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Agricultural Economic Dynamics in a Bayesian DSGE Model for Iran

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Abstract

Iran's economy is suffering from sharp and persistent economic shocks and agriculture plays an undeniable role in its economic growth and development. The aim of this paper is to study the relative contributions of various macroeconomic shocks to generating fluctuations in Iran's agriculture sector. To do so, a Dynamic Stochastic General Equilibrium (DSGE) model, emphasizing on the agricultural sector, is developed. The model is estimated with Bayesian techniques using 9 macroeconomic variables. The findings indicate that agricultural productivity shock is the main driver of the economic fluctuations in the sector. Monetary shock and, to a lesser extent, government spending, preference and labor supply shocks, however, play an important role in agricultural dynamics. The two other shocks considered (oil revenue and money demand) are of less importance relatively. The historical decomposition shows after 2009, when imposed economic sanctions against Iran increase, the monetary shock becomes one of the main sources in explaining agricultural fluctuations. The results further confirm the symptoms of Dutch Disease (DD) in Iran's agriculture.

Keywords: Agricultural Sector, Macroeconomic Shocks, DSGE Model, Bayesian Techniques, Iran**.**

JEL Classification: C69, N5.

1. Introduction

What are the main driving forces behind agricultural fluctuations? This is a crucial question for a country, like Iran, that is suffering from sharp and persistent economic shocks and agriculture plays an undeniable role in its economic growth and development. However, the lack of studies

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investigating agricultural dynamics through the use of an estimated theoretical framework is quite baffling. Knowing the contributions of exogenous shocks to the economic fluctuations along with analyzing the reactions of the main economic variables to the shocks allow policymakers to adopt proper policies and forecast the full impact of their decisions. Furthermore, understanding the dynamic effects offers important information for investors to construct portfolio strategies and contribute to a more efficient allocation of scarce resources among different economic sectors (Ramey, 2016). Agriculture plays a fundamental role in the development of Iran's economy by providing 85% of the food needed by the population and 90% of the raw materials needed to feed industries. In 2014, based on *Iran's central bank* publications, agriculture contributed 13.9% to the country's GDP, 22% to employment and 25% to exports of non-oil goods. Agriculture also acts as a source of income to a large proportion of rural households and a market for industrial products. In recent years, due to the international sanctions against Iran's economy, much attention has been paid to the domestic economic capacities and agriculture in particular. Although there exists a large body of literature that investigate the relative contributions of different shocks in driving macroeconomic and sectoral fluctuations (Goncalves et al., 2016; Martin-Moreno et al., 2016; Lee and Song, 2015; Kamber et al., 2016; Rasaki and Malikane, 2015), few have examined such relationships in agricultural sector. However, the available studies associated with agricultural economic dynamics have mostly investigated the responses of some agricultural variables (especially agricultural prices) to one or, to a lesser extent, more than one shock (with a special focus on energy, productivity, and monetary shocks) using vector autoregressive (VAR) based models mainly. For instance, Zhang et al. (2015), Wang et al. (2014), Harri and Hudson (2009) and Serra (2011) investigate the responses of agricultural commodity prices to oil shocks. Ling Wang and McPhail (2014), examine the impacts of energy price shocks on U.S. agricultural productivity growth and commodity prices' volatility. Fuglie (2008) stresses on productivity shocks and agricultural prices. Apere and Karimo (2015) investigate the transmission channel of monetary policy shocks to agricultural output. Hashemi (2014) examines exchange rates, inflation, and monetary shocks on agricultural prices. Torkamani and Parizan

(2006) investigate the effects of monetary policy and exchange rate shocks in the relative agricultural prices. Qiu et al. (2012) examine how supply/demand structural shocks affect food and fuel markets. Perez and Siegler (2006), using graph-theoretic methods, focus on agricultural and monetary shocks. Janjua and Javid (1998) investigate the role of some exogenous shocks on fixed investment in Pakistan's agricultural sector, by Implicit Dynamics Benchmark Model (IDBM). Regarding Computable General Equilibrium (CGE) models, analyzing more dynamics relatively, we can point out the following studies: Gunawardena (2012) evaluates the contribution of agricultural Productivity shock to the volatility in different sectors including agriculture. Similar studies have been done by Arndt et al. (2000) and Bautista (1986). Hanson et al. (1993) estimate the effects of a world oil price shock on the U.S. agriculture economy. Karingi and Siriwardana (2003) analyze the effects of adjustment to terms of trade shocks on agriculture and income distribution in Kenya. Accordingly, one can hardly find a study investigating the relative contributions of a set of various economic shocks to the fluctuations in agricultural variables. What are the main drivers of agricultural output, consumption, investment, and employment? What is the contribution of preference or money demand shocks relative to monetary shock to agricultural price changes? How much of the volatility in agricultural consumption can be attributed to productivity, oil revenue, money demand, and government spending shocks? Such issues have not been addressed in the literature. The main purpose of this paper is to examine the role of a rich set of macroeconomic shocks (including agricultural productivity, monetary, government spending, preference, oil revenue, money demand, and labor supply) in generating fluctuations in Iran's agriculture as a small open economy. Besides, we study the impulse response functions (IRfs) of the sector to the main driving forces. This study also contributes to the literature by formulating and estimating a Dynamic Stochastic General Equilibrium (DSGE) model for Iran's economy emphasizing the agricultural sector. To the best of our knowledge, this is the first paper that disaggregates agriculture through a DSGE model and determines the main drivers in agricultural fluctuations.

2. Materials and Methods: The General Model

A DSGE model is constructed from a micro foundation under which economic agents, such as households, firms, and governments, behave optimally in allocating their resources and developing rational expectations, and a number of exogenous stochastic shocks are regarded as factors that affect the fluctuations in variables. The baseline model, in this study, is a small open economy DSGE model, with price rigidities, capital accumulation, investment adjustment cost, and habit formation, emphasizing on the agricultural sector.

2.1 Households

A representative household maximizes the expected stream of discounted instantaneous utilities by choosing the amount of consumption goods to buy, C_t, labor to supply, l_t, and real money balances to hold, $\frac{M_t}{P_t}$. The utility is given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t \xi_{b,t} \left\{ \frac{(C_t - hC_{t-1})^{1-\sigma_c}}{1-\sigma_c} + \xi_{m,t} \frac{(\frac{M_t}{P_t})^{1-\sigma_m}}{1-\sigma_m} - \xi_{l,t} \frac{(l_t)^{1-\sigma_l}}{1-\sigma_l} \right\}$$

Where $\beta \epsilon (0, 1)$ is the intertemporal discount factor, E is expectation operator, h is the degree of habit formation and P_t is an aggregate price index. The inverse elasticity of intertemporal substitution of consumption, the inverse elasticity of money demand, and the inverse elasticity of Fritch labor supply are denoted by σ_c, σ_m and σ_l respectively. $\xi_{b,t}$ $\xi_{l,t}$ and $\xi_{m,t}$ are three shocks: general preference shock, labor supply shock, and money demand shock, respectively, which obey the following AR (1) process:

$$\xi_{\epsilon,t} = \rho_{\epsilon,t}\xi_{\epsilon,t-1} + \varepsilon_{\epsilon,t}, \text{for } \epsilon = b, l \text{ and m} \quad (1)$$

Total consumption is defined over constant elasticity of substitution (CES) aggregator:

$$C_t = [\alpha_c{}^{1/\omega_c} c_{na,t}{}^{(\omega_c-1)}/_{\omega_c} + (1-\alpha_c)^{1/\omega_c} c_{ag,t}{}^{(\omega_c-1)}/_{\omega_c}]^{\frac{\omega_c}{\omega_c-1}} \quad (2)$$

Where $c_{na,t}$ is non-agricultural goods and $c_{ag,t}$ is agricultural goods, α_c is the proportion of non-agricultural goods in consumption and ω_c is the elasticity of intertemporal substitution between agricultural and non-agricultural goods. The overall consumer price index is given as:

$$P_t = [\alpha_c P_{na,t}{}^{1-\omega_c} + (1-\alpha_c) P_{ag,t}{}^{1-\omega_c}]^{\frac{1}{1-\omega_c}} \qquad (3)$$

Where $P_{na,t}$ is a non-agricultural price index and $P_{ag,t}$ is an agricultural price index.

We also assume that l_t follows a Cobb-Douglas technology: $l_t = l_{na,t}^{\omega_{lna}} l_{ag,t}^{\omega_{lag}}$, Where $l_{na,t}$ and $l_{ag,t}$, respectively, represent non-agricultural and agricultural labor. ω_{lna} and ω_{lag}, respectively, denote the share of non-agriculture and agriculture labor in labor supply where $\omega_{lna} + \omega_{lag} = 1$. The reprehensive household enters in period t with holdings of domestic bonds B_{t-1} at a price that depends on the interest rate, r_t. During period t, the household pays a lump-sum tax, T_t, to government and receive lump-sum transfers,TR_t. It, also, in period t, earns nominal wages, $W_{na,t}$ and $W_{ag,t}$ for their labor supply, respectively in the non-agricultural and agricultural sectors and receives dividend payments from sectors, $D_t = D_{na,t} + D_{ag,t}$. At last, the household accumulates $k_{na,t}$ and $k_{ag,t}$ units of non-agricultural and agricultural capital for a nominal rental $R_{na,t}$ and $R_{ag,t}$ respectively. The evolution of capital stock in each sector is given by:

$$k_{j,t+1} = (1-\delta)k_{j,t} + i_{j,t} - \Psi_j(k_{j,t+1}, k_{j,t}), \text{for } j = na, ag \qquad (4)$$

Where δ is the depreciation rate of capital that is common to all sectors and $\Psi_j(k_{j,t+1}, k_{j,t})$ is a capital-adjustment cost that following Ireland (2003) is given by:

$$\Psi_{j,t}(0) = \frac{\psi_j}{2}(\frac{k_{j,t+1}}{k_{j,t}} - 1)^2 k_{j,t}, \text{for } j = na, ag \qquad (5)$$

Each household's spending equals income, so the budget constraint is as follows:

$$P(C_t + i_t) + \frac{B_t}{r_t} + M_t = B_{t-1} + M_{t-1} + \sum_{j=na,ag} R_{j,t}k_{j,t} + \sum_{j=na,ag} W_{j,t}l_{j,t} + TR_t - T_t + D_t \quad (6)$$

Total investment in both sectors is given by: $P_t i_t = P_{na,t} i_{na,t} + P_{ag,t} i_{ag,t}$. The household maximizes its utility subject to the budget constraint and the law of motion for capital.

2.2 Non-agricultural Firms

The firms that are involved in the production of finished non-agricultural goods make use of constant returns-to-scale production technology where the i intermediate goods serve as the only inputs. Hence, the quantity of finished goods that are produced is determined by the expression:

$$Y_{na,t} = (\int_0^1 (Y_{na,t}(i))^{\frac{\theta-1}{\theta}} di)^{\frac{\theta}{\theta-1}} \quad (7)$$

Here $Y_{na,t}$ denotes the final non-agricultural good, $Y_{na,t}(i)$ denotes the differentiated intermediate goods and θ represents the elasticity of substitution between intermediate goods. The demand for the differentiated product of the ith firm, $Y_{na,t}(i)$, follows:

$$Y_{na,t}(i) = (\frac{P_{na,t}(i)}{P_{na,t}})^{-\theta} Y_{na,t} \quad (8)$$

Where $P_{na,t}(i)$ denotes the price of the differentiated good i. There is a continuum $i \in [0,1]$ of intermediate goods producers operating in a monopolistically competitive market that transform the homogeneous input from labor service, $l_{na,t}(i)$, and capital, $k_{na,t}(i)$, (rented from households) into a differentiated output, paying the salary $W_{na,t}(i)$, and capital rental rate $R_{na,t}(i)$. The production function is given by the following technology:

$$Y_{na,t}(i) = A_{na,t} k_{na,t}^{\alpha_{na}}(i) l_{na,t}^{1-\alpha_{na}}(i) \tag{9}$$

Where $A_{na,t} = \rho_{na} A_{na,t-1} + \varepsilon_{na,t}$ is a stationary technology shock common for all firms and α_{na} is the share of capital in production. To maximum its profits the producer chooses $k_{na,t}(i)$ and $l_{na,t}(i)$ and also, set its (optimal) price, $\widetilde{P}_{na,t}$, as in Calvo (1983) and Yun (1996). The non-agricultural firms' profit maximization problem is given as follows:

$$\max_{k_{na,t}(i), l_{na,t}(i), P_{na,t}(i)} E_0 \sum_{s=0}^{\infty} [(\beta \varphi_{na})^s \lambda_{t+s} D_{na,t+s}(i)/P_{t+s}] \tag{10}$$

Subject to (8) and (9)

Where $D_{na,t+s}(i) = \pi^s \widetilde{P}_{na,t}(i) Y_{na,t+s}(i) - R_{na,t+s} k_{na,t+s}(i) - W_{na,t+s} l_{na,t+s}(i)$ is profit function, $(\beta^s \lambda_{t+s})$ is the producer' discount factor and λ_{t+s} is the marginal utility of consumption in period $t + s$. The optimal pricing condition by the maximization of (10), after some manipulating, yields the following real non-agricultural price index (see Benkhodja, 2011):

$$p_{na,t} = [\varphi_{na}(\pi \frac{P_{na,t-1}}{\pi_t})^{1-\theta} + (1-\varphi_{na})(\widetilde{P}_{na,t})^{1-\theta}]^{\frac{1}{1-\theta}} \tag{11}$$

2.3 Agricultural Firms

We assume the agricultural sector is perfectly competitive because it is characterized by many small producers with virtually no ability to alter the selling price of their products and present it by a single firm because firms are too small to influence the behavior of other firms, and they are symmetric in equilibrium. Competitive agricultural firm's production function is given as:

$$Y_{ag,t} = A_{ag,t}(k_{ag,t})^{\alpha_{ag}}(l_{ag,t})^{1-\alpha_{ag}} \tag{12}$$

Definitions of the variables and parameters are as similar as those of the former section but for the agricultural sector. The firm maximizes the expected present value of its profits:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \Lambda_t [(P_{ag,t} Y_{ag,t} - R_{ag,t} k_{ag,t} - W_{ag,t} l_{ag,t})/P_t] \qquad (13)$$

Subject to (12)

Where Λ_t is the shadow price of wealth and β^t is the time preference. Denoting by $\Gamma_{ag,t}$ the Lagrange multiplier on the production function (i.e. the nominal marginal cost).

2.4 Importing Firms

The final imported good, $Y_{M,t}$, is a composite of differentiated imported goods, $Y_{M,t}(i)$, produced by a continuum of monopolistic domestic importers. Analogous to obtaining the real non-agricultural price index, the following real import price index is obtained:

$$p_{M,t} = [\varphi_M (\pi \frac{P_{M,t-1}}{\pi_t})^{1-\theta} + \left(1 - \varphi_M\right) \widetilde{P}_{M,t})^{1-\theta}]^{\frac{1}{1-\theta}} \qquad (14)$$

2.5 Final Good Producer

The producer of the final good, operating under perfect competition, combines non-agricultural and agricultural outputs, which are domestically produced (home goods), and imports, $Y_{M,t}$, using the following CES technology:

$$V_t = [\gamma_{na}^{\frac{1}{\vartheta}} Y_{na,t}^{\frac{\vartheta-1}{\vartheta}} + \gamma_{ag}^{\frac{1}{\vartheta}} Y_{ag,t}^{\frac{\vartheta-1}{\vartheta}} + \gamma_{M}^{\frac{1}{\vartheta}} Y_{M,t}^{\frac{\vartheta-1}{\vartheta}}]^{\frac{\vartheta}{\vartheta-1}} \qquad (15)$$

Where ϑ is the elasticity of substitution between non- agricultural, agricultural and imported goods and γ_{na}, γ_{ag} and γ_M,respectively, denote their corresponding shares in the final good. Profit maximization yields demand functions. The zero-profit condition leads to the price of final good:

$$P_t = [\gamma_{na} (P_{na,t})^{1-\vartheta} + \gamma_{ag} (P_{ag,t})^{1-\vartheta} + \gamma_M (P_{M,t})^{1-\vartheta}]^{\frac{1}{1-\vartheta}} \qquad (16)$$

2.6 Exporting Firms

There is a continuum j ϵ (0, 1) of exporting firms that buy a homogeneous good on the domestic market and transform it into a differentiated good to be sold on the foreign market. Since Iran is a price taker country in world markets (price competitiveness does not play a role) and exports evolve according to the export demand we can simplify the model exports as:

$$X_t = (1 - \rho_x)X + \rho_x X_{t-1} + \varepsilon_{x,t} \quad (17)$$

where X is the steady-state value of exports.

2.7 Monetary Policy

Following Clarida et al. (2000) the monetary authority sets policy according to:

$$\ln\left(\frac{r_t}{r}\right) = \rho_r \ln\left(\frac{r_{t-1}}{r}\right) + (1 - \rho_r)[\rho_\pi \ln\left(\frac{\pi_t}{\pi}\right) + \rho_y \ln\left(\frac{Y_t}{Y}\right)] + \ln(\xi_{\mu,t}) \quad (18)$$

Where ρ_r, ρ_π, and ρ_Y measure the policy responses to nominal interest rate gap, inflation and output respectively and r , π and Y are the corresponding steady-state values. The monetary policy shock, $\xi_{\mu,t}$, follows an AR (1) process: $\xi_{\mu,t}= \rho_\mu \xi_{\mu,t-1} + \varepsilon_{\mu,t}$.

2.8 Model Closure

In addition to the equations presented above, a market-clearing condition is needed to complete the model:

$$Y_t = C_t + i_t + G_t + X_t + oil_t - Y_{M,t} \quad (19)$$

$$Y_t = Y_{na,t} + Y_{ag,t} \quad (20)$$

where government spending, G_t, and oil revenue, oil_t, are assumed to be exogenous with steady-state value G and oil:

$$G_t = \left(1 - \rho_g\right)G + \rho_g G_{t-1} + \varepsilon_{g,t} \quad (21)$$

$$oil_t = (1 - \rho_{oil})oil + \rho_{oil} oil_{t-1} + \varepsilon_{oil,t} \quad (22)$$

3. Data and Estimation

The log-linearized DSGE model contains 41 structural equations with 33 parameters, which include 9 AR (1) processes. The structural parameters are estimated with Bayesian techniques using Iran yearly data over the period of 1994 – 2014. Nine observable variables are used during estimation including: the output (Y_t) is the real GDP, the non-agricultural output ($Y_{na,t}$) and the agricultural output ($Y_{ag,t}$) are the real value-added in non-agricultural and agricultural sectors respectively, the agricultural labor ($l_{ag,t}$) is the employment in the agricultural sector, the inflation series (π_t) is a consumption price index (CPI) inflation rate, the real government spending (G_t) is all government consumption, investment, and transfer payments, the real oil revenue (oil_t) is the export value of crude oil, natural gas, and petroleum products, the real exports (X_t) is all non-oil exports' value and the real imports ($Y_{M,t}$) is all imported goods' values. To fit the model to data all the nine-time series are log-transformed and Hodrick-Prescott (HP) filtered (λ=1600) except for the inflation rate that is just HP filtered. The sources of data for this paper are the World Bank database and the statistical *center of Iran* (ISC). We use Dynare 4.2.2 for model estimation.

4. Calibration and Priors

We calibrate eleven parameters prior to estimation, consistent with standard practice in Bayesian estimations. This is because the data used in the estimation do not contain information about these parameters or they are better identified using other information. To ensure the accuracy of their influence in the model, we used different values for these parameters. Table 1 summarizes the values of the calibrated parameters. We set the discount factor, β, to 0.966, consistent with studies done for Iran, gives an annual steady-state real interest rate around 3.5%. The depreciation rate of capital, δ, is fixed at 0.039% and this value is common to both the sectors. The share of capital in the non-agriculture production, α_{na}, and that in the agricultural production, α_{ag}, are calibrated at 0.44 and 0.38 respectively, to match the average ratios observed in the Iran data for the 1994-2014 period. The share of non-agriculture goods in the consumption basket, α_c, is set at 0.69 on average during the selected period. We set the share of labor for the non-agricultural sector, ω_{lna}, and the agricultural sector, ω_{lag}, to 0.81 and 0.19 respectively, matching the average shares of labors in the two sectors in Iran over the sample span considered. The share of non- agricultural, γ_{na}, agricultural, γ_{ag}, and imported goods, γ_M, in the production of final goods are set equal to 0.51, 0.16 and 0.33 respectively. These values are chosen given that the value of the average ratio of both imports and agricultural good production to the GDP of Iran's economy. The inverse elasticity of the intertemporal substitution of labor, σ_l, is calibrated at 2.91, as in Tavakolian and Ebrahimi (2012).

Table 1: Calibrated Parameters

Parameters	Description	values
β	Discount factor	0.966
δ	The depreciation rate of capital	0.039
α_{na}	Share of capital in non-agricultural production	0.44
α_{ag}	Share of capital in agricultural production	0.38
α_c	Share of non-agricultural goods in consumption	0.69
ω_{lna}	Share of non-agricultural labor in labor supply	0.81
ω_{lag}	Share of agricultural labor in labor supply	0.19
γ_{na}	Share of non-agricultural goods in final goods	0.51
γ_{ag}	Share of agricultural goods in final goods	0.16
γ_M	Share of imported goods in final goods	0.33
σ_l	Inverse elasticity of the labor intertemporal substitution	2.91

The remaining parameters are estimated. To reflect our beliefs about the parameters, we specify prior distributions. Detailed descriptions of the prior distributions for structural DSGE parameters are summarized in columns 3-5 in Table 2. In selecting the prior distributions for the parameters to be estimated, we are guided by some studies available in the Iran literature, such as Manzour and Taghipoour (2015), Tavakolian (2013) and Tavakolian and Ebrahimi (2012) and evidences from previous studies for small open oil-exporting economies like Allegret and Benkhodja (2015), Dib (2008) and Benkhodja (2011). The habit formation parameter, h, is set to have a Beta distribution with a mean of 0.35 and a standard deviation of 0.02, in line with referenced literature for Iran. Priors for the inverse elasticity of intertemporal substitution of consumption, σ_c, and the inverse elasticity of money demand, σ_m, are drawn from Manzour and Taghipour (2015) so that they follow Gamma distribution of means 1.5 and 1.3 respectively, and standard deviations of 0.05. Prior means for Calvo price parameters (φ_{na} and φ_M), are assumed to follow Beta distribution centered at 0.2 with a standard deviation of 0.03, as in Tavakolian (2013). We use a Normal distribution for the capital adjustment costs in each sector (ψ_{na} and ψ_{ag}) with a mean of 4.5 and a standard deviation of 2, closed to Allegret and Benkhodja (2015). Following Dib (2008) and Allegret and Benkhodja (2015), we consider the parameter representing the degree of monopoly power in the intermediate good market, θ, is Normally distributed with a mean of 6, implying a 20 percent price-markup at the steady-state, and a standard deviation of 1. Due to lack of prior knowledge, we choose relatively diffuse priors for the elasticity of substitution between agricultural and non-agricultural goods, ω_c, and the elasticity of substitution between non-agricultural, agricultural and imported goods, ϑ, which follows Normal distribution with a mean of 2.5 and a standard deviation of 2.2. Turning to the Taylor rule parameters, consistent with the literature (Rudolf and Zurlinden, 2014; Semko, 2013; Hamedani and Pedram, 2013) we assume that the prior for inflation coefficient, ρ_π, has a Gamma distribution with a mean of 1.5 and a standard deviation of 0.05 and output coefficient, ρ_y, is Beta distributed with a prior mean of 0.6 and a standard deviation of 0.03. We also assume that the prior for the interest rate smoothing parameter, ρ_r, has a Beta distribution with mean 0.8 and a standard deviation of 0.02, fairly common in the literature. Lastly, all of the AR (1) coefficients (ρ's), reported in Table 3, are assumed to have a prior to Beta distribution with a standard deviation of 0.05. Also, priors for the standard deviations (σ's) of all shocks have an Inverse Gamma distribution with mean 0.1 and standard deviation of infinity.

5. Results and Discussion

5.1 Posterior Estimates

The last 3 columns in Table 2 present the posterior means and 95% probability intervals for the estimated structural parameters. The estimate of the habit formation parameter is, 0.32, close to the estimate of available studies for Iran, implying a moderate degree of habit formation. The inverse elasticity of consumption substitution and money demand estimated at 1.62 and 1.43 respectively, both are a bit higher when compared to Manzour and Taghipour (2015) estimated at 1.54 and 1.35. The estimated Calvo parameters in non-agricultural and import sectors are 0.26 and 0.18 respectively, indicating imported prices are re-optimized slightly more frequently than domestic prices which are line with referenced literature for Iran and opposite to Allegret and Benkhodja (2015). The posterior estimates of capital-adjustment cost parameters are 4.01 and 4.65 respectively in non-agricultural and agricultural sectors. These posterior means suggest that, in the non-agricultural sector, capital stock changing, can occur more quickly than in the agricultural sector. Our posterior mean of the degree of monopoly power in the intermediate good market is 4.27 which is slightly higher than Allegret and Benkhodja (2015) and dib (2008) estimated close to 4. With regard to the elasticity of substitution between agricultural and non-agricultural goods and the elasticity of substitution between the final good components, they exceed from their priors 2.5 to the posteriors 2.64 and 3.25 respectively. Considering the Taylor rule parameters, the estimation of inflation and output coefficients are 1.74 and 0.83 respectively that are somewhere in the middle of the range typically reported in the literature. Also, the interest rate smoothing parameter falls from the prior 0.8 to the posterior 0.71. As reported in Table 3, the autoregressive parameters (except ρ_{oil}) are estimated in the range of 0.63–0.79, pointing to a relatively high persistence. The shocks estimated to have the highest standard deviations are productivity and monetary shocks (1.75-1.40), giving an indication that these shocks may have big contributions to explaining the cyclical variations in the time series.

5.2 Model Fit

Having constructed a new DSGE model for Iran, it is important to evaluate the quality of the model. There are different ways to assess the empirical fit of the model. we consider two ways to do that. First, by comparing the second moments from the real date (the HP filtered data) and the results for the estimated model (the simulated data).

Table 2: Prior and Posterior Distribution for the Structural Parameters

Parameter	Description	Prior distributions			Posterior modes		
		Type	Mean	SD	Mean	SD	95%
h	Degree of habit	Beta	0.35	0.02	0.3225	0.0303	[0.2981,0.3437]
σ_m	Inverse elasticity of money demand	Gamma	1.30	0.05	1.4314	0.0627	[1.4081,1.4497]
σ_c	Inverse elasticity of consumption substitution	Gamma	1.50	0.05	1.6223	0.0521	[1.6175,1.6231]
φ_{na}	Calvo parameter- non-agri	Beta	0.20	0.03	0.2634	0.0251	[0.2462.0.2761]
φ_M	Calvo parameter-import	Beta	0.20	0.03	0.1881	0.0541	[0.1621,0.2119]
ψ_{na}	Capital adjustment-non-agri	Normal	4.50	2.00	4.0117	0.0503	[3.9825,4.0220]
ψ_{ag}	Capital adjustment-agri	Normal	4.50	2.00	4.6528	0.0489	[4.5581,4.7421]
θ	Intermediate goods-elasticity	Normal	6	1.00	4.2768	0.0320	[4.2681,4.2821]
ω_c	Non-agri and agri goods-elasticity	Normal	2.50	2.20	2.6454	0.0533	[2.6221,2.6581]
ϑ	Non-agri, agri and imported goods-elasticity	Normal	2.50	2.20	3.2507	0.0654	[3.2381,3.2623]
ρ_π	Inflation reaction coefficient	Gamma	1.5	0.05	1.7412	0.0621	[1.7296,1.7503]
ρ_y	Output reaction coefficient	Beta	0.6	0.03	0.8301	0.0436	[0.8115,0.8486]
ρ_r	Degree of the interest rate smoothing	Beta	0.8	0.02	0.7152	0.0564	[0.7032,0.7261]

Table 3: Prior and Posterior Distribution for Autoregressive Parameters

Parameter	Description	Prior Distributions			Posterior Modes		
		Type	Mean	SD	Mean	SD	95%
Persistence							
ρ_b	Preference	Beta	0.65	0.05	0.6842	0.0311	[0.6691,0.6951]
ρ_{na}	Non-agricultural technology	Beta	0.70	0.05	0.7235	0.0405	[0.7112,0.7331]
ρ_{ag}	Agricultural technology	Beta	0.75	0.05	0.7964	0.0309	[0.7892,0.8009]
ρ_m	Money demand	Beta	0.55	0.05	0.7838	0.0403	[0.7698,0.7953]
ρ_g	Government spending	Beta	0.45	0.05	0.6332	0.0310	[0.6194,0.6428]
ρ_{oil}	Oil revenue	Beta	0.35	0.05	0.4134	0.0501	[0.4022,0.4228]
ρ_μ	Monetary policy	Beta	0.60	0.05	0.6841	0.0330	[0.6709,0.6951]
ρ_l	Labor supply	Beta	0.65	0.05	0.7327	0.0116	[0.7202,0.7417]
ρ_x	Export	Beta	0.70	0.05	0.7852	0.0083	[0.7686,0.7991]
Standard Deviation							
ε_b	Preference	Inv. Gamma	0.1	Inf	0. 9694	0.0322	[0.9412,1.0188]
ε_{na}	Non-agricultural technology	Inv. Gamma	0.1	Inf	1.7542	0.1130	[1.7303,1.7761]
ε_{ag}	Agricultural technology	Inv. Gamma	0.1	Inf	1.6761	0.1203	[1.6503,1.6999]
ε_m	Money demand	Inv. Gamma	0.1	Inf	0. 3592	0.0317	[0.3361,0.3801]
ε_g	Government spending	Inv. Gamma	0.1	Inf	0.4964	0.0612	[0.4725,0.5177]
ε_{oil}	Oil revenue	Inv. Gamma	0.1	Inf	0.4286	0.0672	[0.4172,0.4377]
ε_μ	Monetary policy	Inv. Gamma	0.1	Inf	1.4016	0.1334	[1.3911,1.4087]
ε_l	Labor supply	Inv. Gamma	0.1	Inf	0.5632	0.0421	[0.5472,0.5768]
ε_x	Export	Inv. Gamma	0.1	Inf	0.4363	0.0634	[0.4143,0.4572]

Matching the second moments of the data and the estimated model is considered crucial for the evaluation of the model's empirical fit. Table 4 reports this natural robustness check for observable variables. These numbers show that the simulated moments (standard deviations and correlations) match the actual ones quite well. So the model is well-constructed to replicate volatility and cyclicality of the variables.

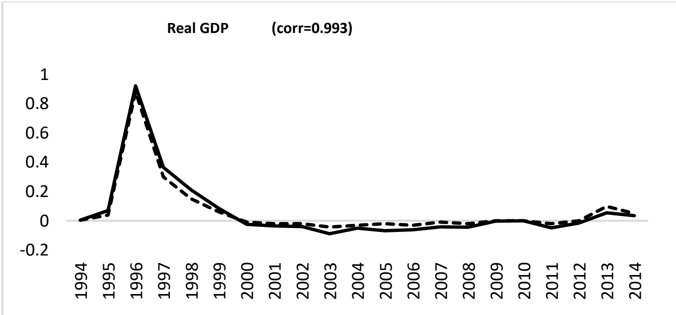
Table 4: Second Moments

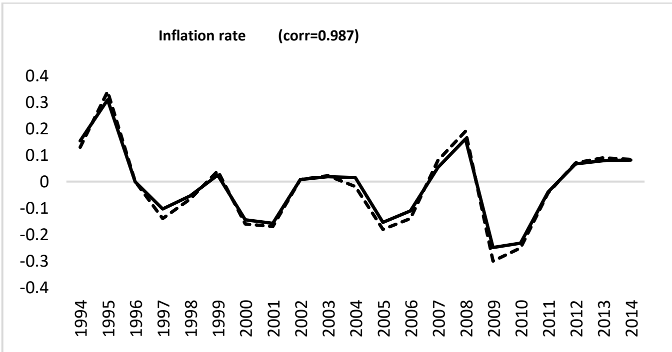
Standard Deviations			Correlations		
	Actual	**Simulated**		**Actual**	**simulated**
Real agricultural output ($\mathbf{Y_{ag,t}}$)	1.027	1.037	$Y.Y_{ag}$	0.742	0.831
Real non-agricultural output ($\mathbf{Y_{na,t}}$)	1.296	1.415	$Y.Y_{na}$	0.653	0.585
Agricultural labor ($\mathbf{l_{ag,t}}$)	0.585	0.528	$Y.oil$	0.556	0.648
Real GDP ($\mathbf{Y_t}$)	0.472	0.345	$Y.M$	0.512	0.574
Inflation rate ($\boldsymbol{\pi_t}$)	0.675	0.574	$Y.X$	0.786	0.833
Real export ($\mathbf{X_t}$)	2.134	2.271	$Y_{ag}.l_{ag}$	0.833	0.775
Real import ($\mathbf{M_t}$)	0.054	0.0478			
Real oil revenues ($\mathbf{oil_t}$)	1.212	1.350			
Government spending ($\mathbf{G_t}$)	0.872	0.937			

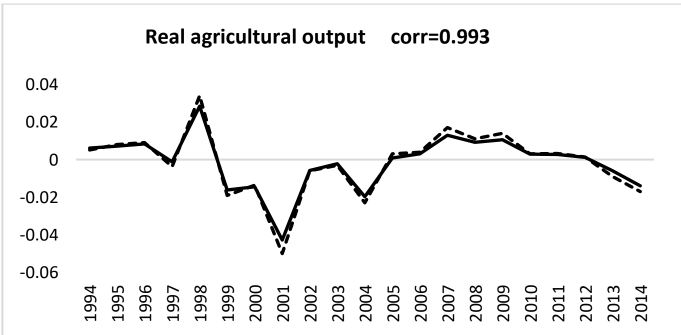
Note: The model's moments are simulated using the posterior mean values of the estimated parameters.

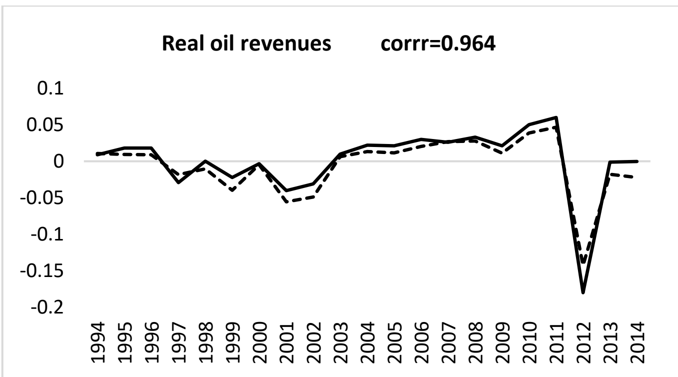
In a second way, we compare historical time series with the model-implied time series for observable variables to check if the estimated DSGE model is an appropriate empirical tool for the data generating process. Figure 1 shows the historical time series and model-implied time series for all 9 variables. However, there are minor differences between data and simulated series for some variables, in general, there is a reasonable overlap between these two series and the model is able to replicate the time series. On the other hand, the results indicate that the model can match the cyclical properties very well.

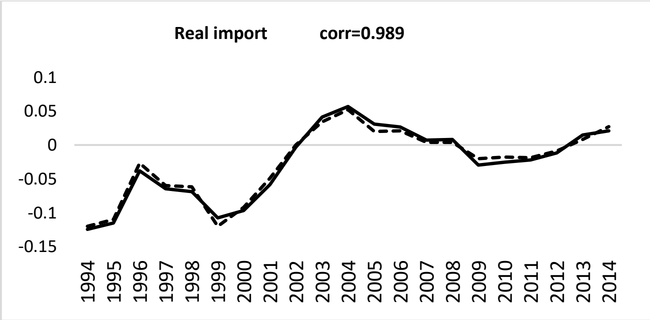
The historical time series are denoted by solid lines and model implied series are denoted by dash lines. The numbers in parenthesis imply the correlation between historical and model implied series.

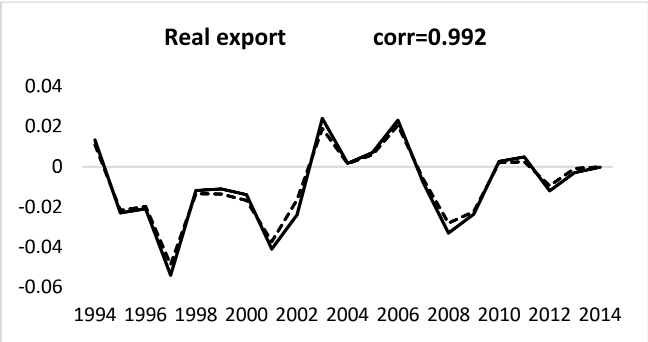

Real GDP (corr=0.993)
1
0.8
0.6
0.4
0.2
0
-0.2
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014

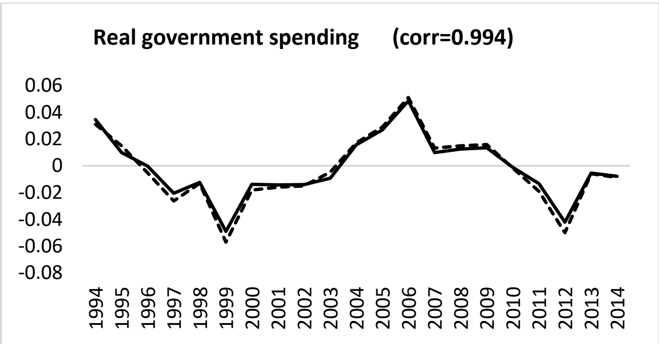

Inflation rate (corr=0.987)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014

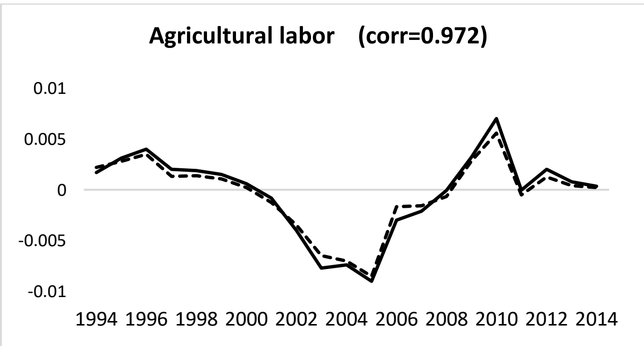

Real agricultural output corr=0.993
0.04
0.02
0
-0.02
-0.04
-0.06
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014


Real oil revenues corrr=0.964
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014


Real import corr=0.989
0.1
0.05
0
-0.05
-0.1
-0.15
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014


Real export corr=0.992
0.04
0.02
0
-0.02
-0.04
-0.06
1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014


Real government spending (corr=0.994)
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014


Agricultural labor (corr=0.972)
0.01
0.005
0
-0.005
-0.01
1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014

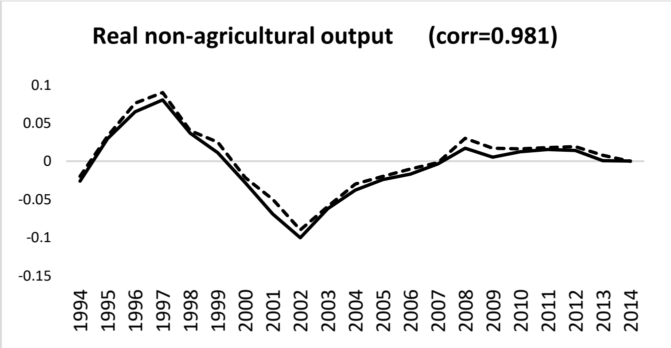


Figure 1: Historical Model Fit

5.3 Forecast Error Variance Decomposition

Variance decomposition provides an appropriate tool to assess the contributions of different shocks to the fluctuations of the variable of interest at different horizons. Table 5, according to posterior estimates, summarizes the conditional variance decomposition of the forecast errors for real agricultural variables, namely: output (Y_{ag}), consumption (c_{ag}), price index (p_{ag}), investment (i_{ag}) and agricultural employment (l_{ag}) at different horizons. The results clearly provide evidence, that agricultural output is substantially driven by agricultural productivity disturbances in both the short and long run. The shock explains about 44-40% of the variance in agricultural output at different horizons. Monetary and government spending shocks also play an important role in explaining the output movements. Monetary shock accounts for 16-17% in the short-run (one or two years) but its importance, in the long run, decreases to about 13%. By contrast, government spending shock accounting for about 10% in the short-run, becomes a bit more important in the mid and long run with 15-14%. Regarding the drivers of agricultural consumption, a big part of the fluctuations are explained by the preference shock (30-25%) and productivity shock (23-21%). Monetary shock (15-14%) and government spending shocks (9-13%) also contribute significantly to the volatility of agricultural consumption. As for the agricultural price index, its dynamics are mainly explained by agricultural productivity shock (27-25%), monetary shock (21-20%) and preference shock (13-11%). Additionally, as the time lag increases, the labor supply shock gains more importance (accounting for about 8% in the short run, its contribution rises to about %16 in the long run). The cyclical fluctuations in agricultural investment are driven mainly by productivity, monetary and government spending shocks which, respectively, account for 28–26%, 26-24% and 19-17% of the observed variance in the investment at different horizons. Lastly, agricultural employment is largely explained by labor supply. This shock in the short run accounts for about 25% while its contribution, in the long run, gains more relevance with 29%. Productivity, monetary and government spending shocks also play a significant role in explaining the fluctuations. They jointly account for about 51-46% of the volatility of agricultural employment.

Table 5: Variance Decomposition

Variable	Year	productivity in Agri (ε_{ag})	Monetary (ε_{μ})	Government (ε_{g})	Oil (ε_{oil})	Preference (ε_{b})	L supply (ε_{l})	Money demand (ε_{m})
	1	44.11	16.02	9.42	9.01	11.09	5.11	5.24
	2	45.88	17.34	10.32	7.02	11.14	3.21	5.09
y_{ag}	5	45.35	17.16	15.39	4.28	9.25	3.33	5.24
	10	41.84	14.21	14.31	3.19	7.62	8.94	9.89
	20	39.71	12.85	13.76	3.08	7.21	11.42	11.97
	1	23.13	15.27	9.13	8.16	29.95	3.45	10.91
	2	23.54	15.6	10.11	8.21	30.22	4.21	8.11
c_{ag}	5	23.29	15.35	14.38	6.56	26.33	4.43	9.66
	10	21.61	14.77	13.76	6.24	25.08	7.62	10.92
	20	20.65	13.87	12.68	5.69	24.86	10.97	11.28
	1	27.23	21.15	12.26	11.33	13.28	7.46	7.29
	2	28.03	22.13	11.47	10.02	13.34	7.95	7.06
p_{ag}	5	27.84	21.35	11.24	9.24	12.77	9.35	8.21
	10	25.65	20.69	11.03	9.17	11.17	12.71	9.58
	20	24.67	19.68	9.96	9.02	10.84	15.97	9.86
	1	27.56	25.69	18.89	9.25	7.52	5.62	5.47
	2	28.21	26.06	18.77	8.91	8.51	4.43	5.11
i_{ag}	5	27.81	25.82	17.43	9.16	8.25	7.43	4.1
	10	26.98	25.21	16.73	8.87	8.21	9.84	4.16
	20	25.54	23.68	16.76	8.48	7.96	9.74	7.84
	1	18.26	15.73	16.85	8.33	8.59	24.68	7.56
	2	18.74	16.14	16.01	8.09	9.11	26.77	5.14
l_{ag}	5	18.54	15.97	15.79	7.94	8.07	26.67	7.02
	10	17.89	14.73	15.51	7.52	8.15	27.98	8.22
	20	17.32	13.97	14.87	6.87	7.89	28.84	10.24

Note: Figures correspond to the posterior mean value of the variance of the forecast errors at different horizons.

5.4 Impulse Response Analysis

Having identified the main driving forces in agricultural sector fluctuations, to better understand the transmission mechanism of the shocks, we conduct an impulse response analysis for Iran agriculture. Figures 2 through 6, illustrate Bayesian impulse responses of the agricultural variables to a one-standard-deviation shock to the agricultural productivity, monetary, government spending, oil revenue and preference to a horizon of up to 40 years. Each response is expressed as the percentage deviation of a variable from its steady-state level.

5.4.1 Agricultural Productivity Shock

The first shock that we consider is an agricultural productivity shock. Figure 2 illustrates that a positive shock in agricultural productivity leads to a rise in agricultural output and a drop in marginal cost as firms can produce more for the given amount of labor and capital. This enables firms to lower producer prices. The drop in marginal costs, however, is greater than the drop in the price index. Following the rise in output and the fall in prices, agricultural consumption and investment increase. Additionally, higher productivity makes it more attractive for the firm to increase labor. Nevertheless, this finding could be different if we considered price rigidities for agricultural firms in the model. In theory, positive productivity shocks in real business cycle models with real rigidities (Francis and Ramey, 2005) or in sticky price models (Gali, 1999) can generate negative effects on employment. Whereas, not considering the rigidities may lead to different results as in this study. We also observe the responses of output and investment, respectively, are greater than those of other variables.

5.4.2 Monetary Policy Shock

As implied in Figure 3, in response to a negative interest rate shock, can be thought of as an expansionary monetary policy shock, agricultural consumption rises since the lower interest rate makes saving unattractive and households respond by substituting intertemporally from investment to consumption. Consumption expansion leads to an increase in agricultural prices and output. While, in magnitude, their reactions are greater than the consumption response. The positive monetary shock also raises agricultural employment and investment. However, the employment barely responds to the shock.

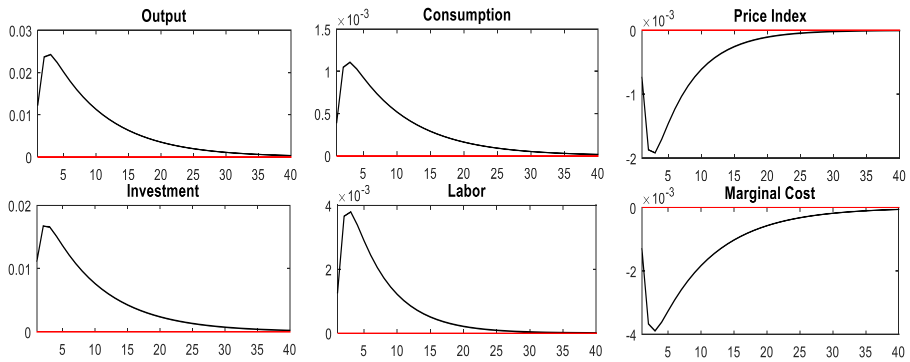


Figure 2: IRFs of the Main Agricultural Variables to a Positive One-Standard-Deviation Agricultural Productivity Shock

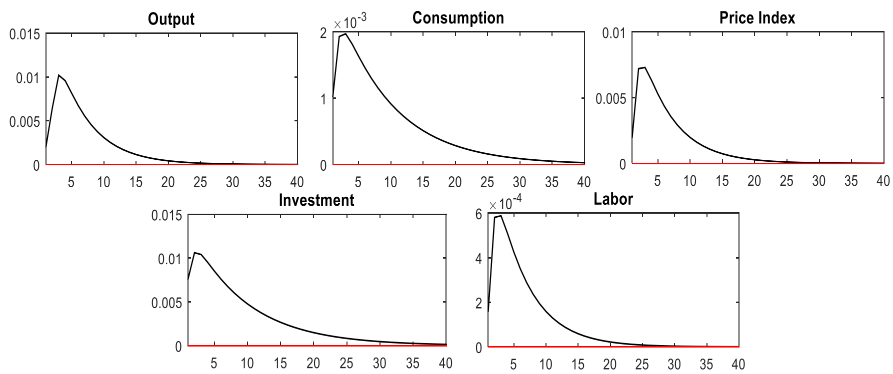


Figure 3: IRFs of the Main Agricultural Variables to a Negative One-Standard-Deviation Interest Rate Shock

5.4.3 Government Spending Shock

Following a positive government spending shock, agricultural output, employment, price index and consumption rise due to the expansion in public spending provides extra aggregate demand in the economy. The expansion in demand drives up output and marginal costs, and firms increase prices. However, output and employment imply stronger reactions. Additionally, agricultural investment falls since the increased government spending crowds out private investment (see Figure 4).

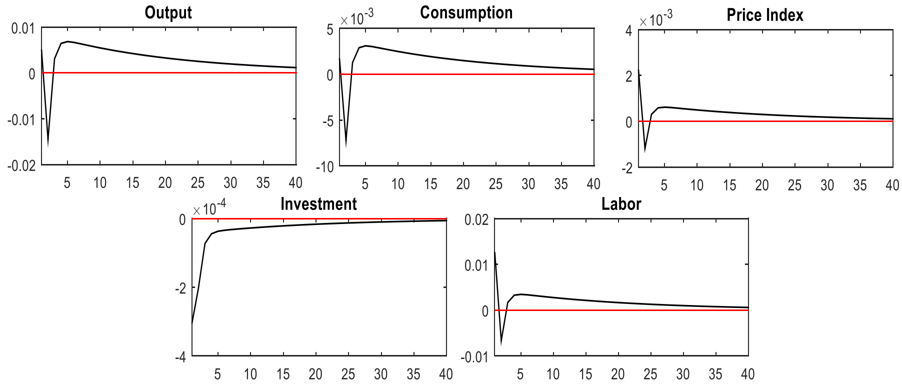


Figure 4: IRFs of the Main Agricultural Variables to a Positive One-Standard-Deviation Government Spending Shock

5.4.4 Oil Revenue Shock

Oil revenues are a key variable for Iran's economy as it makes up 80% of its total export earnings and 50% to 60% of its government revenue. So, evaluating the impact of oil revenue disturbances on Iran's economy is of high importance. Following a positive oil revenue shock (Figure 5), resulting in an increase in Iran's foreign currency earnings, imports and total demand (not shown in the figure), agricultural consumption rises and so do agricultural prices. Contrarily, the agricultural output, investment, and employment fall despite the rise in the consumption of agricultural goods, suggesting a substitution in favor of imported agricultural goods. A possible explanation for this finding could be because of a phenomenon called Dutch Disease (DD) in economic literature. Growing oil revenues raise the agricultural import and bring forth de-agriculture phenomenon. The government de-emphasizes this sector. Practitioners in the agriculture sector move into other sectors and the growth rate in production, cultivated areas, and labor productivity sharply slumped. Such consequences result in a decrease in the size of this sector. Many works have confirmed the symptoms of Dutch Disease in Iran's agriculture and showed that DD in Iran' economy has appeared as anti-agriculture phenomena (Ghasabi Kohne Ghouchan et al., 2014; Piri et al., 2011; Fardi, 2009; Bakhtiari and Haghi, 2001; Fardmanesh, 1999).

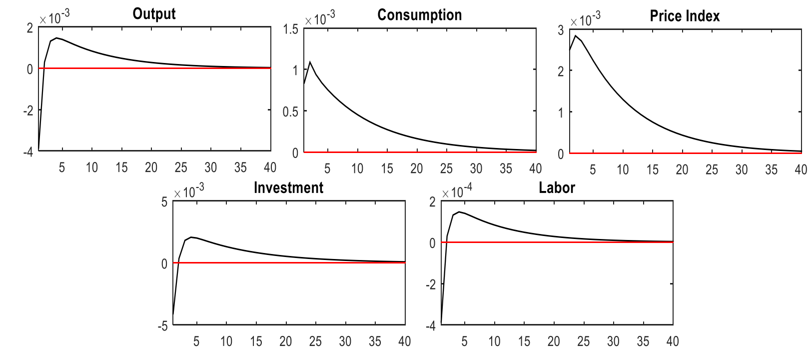


Figure 5: IRFs of the Main Agricultural Variables to a Positive One-Standard-Deviation Oil Revenue Shock

5.4.5 Preference Shock

The preference shock affects the utility households obtain from aggregate consumption today relative to future consumption. Impulse responses to this shock are displayed in Figure 6. A positive consumption preference shock leads to an increase in the households' demand for agricultural consumption by increasing the current marginal utility of consumption, and hence an increase in agricultural investment and output. Output expansion leads to a rise in marginal cost and as a result agricultural price index increases. It also induces firms to employ more labor. The results also suggest the shock has the greatest influence on the consumption and the weakest on employment.

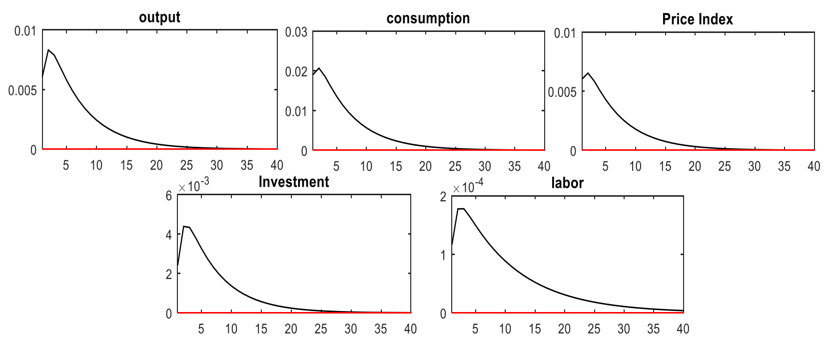


Figure 6: IRFs of the Main Agricultural Variables to a Positive One-Standard-Deviation Preference Shock

5.5 Historical Decomposition

To evaluate the historical contribution of each exogenous shock in agricultural fluctuations in Iran we calculate the historical forecast error variance decomposition of agricultural output, consumption and price index for the period 1994-2014. Figure 7 depicts the historical decomposition of agricultural output. As well as the results of variance decomposition, variation in agricultural output is mainly explained by agricultural productivity shock all over the period. Along with the productivity shock, monetary and preference shocks, also play an important role in output dynamics especially after 2009 when imposed economic sanctions against Iran increase. The results further show that oil revenue shock becomes relevant between 2000 and 2008 (as world oil price goes up), chiefly, concerning the downward movements of the output. Our results shown in Figure 8 illustrate that agricultural consumption fluctuations are largely explained by preference, productivity, and monetary shocks. The contribution of monetary shock, however, dominates that of other shocks since 2010. Furthermore, results highlight the remarkable role of monetary shock in agricultural consumption downturn between 1995 and 1998. We also observe that oil shock gains some importance between 2001 and 2006. As shown in Figure 9, cyclical movements in agricultural prices are driven jointly by shocks to preference, productivity, and monetary policy. In particular, the downturn in agricultural prices between 2003 and 2009 is driven mainly by preference and productivity shocks. While after 2009 monetary shock is the main driver of agricultural prices. The historical shock decomposition further suggests that the contribution of oil shock to cyclical movements in agricultural prices becomes more important in particular years of the series especially before 2000.

6. Conclusion

This paper investigates the sources of fluctuations in Iran's agriculture using an estimated DSGE model for Iran's economy disaggregating the agricultural sector for the 1994-2014 period. We focus on assessing quantitatively the contributions of structural shocks to driving the cyclical behavior of agricultural output, consumption, prices, investment, and employment. We consider a rich set of shocks including: agricultural productivity, monetary, government spending, preference, oil revenue, money demand, and labor supply shocks. The findings indicate that, generally, in explaining agricultural fluctuations, the contribution of

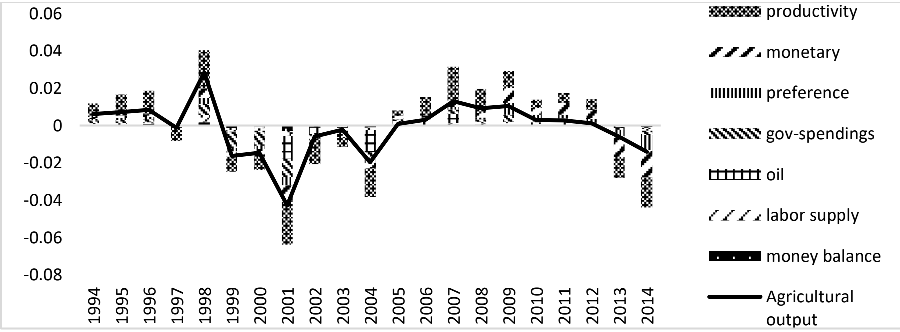


Figure 7: Historical Decomposition of the Real Agricultural Output

Note: The Figure shows how various shocks contribute to the (percentage) deviations from steady-state of the real agricultural output (solid black line) in Iran over the sample 1994–2014.

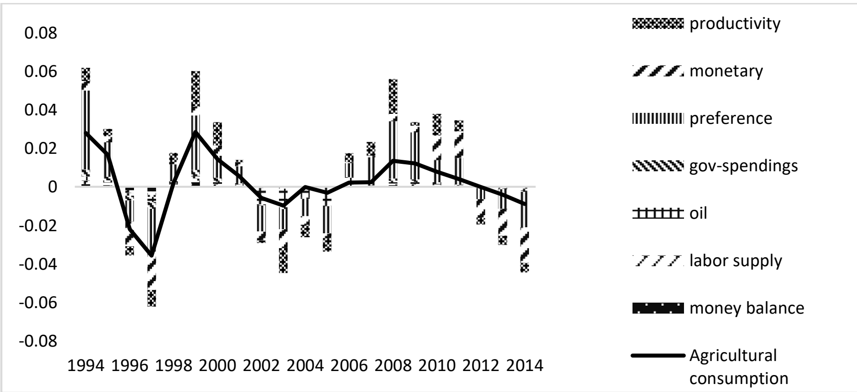


Figure 8: Historical Decomposition of the Real Agricultural Consumption

Note: The figure shows how various shocks contribute to the (percentage) deviations from the steady-state of the real agricultural consumption (solid black line) in Iran over the sample 1994–2014.

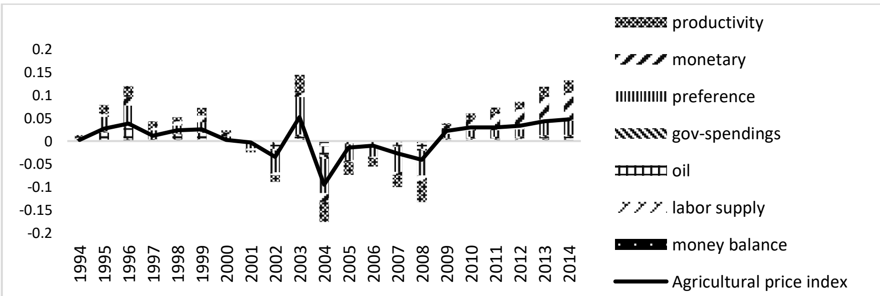


Figure 9: Historical Decomposition of the Real Agricultural Price Index

Note: The figure shows how various shocks contribute to the (percentage) deviations from the steady-state of the real agricultural price index (solid black line) in Iran over the sample 1994–2014.

agricultural productivity shock dominates that of other shocks. Monetary shock and, to a lesser extent, government spending, preference and labor supply shocks, however, play an important role in agricultural dynamics. More precisely, the main driver of agricultural output variations is productivity shock where along with monetary shock explains about 60-53% of the variations at different horizons. The variance in agricultural consumption is mostly explained by preference shock (30-25%). Also, productivity and monetary shocks, together, explain 38-35%. The main responsible for agricultural price index dynamics is the agricultural productivity shock (27-25%). However monetary (21-20%) and preference shock (13-11%) are of high importance. The cyclical fluctuations in agricultural investment are mainly driven by productivity shock (28–26%), monetary shock (26-24%) and government spending shock (19-17%). The agricultural employment is substantially driven by labor supply shock in both the short and long run (25-29%). Also, productivity, monetary and government spending shocks jointly account for about 51-46% of the volatility of the employment. Comparing the agricultural IRFs, which are consistent with the predictions of theoretical models, indicates, generally, in terms of persistence the effects of productivity, government spending, and oil revenue shocks are more long-lasting and in terms of magnitude, the effects of productivity shock are larger when compared to those of the other shocks. In addition, considering the IRFs to the oil shock, the results confirm the symptoms of Dutch Disease in Iran’s agriculture.

A historical decomposition analysis reveals that the output movements, over the sample span considered, are mainly explained by productivity shock. Monetary and preference shocks also play an important role in output dynamics especially after 2009 when imposed economic sanctions against Iran increase. Agricultural consumption fluctuations are largely explained by preference, productivity, and monetary shocks. The contribution of monetary shock, however, dominates that of other shocks since 2010. Cyclical movements in agricultural prices are driven jointly by shocks to preference, productivity, and monetary policy. While, after 2009, the monetary shock is the main driver of agricultural prices. The historical shock decomposition further suggests that the contribution of oil shock to the cyclical movements becomes more important in particular years chiefly when Iran’s oil revenues rise.

The results of this study have important policy implications for Iran’s agriculture. Given that the agricultural productivity shock, generally, is the main driver in agricultural fluctuations and considering its positive effects on the sector, it is imperative that officials take effective steps such as encouraging and supporting farmers to substitute modern production methods for traditional methods, promoting farmer’s knowledge about new techniques and technologies, allocating required credits, etc. to improve the productivity in this sector. Regarding the adverse effects of the positive oil shock on the agricultural sector, policymakers should practice institutional responses including the establishment of oil stabilization and saving funds to not expose the economy to temporarily booms, during growing oil revenues, leading the agricultural sector to be de-emphasized. In addition, the government should allocate a share of foreign exchange earnings arising from a positive oil shock to be spent on supporting and strengthening agriculture instead of importing agricultural consumption goods and weakening it.

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