expenditures, \( b_{t-1} \) for the previous period’s bonds, \( T_t \) for households Tax, \( b_t \) for current period’s bonds, \( DC_t - DC_{t-1} \) for public net Debt to the Central Bank, and \( or_t \) for oil revenue. Public expenditure, including consumption and investment, are as follows:

\[
g_t = c_{gt} + I_{gt}
\]

(77)

Government consumption follows the AR(1) process:
\[ \log_{e} g_{t} = \rho_{g} \log \left( c_{a,t-1} \right) + \left( 1 - \rho_{g} \right) \log \left( \epsilon_{g} \right) + \epsilon_{g,t} \]  

(78)

Meanwhile, monetary base and its growth can be written as:

\[ M_{t} = ex_{t} F R_{t} + DC_{t} \]  

(79)

\[ M_{t} - M_{t-1} = \left( DC_{t} - DC_{t-1} \right) + \left( ex_{t} F R_{t} - ex_{t-1} F R_{t-1} \right) - R C B_{t} \]  

(80)

Where,

- \( M_{t} \) stands for Monetary base,
- \( DC_{t} \) for net Debt to the Central Bank,
- \( F R_{t} \) for the Central Bank’s net Foreign assets,
- \( ex_{t} \) for formal exchange rate,
- \( M_{t} - M_{t-1} \) for Monetary growth rate,
- \( R C B_{t} \) for the change in the Central Bank Reserves due to change in exchange rate. Meanwhile, foreign reserves will be defined as follows:

\[ ex_{t} F R_{t} = ex_{t-1} F R_{t-1} + Y_{t}^{ex} - Y_{t}^{m} \]  

(81)

The Central Bank’s foreign assets accumulation consists of foreign assets in the previous period \( \left( F R_{t-1} \right) \) plus exports \( \left( ex_{t} o r F R_{t} \right) \) for oil and \( Y_{a,t}^{ex} \) for agriculture minus imports (including agriculture \( Y_{a,t}^{m} \),  non-agriculture \( Y_{a,t}^{m} \)).

In Iran’s economy, it is assumed that money growth rate is a monetary policy instrument, because the interest rate is controlled. In addition, the policymakers enjoy great discretion in formulating monetary policy based on monetary growth rate, in order to achieve their policy objectives, namely, reducing the deviation of production from potential production and deviation of inflation from inflation target (Manzoor and Taghipour, 2015).

\[ \dot{m}_{t} = \rho_{m} \dot{m}_{t-1} + \lambda^{m} \left( \pi_{t}^{m} - \pi_{t}^{m} \right) + \lambda^{x} \left( y_{t} - y_{t} \right) + \epsilon_{m}^{m} \]  

(82)

Meanwhile, monetary growth rate will be defined by:

\[ m_{t}^{*} = \dot{m}_{t} - \dot{m}_{t-1} + \pi_{t} \]  

(83)

Equation (82) assumes that inflation target \( \left( \pi_{t}^{m} \right) \) follows the AR(1) process too.

\[ \log(\pi_{t}^{m}) = \rho_{m} \log(\pi_{t-1}^{m}) + (1 - \rho_{m}) \log(\pi_{t}^{m}) + \epsilon_{m}^{m} \]  

(84)

\( u_{t}^{m} \) stands for the monetary impulse and is assumed to follow the AR(1) process:

\[ \log(u_{t}^{m}) = \rho_{u} \log(u_{t-1}^{m}) + (1 - \rho_{u}) \log(u_{t}^{m}) + \epsilon_{u}^{m} \]  

(85)

The Central Bank reacts to deviation of inflation rate from inflation target, deviation of GDP from the balance rate, and deviation of real exchange rate from balanced rate (Manzoor and Taghipour, 2015).

\[ \frac{\Delta e_{x,t}}{\Delta e_{x}} = \left( \frac{\Delta e_{x,t-1}}{\Delta e_{x}} \right)^{\kappa_{1}} \left( \frac{\pi_{t}^{i}}{\pi_{0,t}^{i}} \right)^{\kappa_{2}} \left( \frac{FR_{t}}{M_{t}} \right)^{\kappa_{3}} \epsilon_{x,t}^{e} \]  

(86)

Where,

- \( e_{x,t} \) stands for the change in formal exchange rate, \( \pi_{t}^{i} \) for the consumer inflation rate, \( \pi_{0,t}^{i} \) for foreign inflation rate, and \( M_{t} \) for the Central Bank’s net Reserves-Money ratio. Based on actual exchange rate, Equation (90) will become:

\[ \frac{\Delta e_{x,t}}{\Delta e_{x}} = \left( \frac{\Delta e_{x,t-1}}{\Delta e_{x}} \right)^{\kappa_{1}} \left( \frac{\pi_{t}^{i}}{\pi_{0,t}^{i}} \right)^{\kappa_{2}} \left( \frac{fr_{t}}{m_{t}} \right)^{\kappa_{3}} \epsilon_{x,t}^{e} \]  

(87)

\section*{Solving DSGE Model}

\subsection*{The Data Used}

Time series data for 1971-2012 for the following variables (at constant prices of 2011) is used to estimate the model: output gap, agricultural production, rural household consumption, agricultural investment, agricultural exports, agricultural imports, and inflation. Since the cyclic component of time series data is used in DSGE models, it is separated by Hodrick-Prescott filter (using
Effects of Oil Price Shocks on Agricultural Sector

EViews software and $\lambda = 100$). All variables in the model are defined as the logarithm deviation from their stable value. Inflation and money growth rate are obtained from the logarithm of the ratio of these variables to their prior values.

**Steps of Estimation DSGE**

DSGE models are formulated and estimated in six stages. In step 1 (methodology), we describe the model framework including defining the problem, model equations and its constraints. First-Order Conditions (FOCs) are obtained through optimization in step 2. The steady state model is extracted in step 3 (Table 1). In step 4, the first-order conditions and constraints must be log-linear.

In step 5 the model dynamics is resolved using Blanchard and Kahn method (1980). Differential equations are solved using Bayesian approach in step 6.

**BVAR Estimation**

As noted, the Bayesian approach is used to estimate the DSGE model. First, we must determine the prior distribution, mean and standard error of the parameters. Prior distribution of each parameter is selected based on its characteristics and desired distribution characteristics. For example, the Beta distribution is characterized by three parameters: mean standard error, and lower and upper bounds. Bayesian method commonly uses four distributions: Gamma, Normal, Beta and Inverse Gamma.

Bayesian methods are used to calculate the maximization of likelihood of observed variables (real variables) as well as the posterior distributions. Mode of posterior distribution and Hessian matrix are calculated using the Markov Chain Monte Carlo method (MCMC). Metropolis Hastings Sampling is used to draw the posterior distribution (Asgari et al., 2015). The Metropolis-Hastings sampling is used with 10 blocks and 1.5 million harvests per block. Results are shown in Table 2.

Diagnostic tests such as Brooks-Gelman and acceptance rate indicate the desirability of the results. The acceptance rate of each block is in the range of 0.2-0.4. Also, the variances within the chains (blue curve) approach the variances between chains (red curve) and then converge.

**DISCUSSION**

In this paper, the effects of oil price shocks on macroeconomic variables in agriculture sector (production, consumption, imports, exports, employment and inflation) are studied. To do this, we examine Impulse Response Functions (IRFs) which show the dynamic behavior of variables over time. In fact, they provide an analysis of macroeconomic variables’ responses to exogenous shocks.

Higher oil prices increase oil revenues which enhance the government’s investment. Following the government’s investment in agriculture, as expected, the agricultural production ($ya$) will increase by 0.14 percent in the short-run. In pursuit of agricultural production, demand for labor force will only increase 0.43 percent and, in turn, the wages of labor force will grow by 4.86 percent.

Higher oil prices increase oil revenues which, in turn, will reduce real exchange rate. Since the real exchange rate represents the competitiveness of an economy, lower real exchange rates reduce the prices of imported goods and increase their competitiveness in domestic markets, and finally increase imported goods.

As Figure 1 shows, higher oil prices negatively affect agriculture via lower exchange rates which, in turn, decrease agricultural exports (1.8 percent). As agricultural production and competitiveness decrease, imports of the same increase (0.94 percent). As agricultural imports increase and agricultural exports decrease, the supply of agricultural products goes up and cuts
inflation by 0.51 percent. According to Euler equation, lower inflation increases consumption by 2 percent. However, lower inflation is not stable and will increase again. A negative consequence of higher oil prices is their effect on private investment in agriculture. Due to expected higher capital efficiency in non-tradeables, private investment in this sector decreases by 20 percent.

Figure 1 also shows that the long-run effects of higher oil prices are lower agricultural production (2 percent) and exports (4 percent), lower employment (2 percent), lower private investment (5 percent), and higher imports (2.5 percent).

Higher oil prices in Iran’s economy during 2006-2010 and their effects on Iran’s agriculture support our results.

**CONCLUSIONS**

Today, DSGE models are used to evaluate economic policies. In this study, within the framework of Keynesian economics, we developed a multi-sector DSGE model for Iranian economy. Formulation of a multi-sector DSGE model with an emphasis on agriculture is among the few works done in the world. Inclusion of agriculture, separation of urban and rural households,
The model consists of three sectors: agriculture, non-agriculture, and oil. It is used to investigate the oil price increases. One of the crucial factors that impact the real economy is the shocks of rising oil prices. They weaken real economy sectors and strengthen the non-tradable sectors.

In the short-run, increasing oil prices have negative impacts on agricultural production, and strengthen the non-tradable sectors.

Table 2. Prior and posterior distributions of parameters.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Prior distribution</th>
<th>Posterior distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount factor</td>
<td>Beta</td>
<td></td>
</tr>
<tr>
<td>Inverse of the elast. of money</td>
<td>Gamma</td>
<td></td>
</tr>
<tr>
<td>Intertemporal elast. of subst.</td>
<td>Gamma</td>
<td></td>
</tr>
<tr>
<td>Inverse of the elasticity of work effort</td>
<td>Gamma</td>
<td></td>
</tr>
<tr>
<td>Elast. of subst. between goods</td>
<td>Gamma</td>
<td></td>
</tr>
<tr>
<td>Elast. of subst. home and foreign goods (Agri.)</td>
<td>Gamma</td>
<td></td>
</tr>
<tr>
<td>Elast. of subst. home and foreign goods (Non-agri.)</td>
<td>Gamma</td>
<td></td>
</tr>
<tr>
<td>Elast.of subst. agri. and non-agri.</td>
<td>Gamma</td>
<td></td>
</tr>
<tr>
<td>Fraction of non-agri. Firms not adjust price</td>
<td>Beta</td>
<td></td>
</tr>
<tr>
<td>Capital elast. in non-agri. production</td>
<td>Gamma</td>
<td></td>
</tr>
<tr>
<td>Labor elast. in non-agri. production</td>
<td>Gamma</td>
<td></td>
</tr>
<tr>
<td>Energy elast. in non-agri. production</td>
<td>Gamma</td>
<td></td>
</tr>
<tr>
<td>Fraction of agri. firms not adjust price</td>
<td>Beta</td>
<td></td>
</tr>
<tr>
<td>Capital elast. in agri. production</td>
<td>Normal</td>
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<tr>
<td>Energy elast. in agri. production</td>
<td>Normal</td>
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<tr>
<td>Elast. of subst. between fertilizer and oil energy in agri.</td>
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<td></td>
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<tr>
<td>Elast. of subst. home and foreign goods (Fertilizer.)</td>
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<tr>
<td>Elast. of agri. export</td>
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<tr>
<td>Elast. of subst. labor and reserves in oil sector</td>
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<td></td>
</tr>
<tr>
<td>AR(1) coefficient (Agri. productivity)</td>
<td>Beta</td>
<td></td>
</tr>
<tr>
<td>AR(1) inflation coefficient (Monetary reaction function)</td>
<td>Beta</td>
<td></td>
</tr>
<tr>
<td>AR(1) production coefficient (Monetary reaction function)</td>
<td>Beta</td>
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<tr>
<td>AR(1) coefficient (Monetary shock)</td>
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<td>AR(1) coefficient (World production of agricultural)</td>
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<td>AR(1) coefficient (Net government debt)</td>
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<td>AR (1) coefficient (Energy use in non-agri.)</td>
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<td>AR(1) coefficient (Agri. import price)</td>
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<td>AR(1) coefficient (Non-agri. import price)</td>
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<td>AR (1) coefficient (Gov. consumption.)</td>
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<tr>
<td>AR(1) coefficient (Non-agri. Productivity)</td>
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<td>AR(1) coefficient (Oil price)</td>
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<tr>
<td>AR(1) coefficient (Money demand)</td>
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<td>AR(1) coefficient (Oil revenue)</td>
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<td>AR(1) coefficient (Target inflation)</td>
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<td>AR(1) coefficient (Gov. expenditure)</td>
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<tr>
<td>AR(1) exchange rate coefficient (In the reaction function of Central Bank)</td>
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<tr>
<td>AR(1) Inflation coefficient (Central Bank’s reaction function)</td>
<td>Normal</td>
<td></td>
</tr>
<tr>
<td>AR(1) foreign reserves coefficient (Central Bank’s reaction function)</td>
<td>Normal</td>
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</tbody>
</table>

Source: Research results.

inclusion of oil sector for analyzing the effects of Dutch disease, and reconsidering the economy for analyzing the effects of foreign shocks are among the innovations of this study.

The model consists of three sectors: agriculture, non-agriculture, and oil. It is used to investigate the oil price increases. One of the crucial factors that impact the real economy is the shocks of rising oil prices. They weaken real economy sectors and strengthen the non-tradable sectors.

In the short-run, increasing oil prices have negative impacts on agricultural production.
investment, consumption and exports. In response to the positive shocks in oil prices, agricultural imports will increase because the shocks reduce the competitiveness of agricultural production.

The results show the negative impacts of Dutch disease on tradable sectors, such as agriculture. Proper management of oil revenues is thus essential at the time of soaring oil prices. Unfortunately, the Iranian governments have not been able to properly manage the oil revenues.

Iran’s monetary and financial policies are set with an eye to oil revenues. Higher foreign exchange revenues, resulting from oil sale and through higher foreign assets of the Central Bank, increase the monetary base which, in turn, will enhance liquidity and inflation. Meanwhile, an equivalent amount of foreign exchange earned through oil exports will enter the economy in the form of government expenditure. Therefore, financial policies, which are largely based on the government’s expenditure, rely on the foreign exchange revenues earned because of higher oil prices. Interestingly, when positive shocks in oil prices occur, the government makes vast investments without paying attention to the median-term horizon of these revenues. If these revenues decrease, the projects cannot be completed. Considering the above statements, a sound management of foreign exchange revenues at the time of oil boom is necessary.

Please put the references in alphabetic order

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Effects of Oil Price Shocks on Agricultural Sector

اثرات افزایش قیمت نفت بر متغیرهای کلان بخش کشاورزی با استفاده از مدل تعادل عمومی پویای تصادفی

چکیده

در این مقاله مدل تعادل عمومی پویای تصادفی ایران تذیه شده است. در این مدل اقتصاد به سه بخش کشاورزی، غیرکشاورزی و نفت تقسیم شده است. به علاوه به دلیل ورود صادرات و واردات، مدل به صورت بی وابسته درآمده است. برای اطمینان از انتقال آن با اقتصاد ایران چسبندگی قیمت نیز به مدل داده‌های شده است. سپس آثار افزایش قیمت نفت بر بخش کشاورزی بررسی شد. برای اینکار از داده‌های سال‌های 91-1383 (به قیمت ثابت سال 1383) با استفاده شد و مدل با روش بیزین برآورد گردید.

نتایج نشان می‌دهند که افزایش قیمت نفت به شدت تاثیر منفی بر متغیرهای کلان بخش کشاورزی دارد و اثر بیماری هنگی بر بخش کشاورزی تأیید می‌گردد.