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Oil Windfalls, Fiscal Policy and Money Market Disequilibrium[1]

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ABSTRACT

In this paper, we base our policy analyses and simulations on three different specifications of a DSGE model developed for a CIS oil rich country and check the impact of the oil windfalls. The first proposed specification is a classical one with a Taylor rule and the second one is a recently new specification with a money growth rule. Beside two familiar specifications, we propose a new specification which assumes a temporary money market disequilibrium in the short run. This disequilibrium is a result of the fiscal misbalance and (non-primary) pro-deficit policy pursued by the fiscal authority. We show that all three specifications allow the fiscal authority to act as the main actor in propagating and amplifying the effects of the oil price shocks to the rest of the economy. When an oil shock hits the economy, its first round effect operates through oil fund transfers to the budget. The second round effects result from an increase in government consumption and government investment expenditures, which augments public capital affecting total factor productivity (TFP) and production, as well as the aggregate demand. We also find that despite significant differences, all three specifications demonstrate similar response dynamics.

JEL classification: E35, E47, E58, E61

Keywords: Fiscal Policy; Oil Windfalls; Public investment; Market Disequilibrium; Oil rich country

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1. Introduction

The first decade of the new century has seen a rising interest in DSGE models both in academia and at the central banks over the world. Central banks focused on developing DSGE models for carrying out daily routine tasks, especially in forecasting and policy analysis. They were considered not only new modeling tools allowing for the diversification of the existing "model suite", but also avoiding the methodological concerns regarding the use of less structural general equilibrium models at their disposal.

Now, although DSGE models become standard tools for quantitative analysis, they are generally developed for advanced economies. In those models, a central bank is assumed to maintain a flexible exchange regime and determines interest rate using the famous Taylor-rule. In these specifications, foreign exchange market is not explicitly modeled and the UIP assumption is imposed (see, for instance, Kollmann (1997), Clarida, *et al* (1999), Erceg, *et al* (2000), Smets and Wouters (2002), Gali and Gertler (2007), Christoffel, *et al* (2008)). Though this classical specification might be relevant in the case of advanced economies, it is generally overlooking important economic dynamics of emerging markets, especially oil rich countries.

Almost all the resource abundant countries maintain a hard peg or more similar regimes and frequently intervene to the exchange market to ensure the stability of the officially determined exchange rate. These interventions lead to significant fluctuations and excess volatility in the money supply. Most occasionally, the monetary authority loses control of the money supply and the fiscal dominance becomes an inevitable economic reality.

However, although those characteristics are important and distinct for oil rich countries, they are generally ignored or not explicitly specified in the classical models. Therefore, it might be interesting to check the potential value-added of explicitly capturing those features in a model.

In this paper, we develop three specifications, including classical specifications with Taylor rule and fixed exchange regime. In all specifications, fiscal sector driven economic growth is captured by the detailed description of the fiscal authority and its spending rules. The revenues from the sales of the oil in the international markets accrue to the state oil fund which transfers a certain amount of its resources to the state budget. Because large portion of the budget expenditures is channeled into public investment projects, we also introduce public capital through TFP into the model. Those specifications allow us to test various fiscal rules which determine the pace of the spending of oil revenues.

In all three specifications, the government imposes income taxes and borrows from public based on a fiscal rule (see, for example, Berg *et al* (2010), Dagher *et al* (2010)). Here, an oil price shock affects the economy through its effect on the fiscal sector, pushing up the fiscal spending. This differs from the mechanism describing how an oil price shock operates in an economy as provided in Medina and Soto (2006). There, the government budget is closed by lump-sum taxes and the oil price shock affects the economy by relaxing the budget constraint of the household sector due to the reduction in lump-sum taxes.

Although FX market is ignored in our first specification, the second and the third specifications remove those shortcomings of the classical models by explicitly introducing FX markets, central bank interventions and market absorption capacities. In the second specification, the monetary authority is assumed to be following an exchange rate rule and intervenes to the FX market to ensure the stability of the peg regime. The central bank is also assumed to exercise some degree of power in controlling money supply by using its monetary instruments, such as reserve requirements, open market operations, etc.

In the third specification, we assume that the money market is out of equilibrium in the short run, but attains equilibrium in the long run. The money market disequilibrium is a consequence of a fiscal misbalance policy pursued by the fiscal authority. That is, because a non-primary (non-oil) fiscal deficit creates an excess demand, it leads to a disequilibrium in the money market, producing an excess supply of money in the short run.

A government fiscal deficit as a cause of an excessive monetary expansion and loss of control of money supply is one of the most frequently encountered topics in any stabilization program literature. For example, Khan and Knight (1981) as well as Ozdemir and Turner (2008) claim that an excess monetary expansion caused by high budget deficits or excessive credit expansion is a source of high aggregate demand and disequilibrium in the market.

Finally, in the last specification, we assume that this disequilibrium in the money market is cleared through three channels - price channel, real income channel and foreign asset channel.

In the benchmark model, we conduct experiments and compare the performance of three different specifications using impulse-response analysis. We also test the performance of those specifications under different fiscal spending rules and monetary policy (flexible exchange regime) scenarios. The model results show that all three specifications capture the main economic dynamics in the presence of fiscal authority as the main distributor of the income from the oil wealth. The other interesting finding is that despite significant differences all three specifications demonstrate similar response dynamics.

The remainder of this paper is organized as follows: Section II develops a theoretical model to carry out different policy experiments, Section III explains the logic behind the choice of the calibrated parameters, Section IV conducts different policy scenarios and simulations and Section V concludes.

2. Theoretical Model

Household sector

The economy is inhabited by a representative household who allocates its income among consumption and investment goods and makes decision on the holdings of domestic currency as well as government bonds (foreign bonds) in every period. It supplies homogenous labor to the firms and earns rents from supplying necessary capital to the production sector. In addition, it earns dividends from the firms as a shareholder and pays taxes.

The household receives utility from consumption and holding money in domestic currency but disutility from working. Its lifetime utility function takes the following form:

$$U = E_t \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma_C}}{1-\sigma_C} + \frac{\gamma_M}{1-\kappa_M} (\frac{M_t}{P_t})^{1-\kappa_M} - \psi \frac{l_t^{1+\tau}}{1+\tau} \right]$$

where E_t denotes expectation term, β is a discount factor, C_t expresses aggregate consumption bundle, l_t indicates labor supply, M_t shows domestic currency stock, respectively. P_t indicates the overall price level determined in the economy.

The consumption bundle C_t and I_t are produced according to the CES technology using both domestic and foreign goods. The functions take the following specific form:

$$C_t = \left[\gamma_C^{\frac{1}{\mu_C}} (C_{H,t})^{\frac{\mu_C - 1}{\mu_C}} + (1-\gamma_C)^{\frac{1}{\mu_C}} (C_{F,t})^{\frac{\mu_C - 1}{\mu_C}} \right]^{\frac{\mu_C}{\mu_C - 1}}$$

$$I_t = \left[\gamma_I^{\frac{1}{\mu_I}} (I_{H,t})^{\frac{\mu_I - 1}{\mu_I}} + (1-\gamma_I)^{\frac{1}{\mu_I}} (I_{F,t})^{\frac{\mu_I - 1}{\mu_i}} \right]^{\frac{\mu_I}{\mu_I - 1}}$$

Hence, optimization of the consumption and investment expenditures among domestic and foreign goods produce demand for domestic and foreign goods as well as overall price level prevailing in the economy:

$$C_{H,t} = \gamma_C (\frac{P_{H,t}}{P_t})^{-\mu_C} C_t, \qquad C_{F,t} = (1-\gamma_C)(\frac{P_{F,t}}{P_t})^{-\mu_C} C_t$$

$$I_{H,t} = \gamma_I (\frac{P_{H,t}}{P_t})^{-\mu_I} I_t, \qquad I_{F,t} = (1-\gamma_I)(\frac{P_{F,t}}{P_t})^{-\mu_I} I_t$$

$$P_t = \left[\gamma_P (P_{H,t})^{1-\mu_P} + (1-\gamma_P)(P_{F,t})^{1-\mu_P} \right]^{\frac{1}{1-\mu_P}}$$

The household expenditure is dictated by the overall budget constraint which is provided below:

$$P_t C_t + P_t I_t + M_t + (\varepsilon_t^{RP} R_t)^{-1} B_t + ((1-\Gamma_{B^*}(e_{B_t^*}, \varepsilon_t^{RP^*}))R_t^*)^{-1} e_t B_t^* + \Theta_t + \Xi_t =$$
$$(1-\tau_W) W_t l_t + R_{K,t} K_{t-1} + M_{t-1} + B_{t-1} + e_t B_{t-1}^* + D_{H,t}$$

where I_t indicates investment expenditures, B_t denotes government bonds held by public, R_t the nominal return on holding the bond for one period, K_t is the capital stock rent to the production sector, $R_{K,t}$ is the nominal return paid to the household due to the ownership of the capital, W_t shows the nominal wage rate, $D_{H,t}$ is the dividends and τ_W is the income tax imposed on the household and e_t denotes the domestic price of per unit foreign currency.

Following Christoffel, *et al* (2008), it is assumed that the household faces external financial intermediation premium $\Gamma_{B^*}(e_{B_t^*}, \varepsilon_t^{RP^*})$ which depends on the net holdings of internationally traded foreign bonds expressed in national currency relative to the domestic nominal output, $s_{B^*,t} = e_t B_t^* / Y_t$ and have the following form:

$$\Gamma_{B^*}(e_{B_t^*}, \varepsilon_t^{RP^*}) = \gamma_{B^*}((\varepsilon_t^{RP^*})^{\frac{1}{\gamma_{B^*}}} \exp(\frac{e_t B_t^*}{Y_t}) - 1)$$

Under this specification households do not hold foreign bonds and economy's net foreign asset position is zero at the steady state. The incurred intermediation premium is rebated in lump-sum manner, indicated by Ξ_t.

The physical capital depreciates at a rate of δ every period and accumulates according to the well-known law of motion given below:

$$K_t = (1-\delta)K_{t-1} + I_t$$

The household maximizes the discounted value of its lifetime utility function subject to the budget constraint and capital accumulation equation. Denoting the Lagrange multipliers by Λ_t / P_t and taking the derivative with respect to C_t, K_t, M_t, l_t and B_t (B_t^*) we obtain the following FOCs:

$$\Lambda_t = C_t^{-\sigma_C}$$

$$\beta \frac{\Lambda_{t+1}}{\Lambda_t}(\frac{R_{K,t+1}}{P_{t+1}} + (1-\delta)) = 1$$

$$\gamma_M (\frac{M_t}{P_t})^{-\kappa_M} = \Lambda_t - \beta \Lambda_{t+1} \frac{P_t}{P_{t+1}}$$

$$\Lambda_t \frac{(1-\tau_W)W_t}{P_t} = \psi l_t^{\tau}$$

$$\beta \frac{\Lambda_{t+1}}{\Lambda_t} \frac{P_t}{P_{t+1}} R_t \varepsilon_t^{RP} = 1$$

$$\beta \frac{\Lambda_{t+1}}{\Lambda_t} \frac{P_t}{P_{t+1}} \frac{e_{t+1}}{e_t} R_t^* (1 - \Gamma_{B^*}(e_{B_t^*}, \varepsilon_t^{RP^*})) = 1$$

Production Sector

There are two sectors in the economy – oil and non-oil sector. It is assumed that the oil sector is totally an extraction sector where the production does not require any input. The non-oil sector is composed of intermediate and final goods producers.

Intermediate goods producers

There are continuum of intermediate goods producers in a monopolistically competitive market and each produces a differentiated product yn_t^j where $j \in [0,1]$. The intermediate firm *j* produces an output by renting capital and hiring labor using the Cobb-Douglas technology defined below:

$$yn_t^j = A_t \left(K_{t-1}^j\right)^{\alpha} \left(l_t^j\right)^{1-\alpha}$$

where A_t denotes public capital augmented technology whose law of motion is as follows:

$$\frac{A_t}{\bar{A}} = \left(\frac{A_{t-1}}{\bar{A}}\right)^{\rho_A} \left(\frac{K_{G,t-1}/\bar{K}_G}{l_t/\bar{l}}\right)^{\chi(1-\rho_a)} \left(\frac{\varepsilon_{A,t}}{\bar{\varepsilon}}\right)$$

where $\chi \in [0,1]$ is a scaling factor, $K_{G,t}$ denotes public capital, $\varepsilon_{A,t}$ is a technology shock and variables with bar represents the steady state values of the respective variables. In the case of $\chi = 0$ the technology shock evolves according to the AR(1) process as in the classical case. This specification allows capturing the fact that though a high government spending raises overall demand, its effect on the production side is limited. That is, the public capital does not lead to adequate increase in the production due to various reasons, for example, inefficiencies in the economy or investment on low return projects, etc.

When a firm sets a price $P_{H,t}^j$ for its products, it faces a quadratic adjustment AC_t^j cost defined below:

$$AC_t^j = \frac{\varphi}{2}\left(\frac{P_{H,t}^j / P_{H,t-1}^j}{\Pi_{H,t-1}} - 1\right)^2 P_{H,t}\, yn_t$$

Thus, a producer maximizes the expected value of the discounted value of its profits subject to the demand and production technology constraints. The producer profit (dividend) is determined after rent, wage and adjustment cost deductions from its revenue. Hence, a producer problem is the maximization of the following expression:

$$E_t \sum_{t=0}^{\infty} \beta^t \Lambda_t D_{H,t}^j$$

where the constraints are as follows:

$$D_{H,t}^j = P_{H,t}^j yn_t^j - R_{K,t} K_{t-1}^j - W_t l_t^j - AC_t^j$$

$$yn_t^j = A_t \left(K_{t-1}^j\right)^{\alpha} \left(l_t^j\right)^{1-\alpha}$$

$$yn_t^j = \left(\frac{P_{H,t}^j}{P_{H,t}}\right)^{-\theta} yn_t$$

The final constraint expresses the demand for the output of the firm *j* by a final goods producer. Defining the Lagrange multiplier of the production technology by MC_t^j (nominal marginal cost) and substituting dividend and demand equations in the objective function and taking the derivative with respect to K_t^j an l_t^j the following FOCs are obtained:

$$R_{K,t} = \alpha \frac{yn_t^j}{K_{t-1}^j} MC_t^j$$

$$W_t = (1-\alpha)\frac{yn_t^j}{l_t} MC_t^j$$

Because all firms face the same problem, the pricing decision ($P_{H,t}^j$) in a symmetric equilibrium will take the following form:

$$\frac{(1-\theta)}{\varphi} + \frac{\theta}{\varphi}\left(\frac{MC_t}{P_{H,t}}\right) + \beta \frac{\Lambda_{t+1}}{\Lambda_t}\frac{yn_{t+1}}{yn_t}\left(\frac{\Pi_{H,t+1}}{\Pi_{H,t}} - 1\right)\frac{(\Pi_{H,t+1})^2}{\Pi_{H,t}} = \left(\frac{\Pi_{H,t}}{\Pi_{H,t-1}} - 1\right)\frac{\Pi_{H,t}}{\Pi_{H,t-1}}$$

Final goods producers

In addition, the heterogeneous domestic goods are assembled by intermediate goods producers into private consumption and investment as well as government consumption bundles using the CES production technology:

$$C_{H,t} = \left(\int_0^1 \left(C_{H,t}^j\right)^{\frac{\theta-1}{\theta}} dj\right)^{\frac{\theta}{\theta-1}}$$

$$I_{H,t} = \left(\int_0^1 \left(I_{H,t}^j\right)^{\frac{\theta-1}{\theta}} dj\right)^{\frac{\theta}{\theta-1}}$$

$$G_t = \left(\int_0^1 \left(G_{H,t}^j\right)^{\frac{\theta-1}{\theta}} dj\right)^{\frac{\theta}{\theta-1}}$$

Therefore, from the optimal use of inputs, the following demand functions are obtained:

$$C_{H,t}^j = \left(\frac{P_{H,t}^j}{P_{H,t}}\right)^{-\theta} C_{H,t}$$

$$I_{H,t}^j = \left(\frac{P_{H,t}^j}{P_{H,t}}\right)^{-\theta} I_{H,t}$$

$$G_{H,t}^j = \left(\frac{P_{H,t}^j}{P_{H,t}}\right)^{-\theta} G_t$$

Oil Sector, Oil Fund and External Sector

The production in the oil sector is fully an exogenous process and does not require any inputs. Because of the small open economy assumption, the demand for oil products y_t^o as well as oil prices $p_t^{o,*}$ is dictated by the international markets. The all extracted oil resources are fully exported to the international markets and sold outside. The revenues in the national currency OR_t obtained from the oil export are partly used to close the non-oil deficit of the state budget and the rest accrues at the State Oil Fund. Therefore, the following equations describe the oil production:

$$OR_t = e_t y_t^o P_t^{O^*}$$

$$\left(\frac{P_t^{O^*}}{\overline{P}^{O^*}}\right) = \left(\frac{P_{t-1}^{O^*}}{\overline{P}^{O^*}}\right)^{\rho_{Po}} \left(\frac{\varepsilon_{PO,t}}{\overline{\varepsilon}_{PO}}\right)$$

$$\left(\frac{y_t^O}{\overline{y}^O}\right) = \left(\frac{y_{t-1}^O}{\overline{y}^O}\right)^{\rho_{YO}} \left(\frac{\varepsilon_{YO,t}}{\overline{\varepsilon}_{YO}}\right)$$

The oil fund resources OF_t^* are managed in USD and earn R_t^* every period. Certain amount of Fund resources (FuT_t) is transferred to the government budget to close the non-oil deficit. Hence, the Oil Fund's resources accumulate according to the following law of motion:

$$OF_t^* = OF_{t-1}^* + R_t^* \frac{(OR_t - FuT_t)}{e_t}$$

Oil products dominate the composition of the export of the country. Therefore, it is assumed that the country only exports oil products and non-oil export sector is relatively small. In addition, import IM_t to the country is determined as below:

$$IM_t = C_{F,t} + I_{F,t}$$

Government Sector

Government collects taxes from households and issues bonds to finance its fiscal expenditures (G_t). In addition, every period a part of oil revenues is transferred from the Oil Fund to close the non-oil fiscal deficit. Government also holds deposits, $D_{G,t}$, at the Central Bank and collects income taxes from households. Therefore, the budget constraint of the government is as follows:

$$P_{H,t} G_t = FuT_t + \left(\frac{B_t}{R_t} - B_{t-1}\right) - \left(D_{G,t} - D_{G,t-1}\right) + \tau_W W_t l_t + (M_t - M_{t-1})$$

We assume that over the period the government holds the level of borrowing from the public constant. Government spending on public investment is composed of two parts (i) the first part reflects the fact that in every period government spends a constant share of its expenditure on investment (ii) the second part reflects the temporary increase in oil revenues transferred from the Fund to the government budget. The dynamics of the public investment and the public capital are provided below:

$$I_{G,t} = \omega_G \overline{G} + \omega_{Oil}\left(G_t - \overline{G}\right)$$

$$K_{G,t} = (1-\delta)K_{G,t-1} + \nu I_{G,t}$$

where $\nu \in [0,1]$ measures the efficiency of the public investment.

In every period, the Fund transfers either (i) all revenues from oil sales in the international markets to the budget or (ii) according to the fiscal rule described below. This rule reflects government's commitment to PIH (Permanent Income Hypothesis) and the shock $\varepsilon_{FT,t}$ is included to allow for the deviation from PIH. Note that this PIH rule is restrictive and states that in every period government spends a constant share of the real oil revenues with respect to the non-oil GDP:

$$\frac{FuT_t/P_t}{yn_t} = \frac{\overline{FuT}/\overline{P}}{\overline{yn}} + \varepsilon_{FT,t}$$

The accumulation of the net government deposit at the Central Bank is described in the following rule which takes into account increase in oil revenues:

$$D_{G,t} = \rho_{DG} D_{G,t-1} + (1-\rho_{DG})\overline{D}_G + (1-\iota)\left(FuT_t - \overline{FuT}\right)$$

where $\overline{D}_G$ is the steady state level of the government deposits and the policy parameter $\iota \in [0,1]$ reflects the pace of government spending due to rise in oil revenues.

Monetary Authority

Monetary authority is modeled using three different specifications (i) classical Taylor and fixed exchange rule (ii) monetary growth rule in the spirit of Taylor rule (iii) short-run money market disequilibrium specification.

In the classical specification of the monetary authority, the model is closed using Taylor rule and uncovered interest rate parity condition (UIP). However, in the next two specifications the UIP assumption is dropped and instead, a simple exchange rate rule will be introduced. Hence, the monetary authority sets the nominal interest rate according to the following rule:

$$\frac{R_t}{\overline{R}} = \left(\frac{R_{t-1}}{\overline{R}}\right)^{\rho_R} \left(\left(\frac{\Pi_t}{\overline{\Pi}}\right)^{\phi_\Pi} \left(\frac{yn_t}{\overline{yn}}\right)^{\phi_Y}\right)^{1-\rho_R} \left(\frac{\varepsilon_{R,t}}{\overline{\varepsilon}_R}\right)$$

In a fixed exchange regime under classical specification, the monetary authority keeps the depreciation of the national currency constant:

$$De_t = \frac{e_t}{e_{t-1}} = const$$

In the second specification where monetary authority follows a monetary growth rule, it is assumed that the monetary authority sets the exchange rate using a simple rule and intervenes to the foreign exchange (FX) market to absorb excess supply or demand of foreign currency.

The change in money supply can be written as the sum of changes of the net foreign assets (NFA) and of the net domestic credits to the economy (DC). It is assumed that the changes in NFA results only from monetary authority's intervention to the FX market. The changes in net domestic credit may come from two sources: changes in the net claims on government and changes in the net claims on banks and the rest. Therefore, the changes in the money supply can be defined as the changes in NFA, changes in the net claims on government and growth in the money supply net of NFA and government deposits and can be written as follows:

$$M_t - M_{t-1} = \mu_t \left(M_{t-1} - NFA_{t-1} - D_{G,t-1}\right) + \left(NFA_t - NFA_{t-1}\right) + \left(D_{G,t} - D_{G,t-1}\right)$$

Here, μ_t reflects the monetary authority's ability to control money growth net of NFA and government deposits. The growth rule followed by the monetary authority is a Taylor type rule and stresses the authority's ability to control money growth using certain mix of monetary instruments under its discretion:

$$\hat{\mu}_t = \rho_\mu \hat{\mu}_{t-1} + (1-\rho_\mu)(-\eta_Y \hat{yn}_t - \eta_\Pi \hat{\pi}_t) + \hat{\varepsilon}_{\mu,t}$$

As mentioned above, NFA changes due to monetary authority's intervention to the FX market in order to absorb excess supply or demand of foreign currency. Monetary authority's intervention to the FX market depends on the market's absorption capacity which partly depends on the persistence of the process:

$$\frac{MA_{FX,t}}{\overline{MA}_{FX}} = \left(\frac{MA_{FX,t-1}}{\overline{MA}_{FX}}\right)^{\rho_{FX}} \left(\left(\frac{OR_t / \overline{OR}}{P_{H,t} yn_t / \overline{yn}}\right)^{\upsilon_{OR}} \left(\frac{M_t / \overline{M}}{P_{H,t} yn_t / \overline{yn}}\right)^{\upsilon_M}\right)^{1-\rho_{FX}}$$

Note that in the case of $\rho_{FX}, \upsilon_{OR}, \upsilon_M$ all equal to zero, $MA_{FX,t}$ is constant and monetary authority sells or purchases fixed proportion of foreign currency supply to the FX market.

Hence, the monetary authority's intervention which determines the changes in NFA can be defined as follows:

$$NFA_t - NFA_{t-1} = \left(FuT_t - P_{F,t} IM_t\right) - MA_{FX,t}$$

To close the model, we assume that the monetary authority follows the simple rule to set the exchange rate:

$$\frac{e_t}{e_{t-1}} = \left(\frac{e_{t-1}}{e_{t-2}}\right)^{\rho_e} \left(\frac{\Pi_t}{\Pi_{F,t}}\right)^{\xi(1-\rho_e)}$$

Note that the case ρ_e and ξ equal zero characterizes fixed exchange rate regime and ρ_e shows the degree of monetary authority's commitment to the fixed exchange regime.

The third specification differs from the second one in some aspects though most part of the second specification is retained throughout the model. The change is in the specification of the money supply equation and the money growth rule is also dropped from the model. Thus, the money supply equation takes the following familiar form:

$$M_t - M_{t-1} = \left(NFA_t - NFA_{t-1}\right) + \left(D_{G,t} - D_{G,t-1}\right)$$

It is also assumed that there is always a short-term disequilibrium in the money market which prevents real money demand to adjust fully to the changes in the real money supply in the short run. This disequilibrium is a result of the fiscal misbalance policy pursued by the government. The fiscal misbalance emerges in the government sector as a consequence of a non-primary budget deficit, financed and sustained by the oil fund transfers. In other words, the non-primary (non-oil) fiscal deficit leads to the disequilibrium of the money market in the short run. However, in the long run we assume that all markets clear and money market disequilibrium disappears.

Because of the Walras Law which ensures that the excess market demands of all sectors must sum to zero, we make a minor change to the budget constraint of the fiscal sector to account for the disequilibrium in the money market. Through this change, the non-primary fiscal deficit (excess demand) is linked to the excess (supply) money in the budget constraint of the fiscal sector. Overall, all these impositions ensure that the increase in the non-oil fiscal deficit or difference in the money gaps across periods are made possible only through rise in the oil fund transfers.

$$P_{H,t}G_t = FuT_t + \left(\frac{B_t}{R_t} - B_{t-1}\right) - \left(D_{G,t} - D_{G,t-1}\right) + \tau_W W_t l_t + (M_t^S - M_{t-1}^S) - (gap_{M,t} - gap_{M,t-1})$$

This disequilibrium in the money market can be eliminated through three potential channels. The first one is the price adjustment channel where opposite movements in the price level helps to restore equilibrium in the money market. The second channel is the real income channel which operates through money demand equation. A rise in the real income of economic agents increases their demand on real money balances which helps to absorb excess money supply. The third channel operates through FX market where people buy and sell foreign assets which helps to bring excess supply of nominal money balances down. That is, when Central Bank builds up its foreign reserves by intervening and buying excess supply of foreign currency in the FX market, in the absence of sufficient sterilization instruments this intervention further rises excess money supply and moves money market away from the equilibrium. Therefore, money disequilibrium gap evolves according to the law of motion defined below:

$$\hat{gap}_{M,t} = \rho_{GM}\,\hat{gap}_{M,t-1} + (1-\rho_{GM})\left(-\varpi_\Pi \hat{\pi}_t - \varpi_Y \hat{yn}_t + \varpi_{FX} \hat{nfa}_t\right) + \hat{\varepsilon}_{GM,t}$$

where $gap_{M,t} = \left(\log\left(\frac{M_t}{P_t}\right) - \log\left(\frac{M_t^d}{P_t}\right)\right)$ and variables with hat over them denotes the log deviation of those variables from their respective steady state values.

Market Clearing

For the markets clear, the demand and supply in different markets must be matched.

Capital and Labor Markets

Capital and labor are supplied by the household whereas demand for those factors of production comes from the intermediate firms. The market clearing conditions are as follows:

$$K_t = \int_0^1 K_t^j dj$$

$$l_t = \int_0^1 l_t^j dj$$

Goods Market

The intermediate goods is used to produce consumption, investment and government goods. Therefore,

$$yn_t^j = C_{H,t}^j + I_{H,t}^j + G_{H,t}^j + \frac{AC_t^j}{P_{H,t}}$$

Aggregating output over the continuum of intermediate firms,

$$yn_t = \int_0^1 yn_t^j dj = (C_{H,t} + I_{H,t} + G_t)\int_0^1 (\frac{P_{H,t}^j}{P_{H,t}})^{-\theta} dj + \int_0^1 \frac{AC_t^j}{P_{H,t}} dj = (C_{H,t} + I_{H,t} + G_t)s_{H,t} + \int_0^1 \frac{AC_t^j}{P_{H,t}} dj$$

In nominal terms,

$$P_{H,t} yn_t = \int_0^1 P_{H,t}^j yn_t^j dj = P_{H,t} C_{H,t} + P_{H,t} I_{H,t} + P_{H,t} G_t + AC_t$$

Because the production in the economy takes place oil and non-oil sector, the overall nominal production Y_t is given in the following expression:

$$Y_t = P_{H,t} yn_t + OR_t$$

Using the equations for nominal consumption, investment expenditures and import,

$$P_t C_t = P_{H,t} C_{H,t} + P_{F,t} C_{F,t}$$

$$P_t I_t = P_{H,t} I_{H,t} + P_{F,t} I_{F,t}$$

and replacing them in the resource constraint, the overall production is determined as below:

$$P_{H,t} yn_t = P_t C_t + P_t I_t + P_{H,t} G_t - P_{F,t} IM_t + AC_t$$

$$Y_t = P_t C_t + P_t I_t + P_{H,t} G_t + OR_t - P_{F,t} IM_t + AC_t$$

Government Domestic Bond Market

The equilibrium level of domestic government bonds evolve according to the government fiscal budget constraint. Because we assume that the government holds the level of the borrowing from the public constant, the government bonds evolve according to the following constraint:

$$B_t = B_{t-1} = const$$

Foreign Bonds Market, Net Foreign Assets and Trade Balance

The supply of internationally traded bonds is perfectly elastic and matches the holdings of foreign bonds by the domestic representative household.

Because three different specifications are assumed in the model, the evolution of the economy-wide net foreign assets is different. In the first specification, the net foreign assets evolves according to

$$(R_t^*)^{-1} B_t^* = B_{t-1}^* + (OF_t^* - OF_{t-1}^*) - \frac{P_{F,t} IM_t}{e_t} + \frac{FuT_t}{e_t}$$

In the remaining two specifications, it is assumed that the domestic household does not hold foreign bonds.

Because the country only exports oil but imports foreign goods from abroad, the overall and non-oil trade balances can be defined as follows respectively:

$$TB_t = OR_t - P_{F,t} IM_t$$

$$TB_t^{no} = -P_{F,t} IM_t$$

3. Calibration

For some of the parameters employed in our calibration exercise, we depend on Azeri data and for some others we borrow from the existing literature. Certain parameters of the model are taken from the previous microeconomic researches and some are obtained from less structural macro-econometric models developed for the country. The steady-state ratios are calculated using the available time series from national income accounts and analytical balance of the CBAR and the rest of the parameters are borrowed from the related literature.

The values of subjective discount factor β and the share of money services $\gamma_M / (1-\kappa_M)$ are obtained from Huseynov and Ahmadov (2012). In their work, the quarterly subjective discount factor and the share of money services are estimated to be 0.99 and 0.01 respectively. Using the money demand elasticity estimates $1/\kappa_M$ from the previous empirical works whose magnitude was estimated to be around 0.1, the γ_M is calculated as 0.09.

Table 1. Calibrated Parameters

Parameters	Values	Source/Method
β	0.99	Based on Huseynov and Ahmadov (2012)
γ_M	0.09	Based on Huseynov and Ahmadov (2012)
γ_{B^*}	0.01	Taken from literature
κ_M	10.0	Based on previous estimates
σ_C, τ_L	1.0	Taken from literature
ψ	4.7	Calculated using steady-state solution of the model
τ_W	0.14	Income tax rate for the first income bracket
$\gamma_C,\ \gamma_I$	0.5	Calculated using consumption basket
$\mu_C,\ \mu_I$	0.23; 0.12	Calculated using data on imported goods
α	0.35	Calculated using data from input-output table
θ	6.0	Based on survey evidence
φ	59.0	Standard value in literature
χ	0.1	Based on data
$\omega_G, \omega_{Oil}\ \nu, \iota$	0.41; 0.11; 0.1; 0.25	Calculated using respective database

The intertemporal elasticity of substitution σ_C and wage elasticity τ_L are calibrated to be one in magnitude. The steady state value of labor $\overline{L}$ is set to 0.33 to satisfy the assumption that a representative household spends approximately one third of its time for her job. Using the steady state solution of the model, the share of leisure in the utility function of the household is calculated as 3.6. To be consistent with the tax rate for the first income bracket in the country (up to 2500 AZN, monthly salary), the income tax rate τ_W is set to 0.14 and can be considered a representative tax rate for the most of the employees.

The previous empirical studies show that the share of *home* goods (γ_C and γ_I) in the composition of consumption basket of households is around *50%*, and the demand elasticity of imported consumption and investment goods are estimated to be 0.23 and 0.12 using the detailed data on the imported products.

The depreciation rate of both public and private capital is assumed to be the same and is set to 0.025 on quarterly basis which ensures *10%* depreciation annually.

Using aggregate data on production, the share of capital α in the Cobb-Douglas production function is calculated as 0.35, asserting that the labor costs comprises *65%* of production. To ensure the condition that a monopolistic firm charges *20%* markup over its marginal cost, the value of θ is set to 6.0 for all firms. With above calibrated values for β and θ we set the value of the nominal adjustment cost parameter φ to 59.0, suggesting that the prices remain sticky for 4-5 quarters.

We set the value of the scaling factor χ in the augmented TFP equation to 0.1, to reflect the fact that public investments generally carried out at lower efficiency.

Table 2. Calibration of shocks

Stochastic driving processes of shocks	Std. dev	ρ_j **for** $j \in [0,4]$
Productivity ε_A	0.058	
Foreign interest rate ε_{RF}	0.001	1.29; -0.45; 0.0; 0.0
Foreign inflation ε_{P^*}	0.0039	0.13; 0.0; 0.0; 0.0
Oil price $\varepsilon_{P^{O*}}$	0.14	0.69; 0.0; 0.0; 0.0
Oil output ε_{YO}	0.1	
Risk premium shock ε_{RP}	0.16	
Foreign risk premium ε_{RPF}	2.0	
Money growth shock ε_{μ}	0.15	
Interest rate shock ε_R	0.0015	
Money gap shock ε_{GM}	0.03	

Using the data on budget expenditures, the calculations show that the public investment expenditures comprises approximately *41%* of government expenditures (ω_G). Moreover, the efficiency of public investments ν and the pace of government spending ι are set to 0.1 and 0.25 respectively.

The parameters in the specifications of the monetary authority are considered as free parameters and calibrated to demonstrate desirable dynamics in the model following an oil price shock.

4. The Experiments

We check the performance of the model by focusing on the impulse-response dynamics of the selected macroeconomic variables after an oil price shock under benchmark scenario and various policy mixes.

4.1. Benchmark Simulation

The response of the selected macroeconomic variables to an oil price shock is displayed through Figures 1-9 (see Appendix) under the benchmark scenario. It is assumed that

- the oil fund transfers all incremental increase in oil revenues to the budget
- monetary authority pursues a peg regime and intervenes FX market to absorb excess supply/demand

Due to model specification, the effect of the oil price shock will propagate to the economy through its first round effect on the fiscal sector. The part of the increase in oil revenues resulted from a rise in oil prices is transferred to the government budget, hence pushing up the budget revenues. The second round effects of the oil price shock are induced by the expansion in government expenditures, namely public consumption and investment spending. The government consumption and investment expenditures boost the aggregate demand, however, beside its effect on the aggregate demand, public investment also augments public capital, hence enhancing total factor productivity (TFP) and aggregate supply.

In all three specifications, the consumption expenditure of the household sector responds adequately and its behavior is consistent with ex-ante expectations. It is worth to note that the effect of the oil price shock is more robust on the consumption dynamics of the third specification. Because of the rise in consumption, the demand for imported consumption goods grows in all specifications, but this growth is more pronounced in the third specification. The private investment expenditures and imported investment goods also demonstrate similar behavior.

The government expenditures and public investment spending also rise, but this increase is more evident in the case of the first specification. The jump in the public investment augments public capital and hence, enhances TFP. The rise in consumption, investment and government purchases leads to expansion in the production and consequently, the real non-oil GDP grows significantly despite the sizable increase in the demand for imported goods. The model demonstrates the effect of the fiscal impetus on the real non-oil economy due to the expansion in the oil production which stimulates fiscal spending, feeding back into the non-oil sector.

The positive advances in the real economy creates upward pressure on the real wages of labor and marginal costs of the firms. The same behavior reveals itself in the dynamics of domestic prices which jumps more forcefully in the third specification. The response dynamics of the foreign prices is the reverse of the domestic prices, and similarly, falls more significantly in the case of third specification.

We observe similar dynamics in the cases of money supply and the interest rate in all specifications. In the first specification interest rate is imported from the external world through UIP condition under fixed exchange regime. In the second specification, it is assumed that the money demand adjusts instantaneously to the money supply. However, in the third specification the money supply deviates from the money demand in the short run because of the temporary disequilibrium assumption.

Despite all these differences in the specification of the monetary authority, money supply exhibits similar responses and contracts in the first ten periods. However, it restores its previous levels and begins to expand after approximately twelve periods. Respectively, the interest rate shoots up in the beginning periods but enters into the negative zone in the later periods.[4,5] In the third specification, money demand and money supply do not overlap in the short run and money gap becomes significant as money demand responds more strongly than money supply.[6]

[4] In the case of the third specification, because money demand responds to the oil price shock more strongly than money supply, the market interest rate rises.

[5] Except the first specification, we expected that in response to the increase in oil fund transfers to the budget, the monetary authority would intervene to the FX market to absorb excess supply of the foreign currency to relax the downward pressure on the exchange rate. This central bank transaction would cause expansion in the money supply as the authority lacked necessary instruments to sterilize its intervention.

[6] The comparatively weak response of the money supply might be tracked down to the substantial jump in the volume of the imported goods. However, even after improving and moderating the effect of the import on the money

4.2. Fiscal Policy Option

The benchmark scenario assumes complete spending of the oil revenues as it accrues to the oil fund. It is also interesting to test a different fiscal spending rule, namely, expenditure smoothing rule (using Permanent Income Hypothesis (PIH)) followed by the fiscal authority (see Figures 10-19 in Appendix).

Under the PIH spending rule, the real macroeconomic variables of interest in the second specification demonstrate stronger responses to the oil price shock. Namely, the consumption, investment expenditures and physical capital stock of the household sector jump more significantly in the second specification. However, in most of the cases the response dynamics of the respective variables in the first and the third specifications are similar.

The oil fund transfers to the government budget based on the fiscal policy rule (PIH) rise more sharply in the second specification and hence, the government expenditures. Consequently, the non-oil GDP rise substantially in the second specification, but falls and approaches to zero after a short time.

The import prices fall, but domestic prices rise more steeply in the second specification. The CPI spikes upwards in the beginning years but then enters a downturn and approaches to zero in later periods. As in the case of real variables, price dynamics of the first and the third specifications are similar and very close to zero.

4.3. Monetary Policy Option

Under the benchmark scenario, the monetary authority maintains a fixed regime and intervenes FX market to absorb excess supply/demand of foreign currency from the market. We will also test the performance of the model under more flexible exchange rate regime (see Figures 20-33 in Appendix).

In the case of a more flexible exchange regime, the macroeconomic variables exhibit even much richer dynamics. When compared to the fiscal policy rule simulation, the response dynamics of the almost all macroeconomic variables of interest are different in all three specifications. The consumption expenditures, import of the consumer goods and physical capital respond more forcefully in the third specification. However, the government and investment expenditures, import, oil fund transfers and non-oil GDP rise more significantly in the first specification.

The import prices slump, but the domestic prices move upwards more sharply in the case of third specification. In the first periods, the consumer prices bounce up but after fiver periods it enters the negative zone.

The exchange rate depreciates in all three specifications due to the exchange rate rule followed by the monetary authority. In the first periods, the depreciation is more evident in the case of the third specification, but the appreciation starts to take place after five periods and become more influential in the case of the second and the third specifications.

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supply which creates the required demand for the excess supply of the foreign currency in the FX market, the money supply "puzzle" still remains.

5. Conclusion

In this paper, we developed a Dynamic Stochastic General Equilibrium (DSGE) model for an oil rich country. Apart from the classical DSGE models where the model is generally closed using Taylor rule for countries maintaining flexible exchange regime or fixing exchange rate for countries pursuing a hard peg, we explicitly modeled the FX market and central bank intervention to the market.

In most of the classical specifications, foreign exchange markets are generally ignored and the exchange rate is typically assumed to be determined by UIP condition, relating exchange rate expectations with interest rate differentials. We also followed the suit and built our first specification based on the classical assumptions.

However, in the second and third specifications, we deviated from the classical assumptions and developed models to capture the main characteristics of FX markets in oil exporting countries. There, we dropped the UIP assumption and replaced it with an exchange rate rule followed by the central bank. Moreover, we also explicitly gave the detailed specification of the fiscal and monetary sectors. The mechanism of the spending of oil revenues through fiscal channel and its all-round feedback on the rest of the economy and growth were carefully outlined.

The comparison of the response dynamics of main macroeconomic variables in those specifications reveal interesting results. Most of the time, the responses of those variables to the shocks have the same direction, though different magnitudes. Namely, when we define a different spending policy rule for the fiscal authority or an exchange rule for the monetary authority the model provide consistent results in all specifications. We find that all three specifications allow the fiscal authority to act as the main actor in propagating and amplifying the effects of the oil price shocks to the rest of the economy.

For the benchmark simulation, the response dynamics of the most of the main macroeconomic variables are in line with ex-ante expectations. The most surprising response dynamics are observed in the cases of the money supply and the market interest rate after an oil price shock. However, despite significant differences all three specifications demonstrate strikingly similar response dynamics.

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APPENDIX

A. Impulse-response functions

A1. Benchmark simulation

Figure 1. Consumption

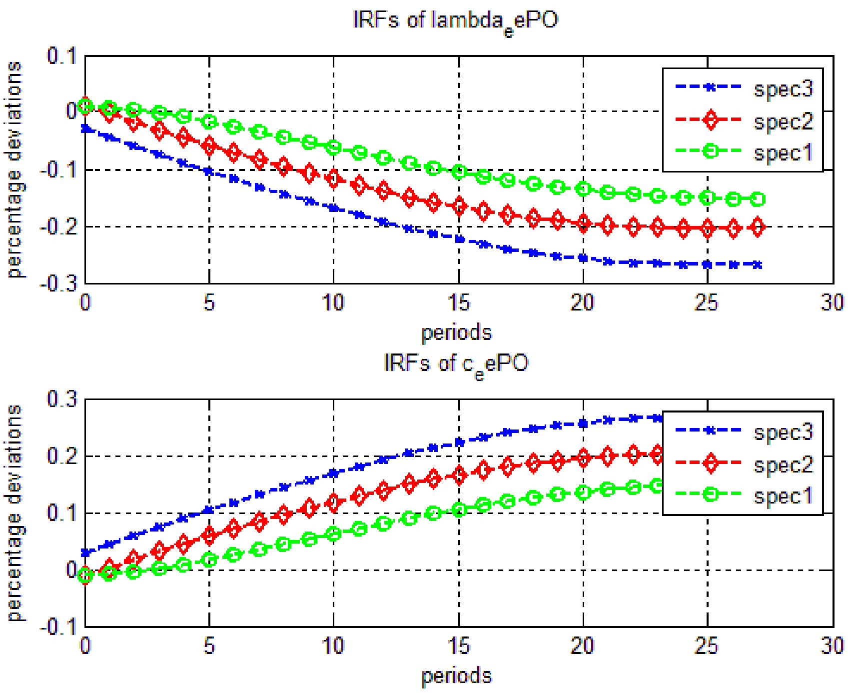


Figure 2. Government expenditures and public investment

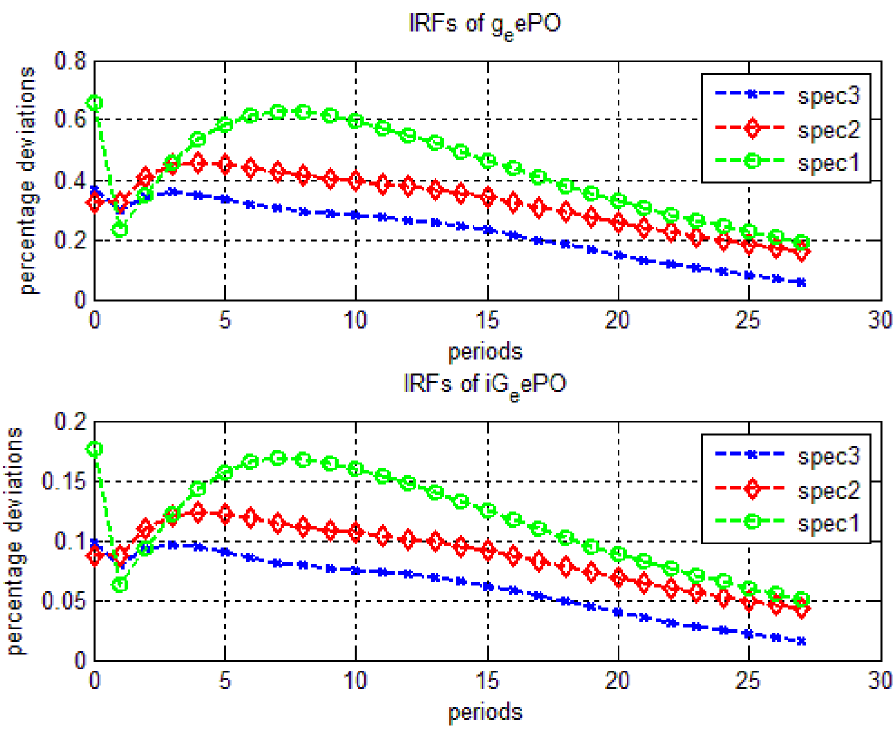


Figure 3. Imported consumer and investment goods

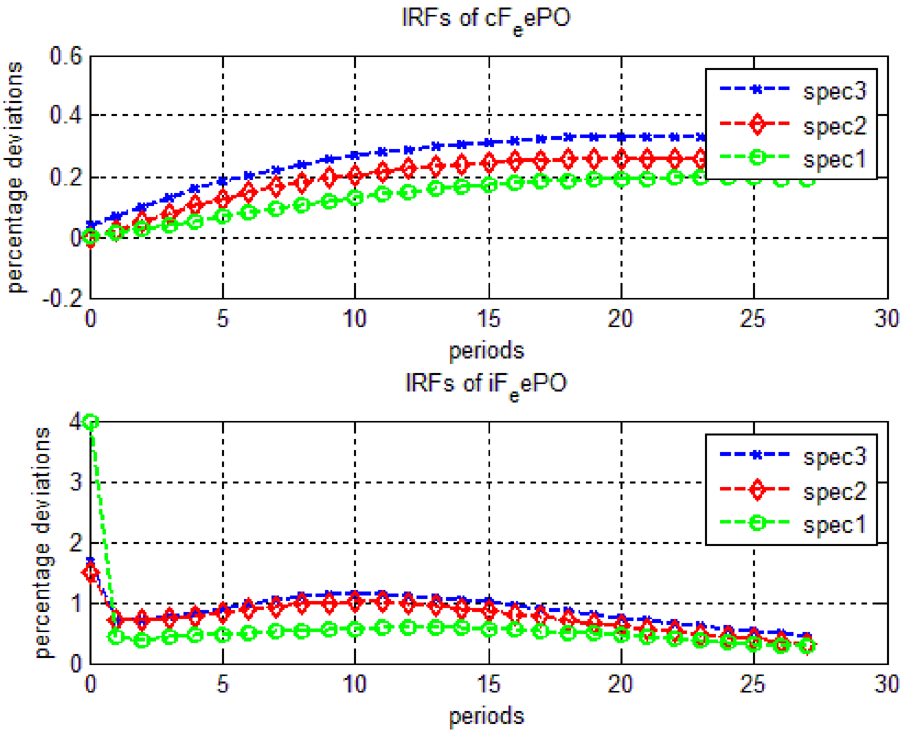


Figure 4. Import

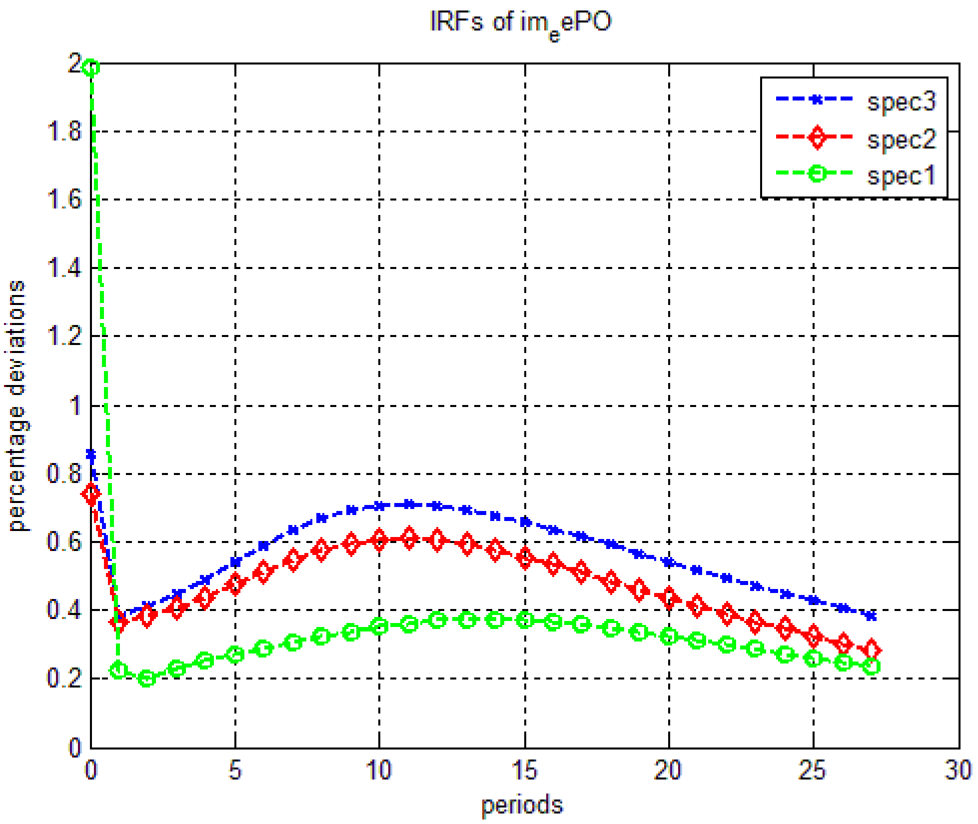


Figure 5. Interest rate

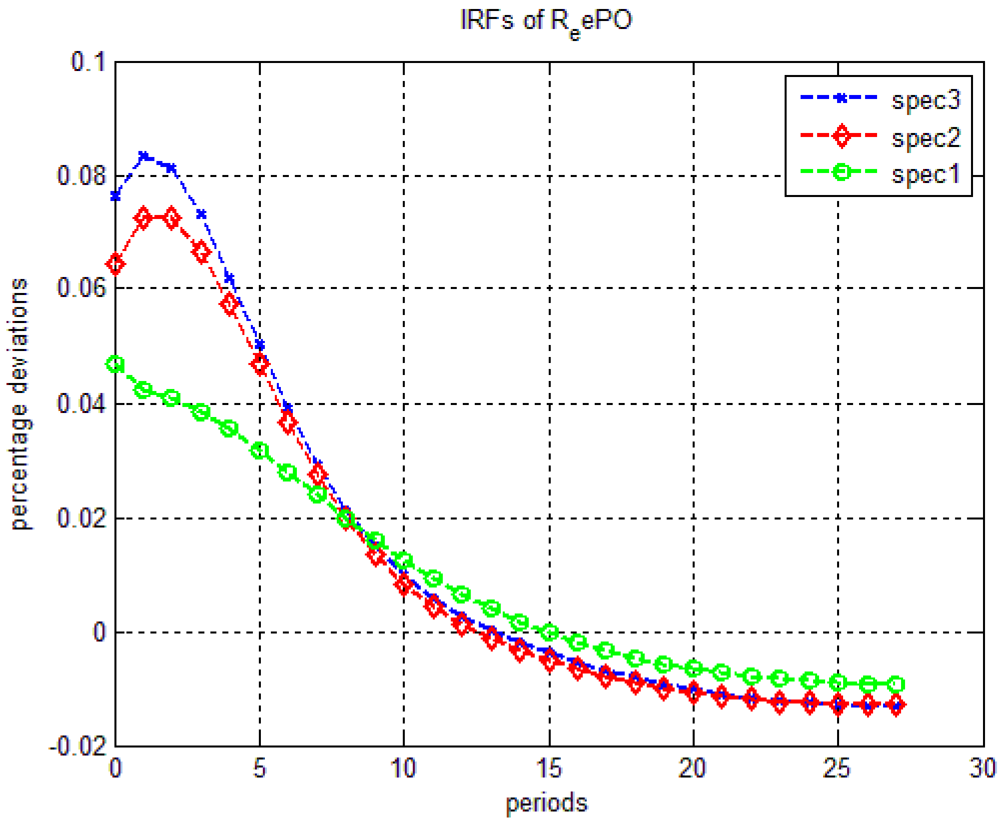


Figure 6. Money supply

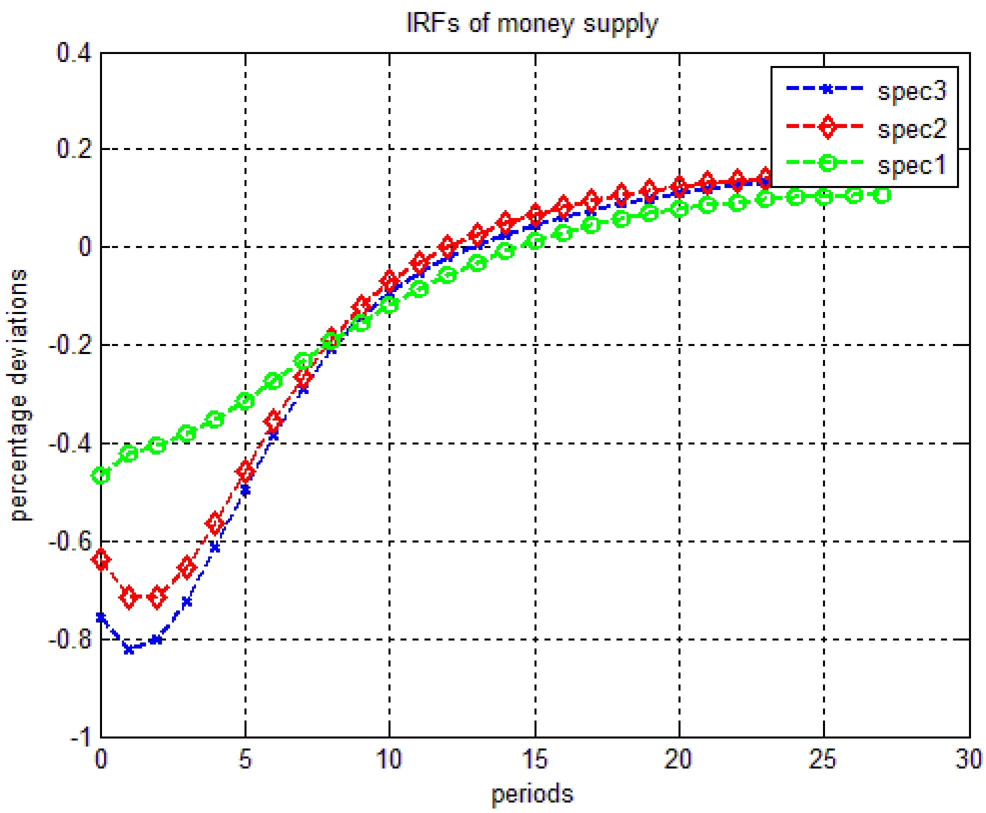


Figure 7. Wage and non-oil GDP

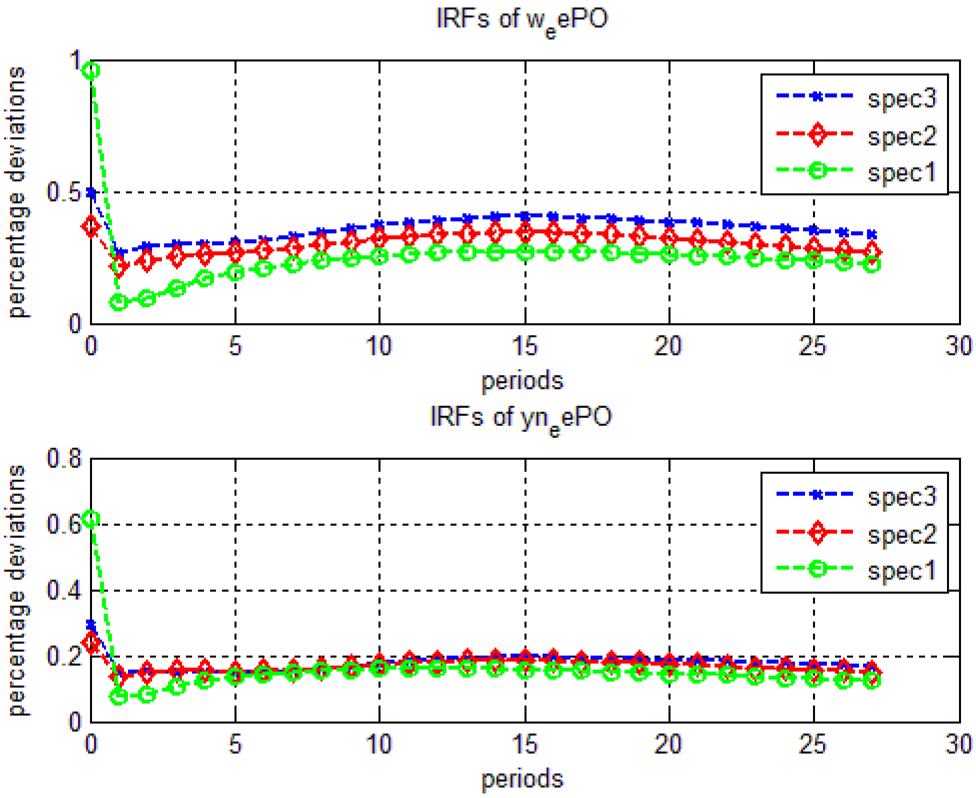


Figure 7. Public capital and marginal cost

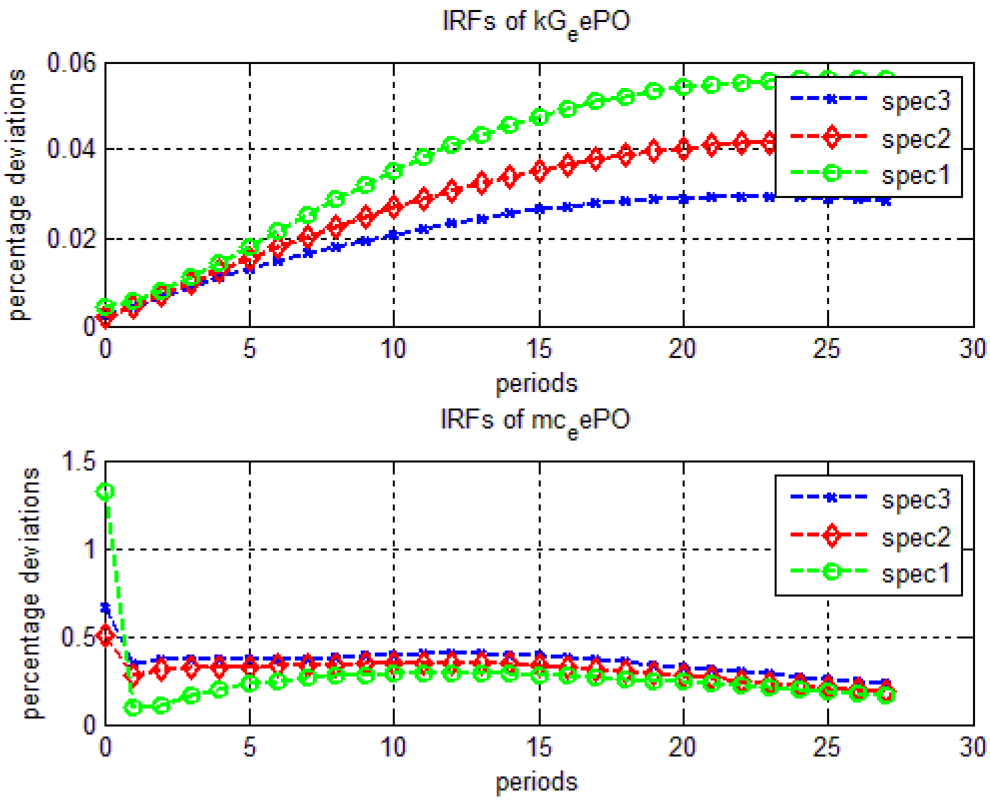


Figure 8. Domestic and imported prices

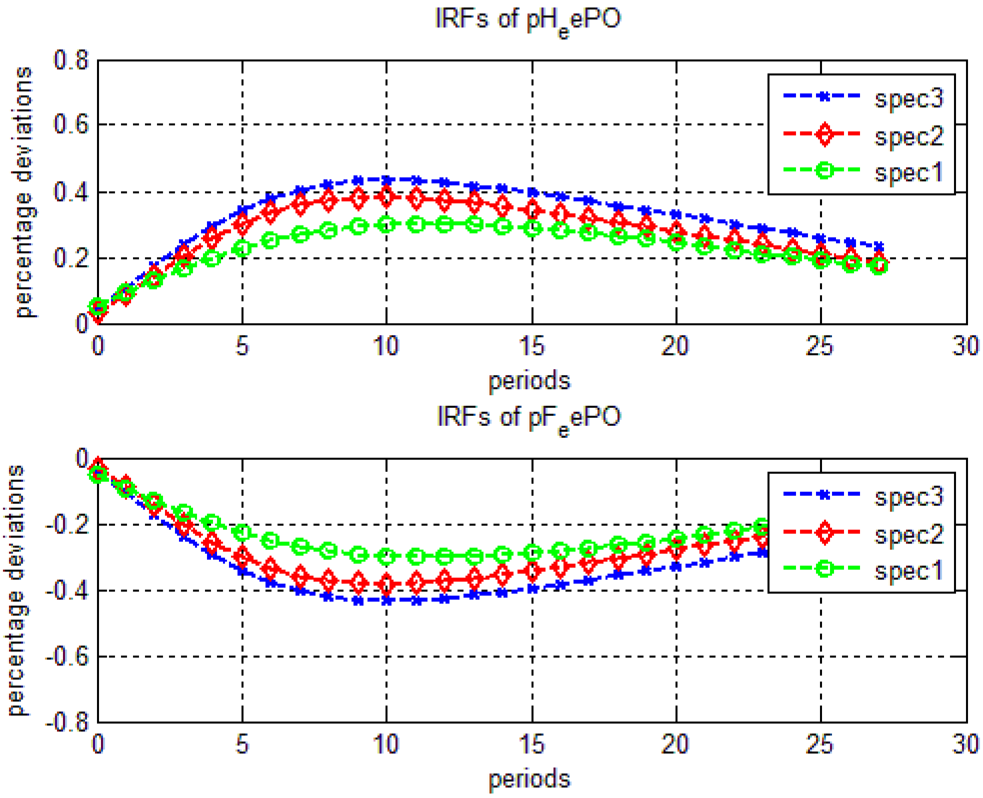
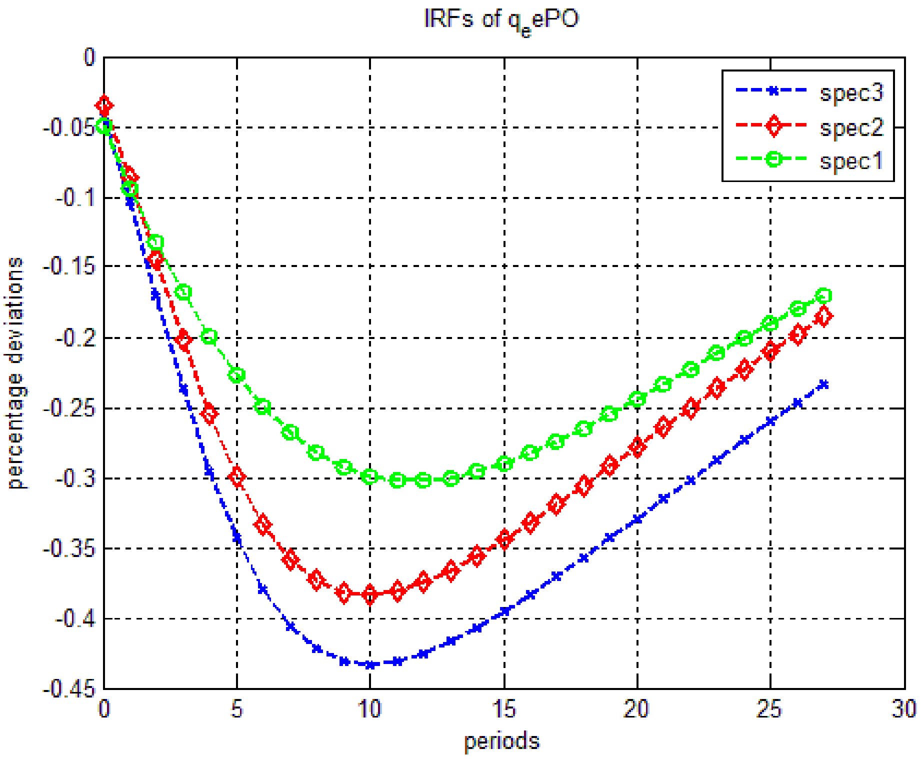


Figure 9. Real exchange rate



A2. Fiscal policy rule

Figure 10. Consumption

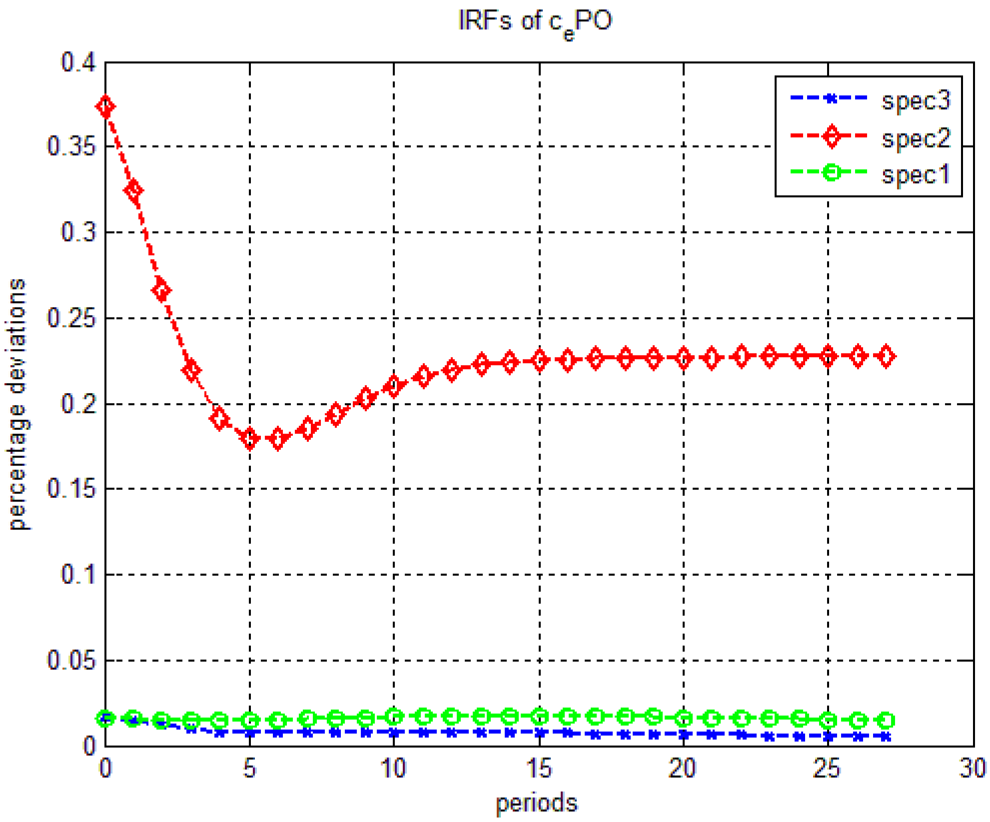


Figure 11. Investment

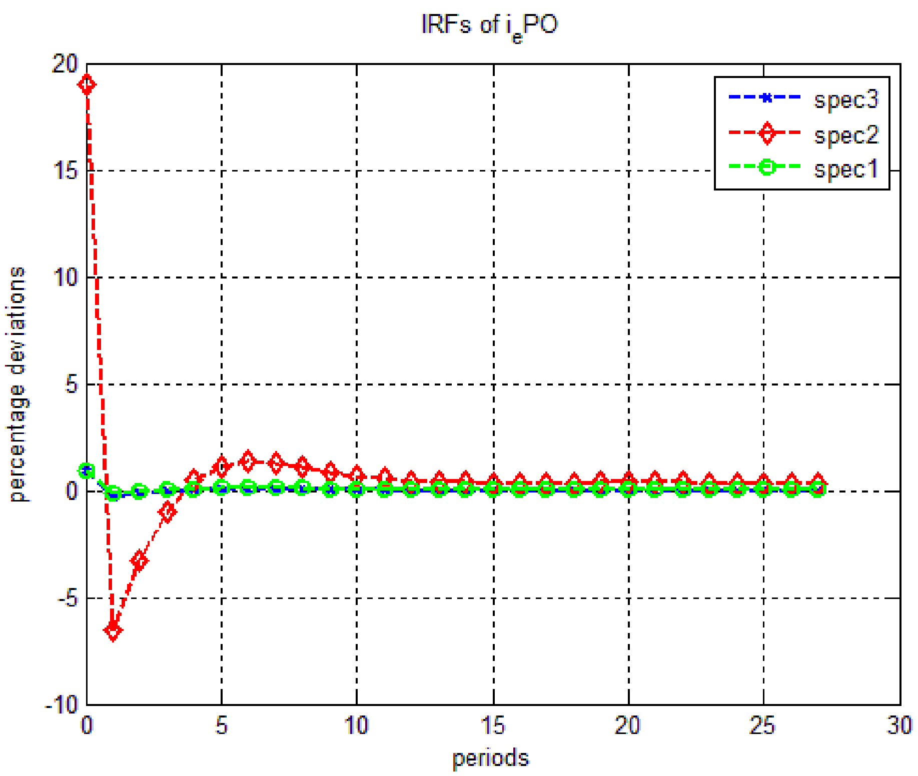


Figure 12. Government expenditure

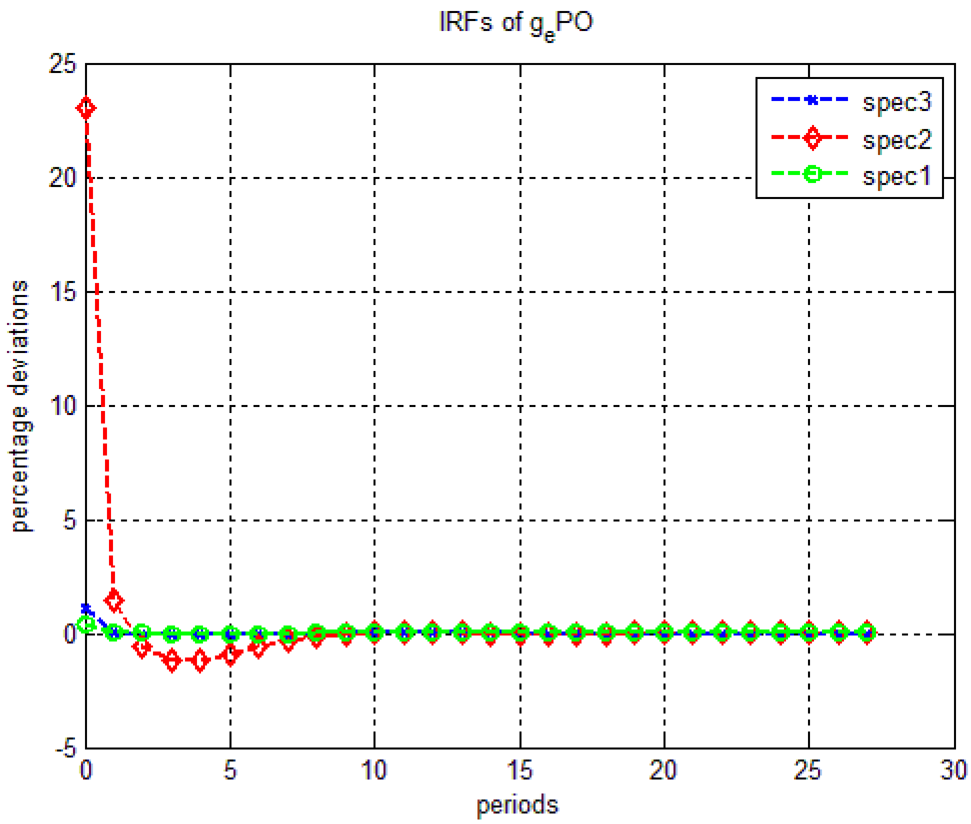


Figure 13. Public capital

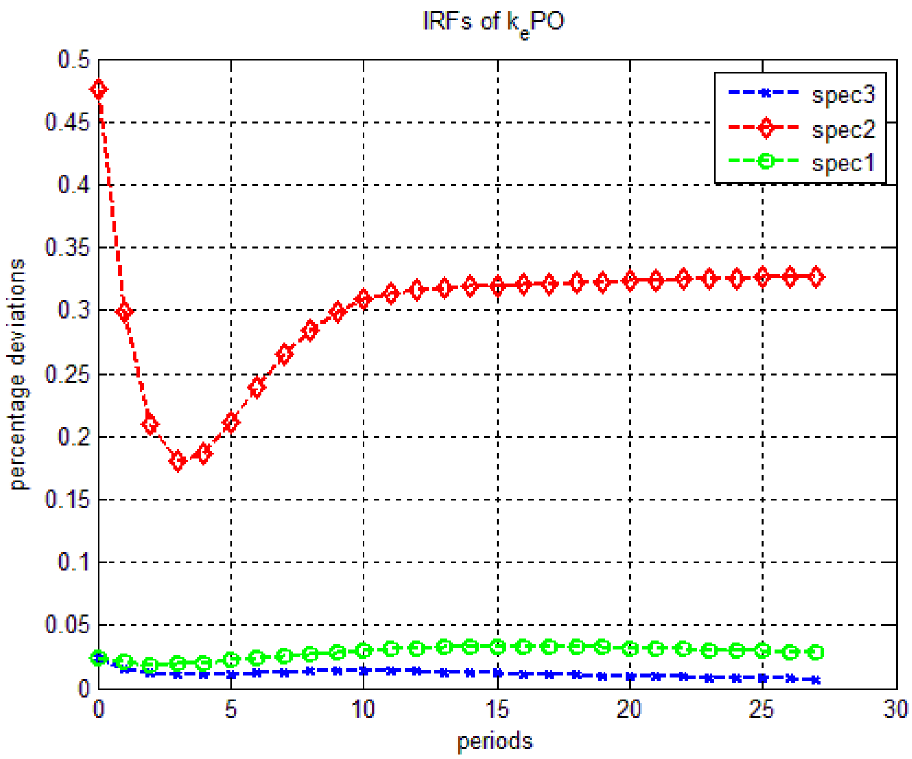


Figure 14. Import

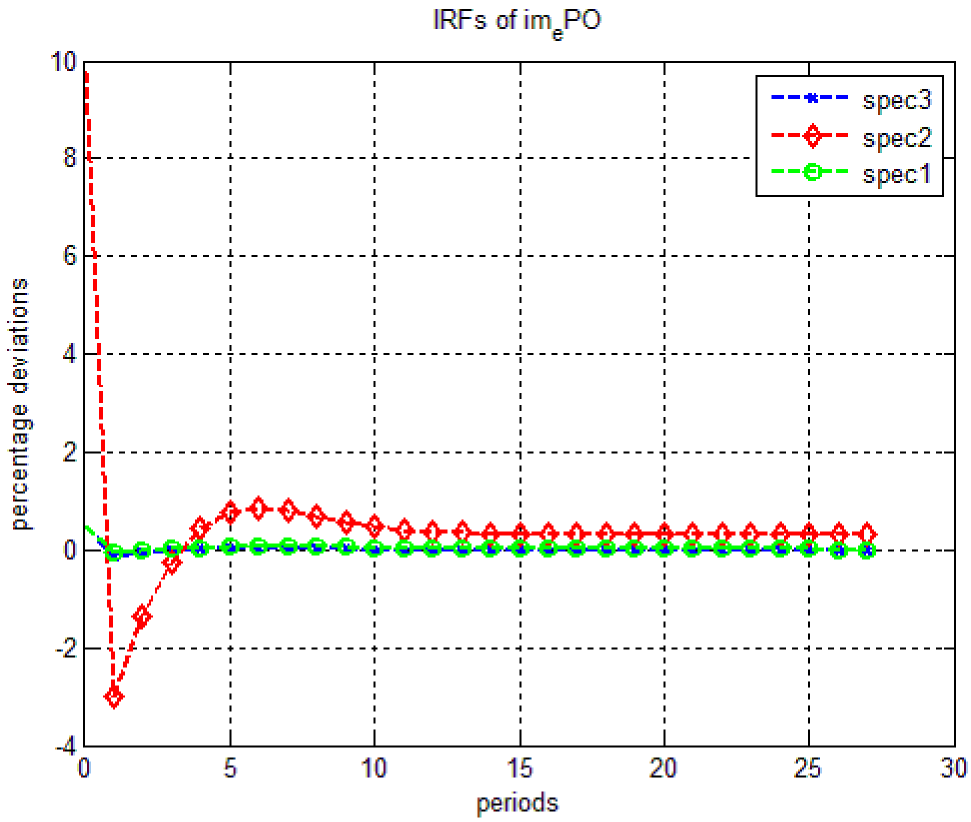


Figure 15. non-oil GDP

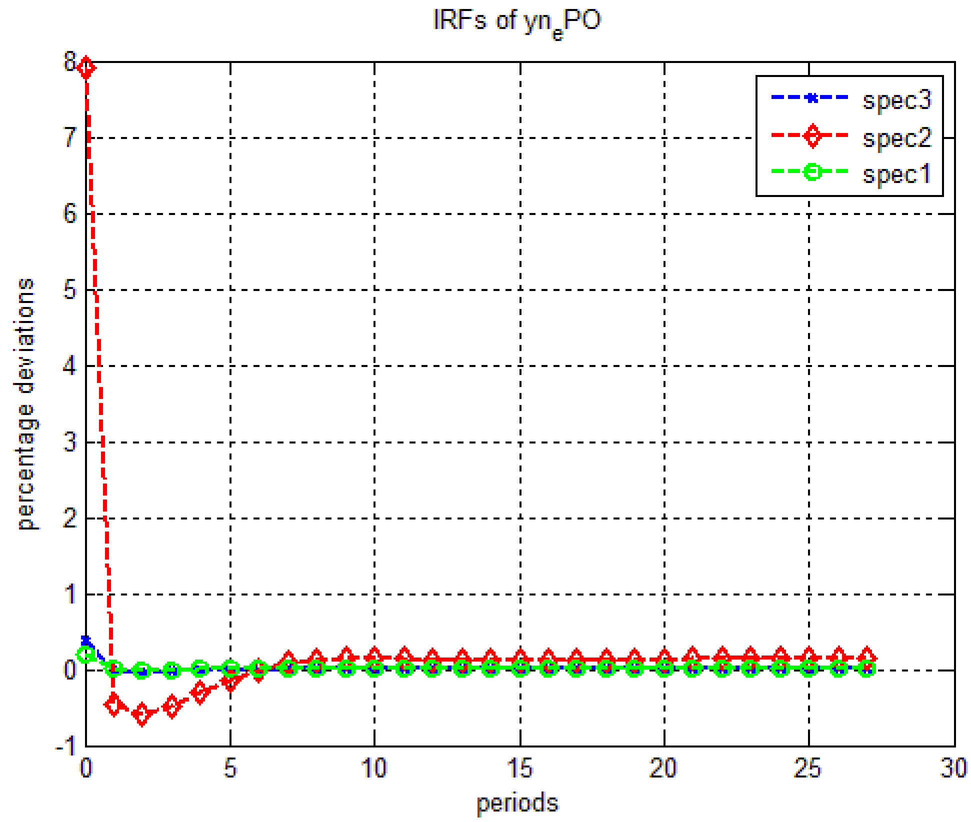


Figure 16. Imported consumer goods

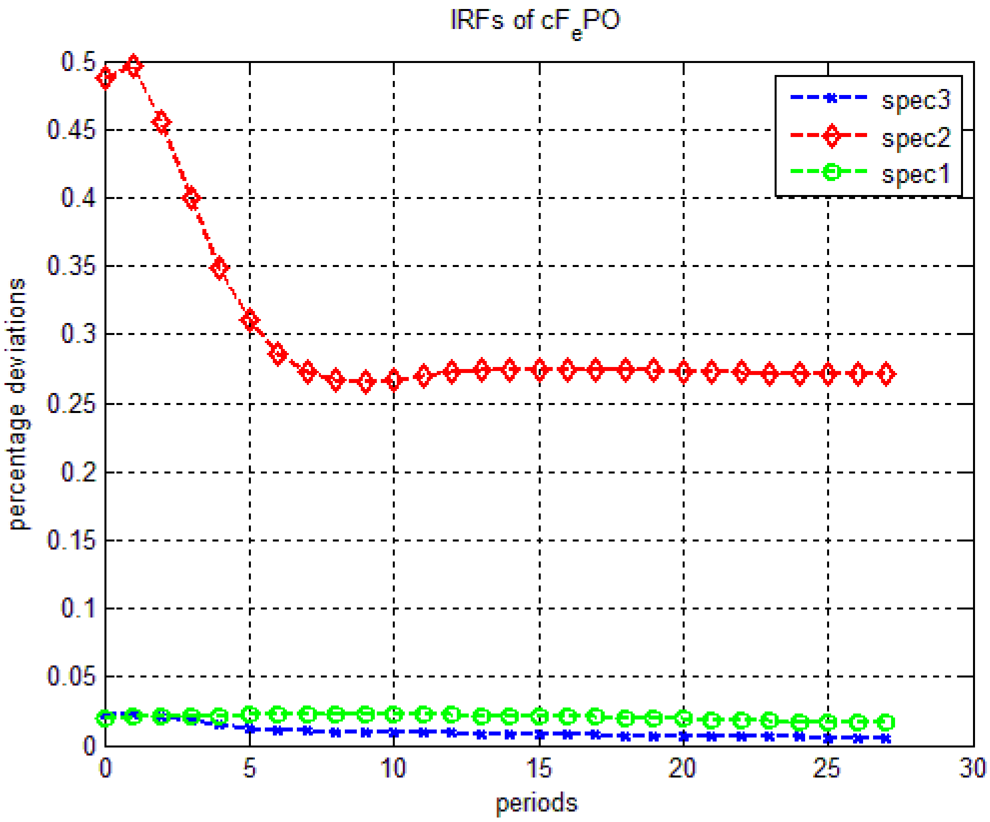


Figure 17. CPI

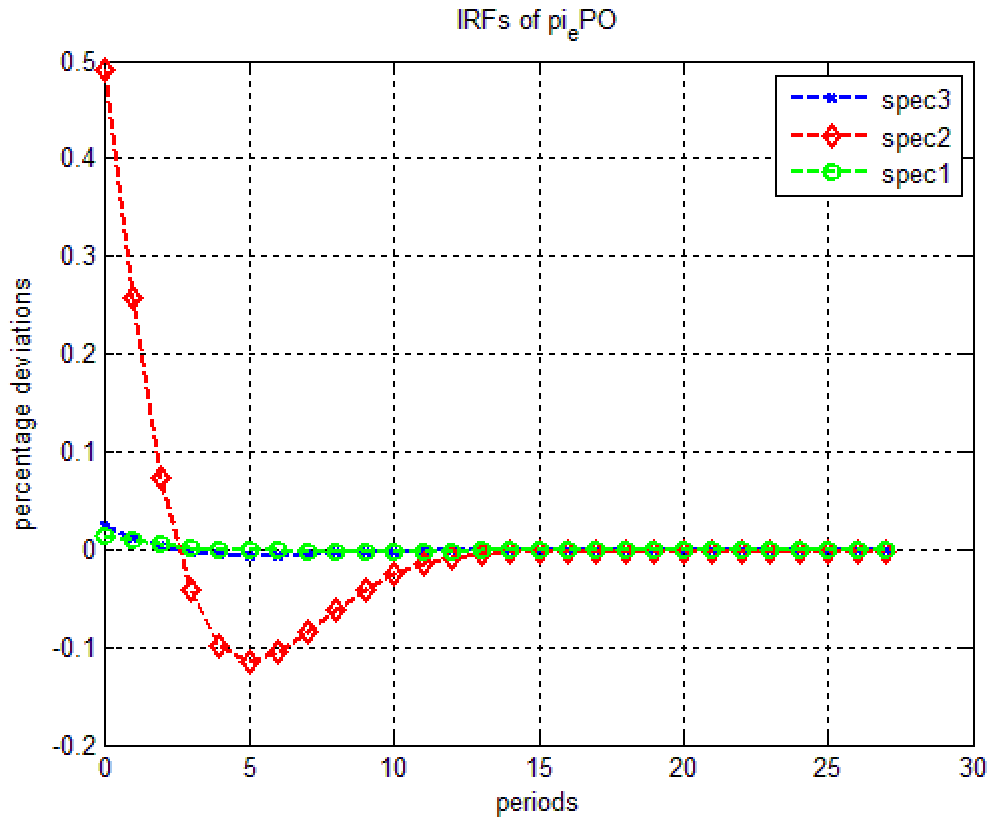


Figure 18. Price of imported goods

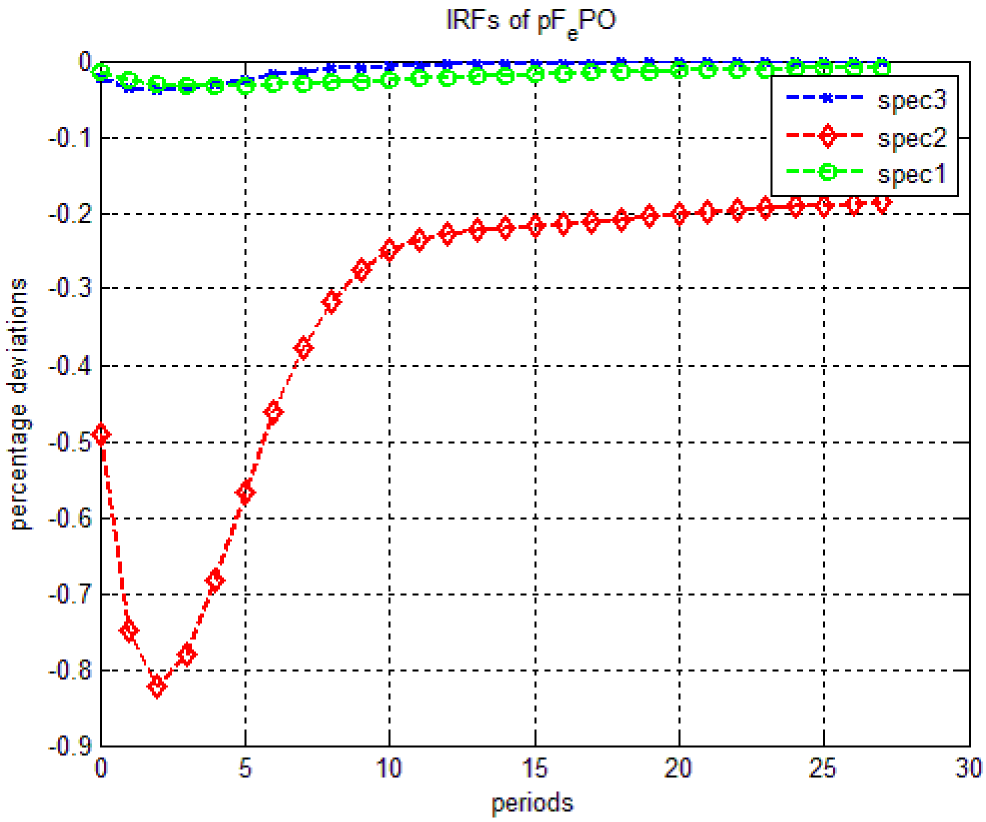
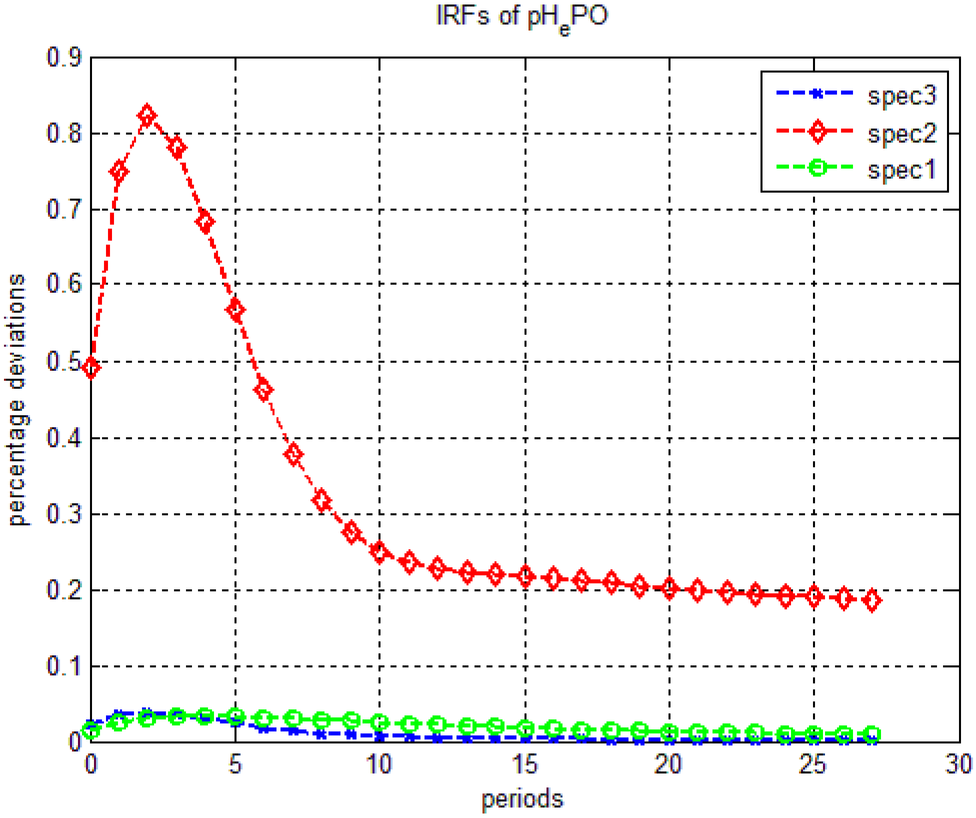


Figure 19. Price of domestic goods



A3. Monetary Policy rule

Figure 20. Consumption

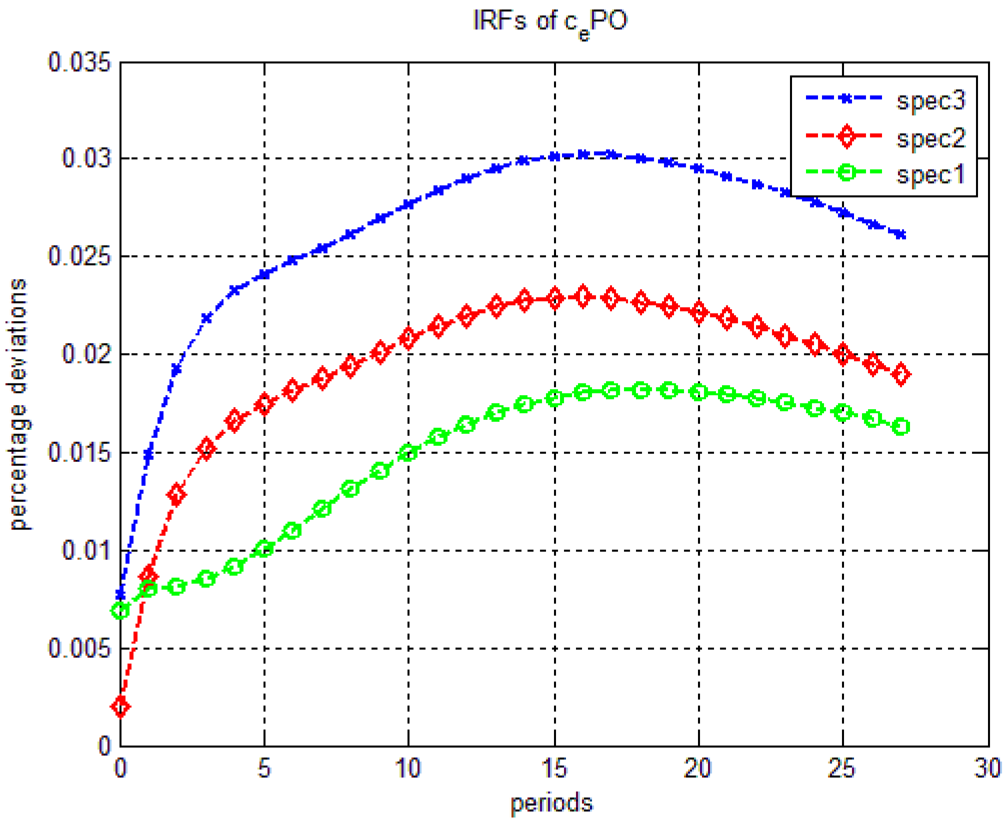


Figure 21. Investment

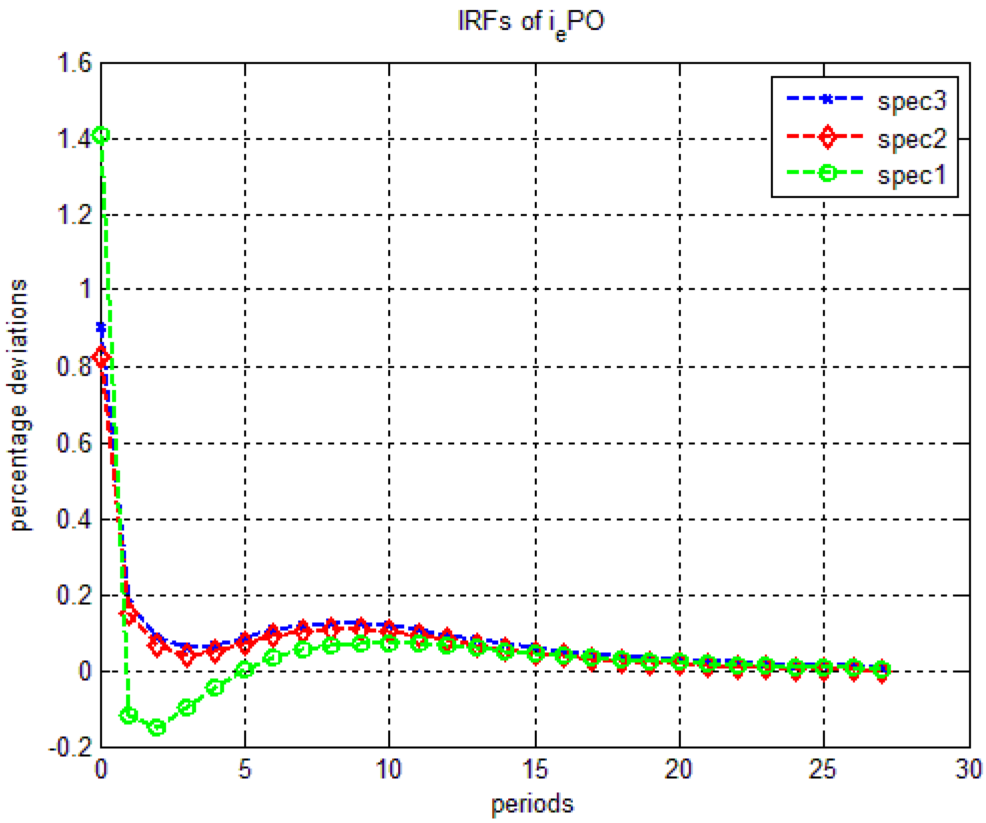


Figure 22. Government expenditure

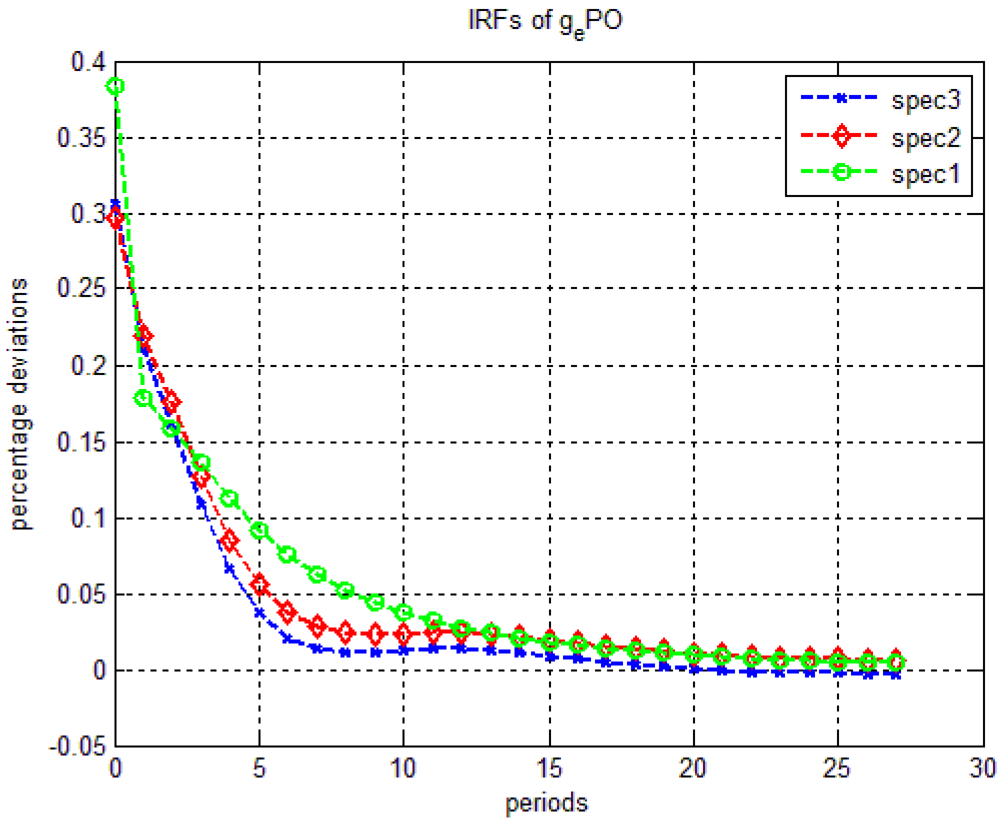


Figure 23. Imported consumer goods

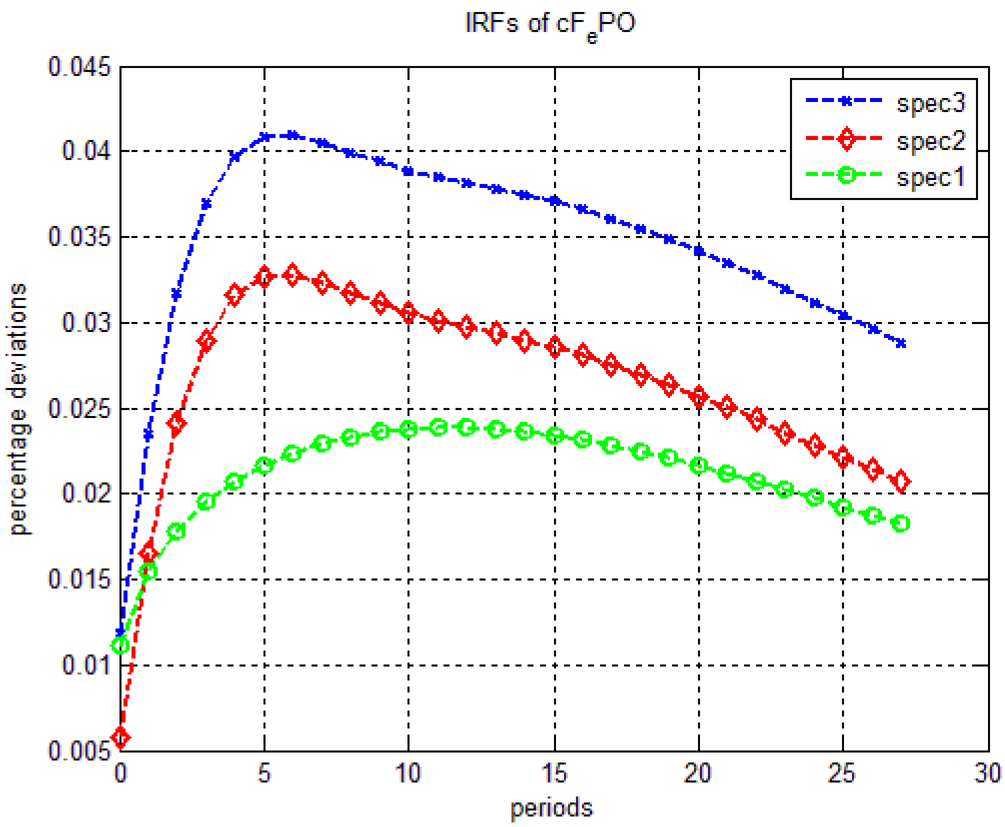


Figure 24. Imported investment goods

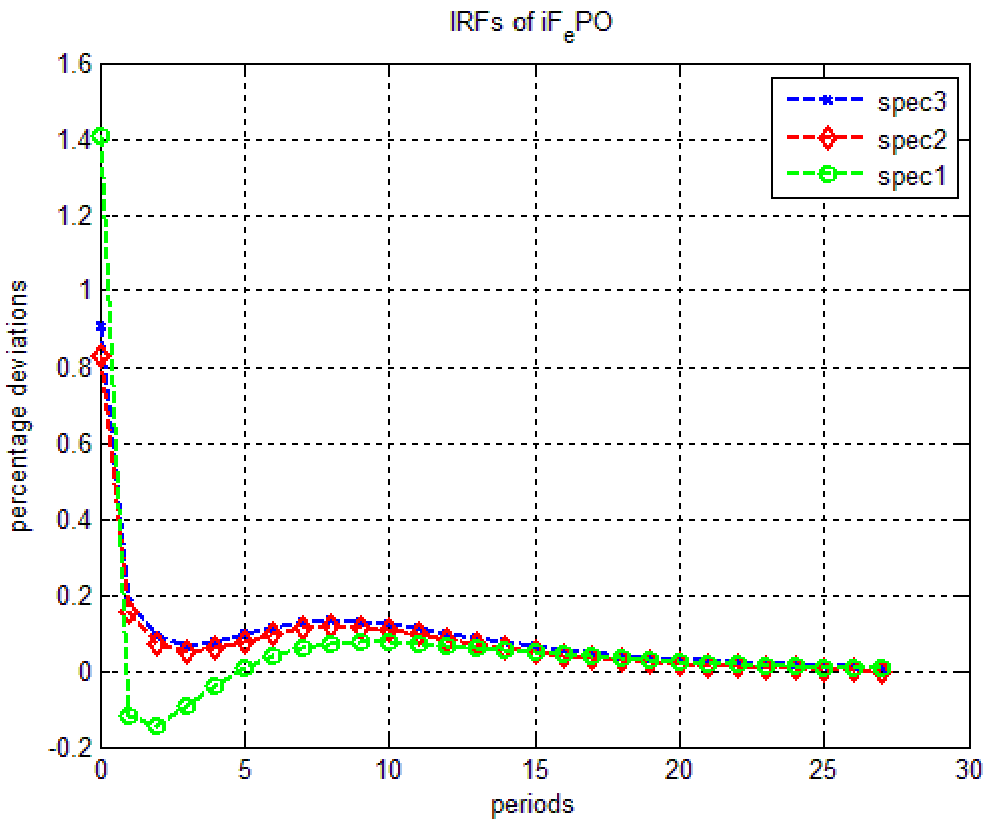


Figure 25. Import

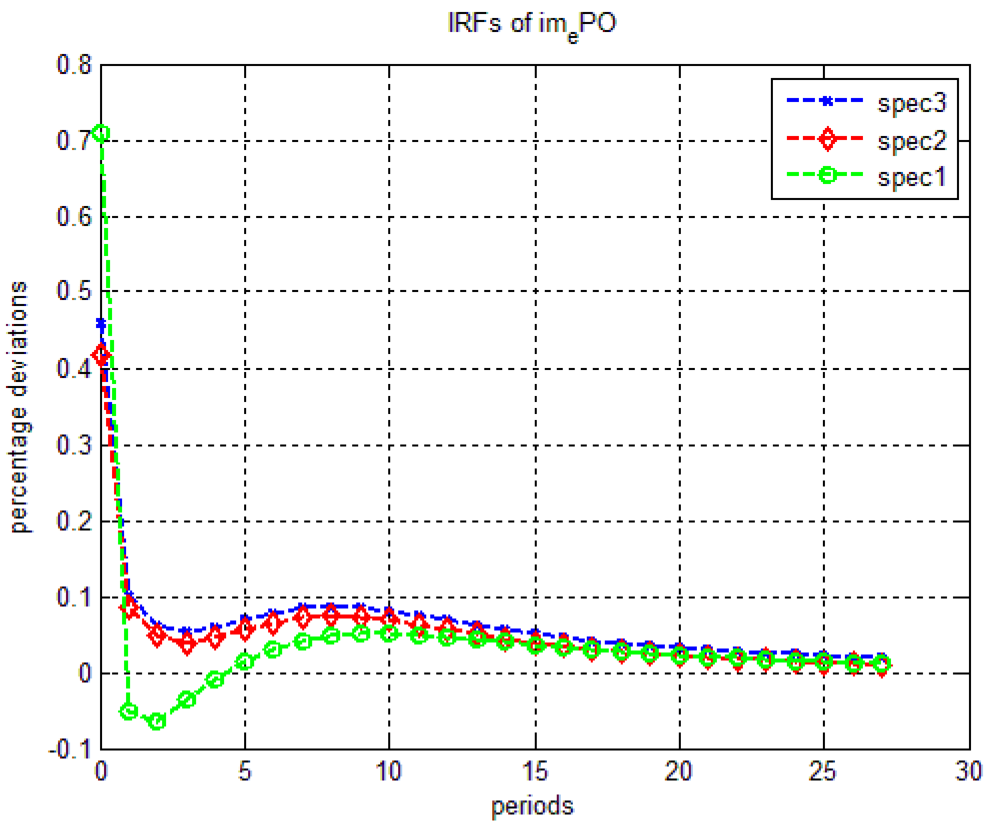


Figure 26. non-oil GDP

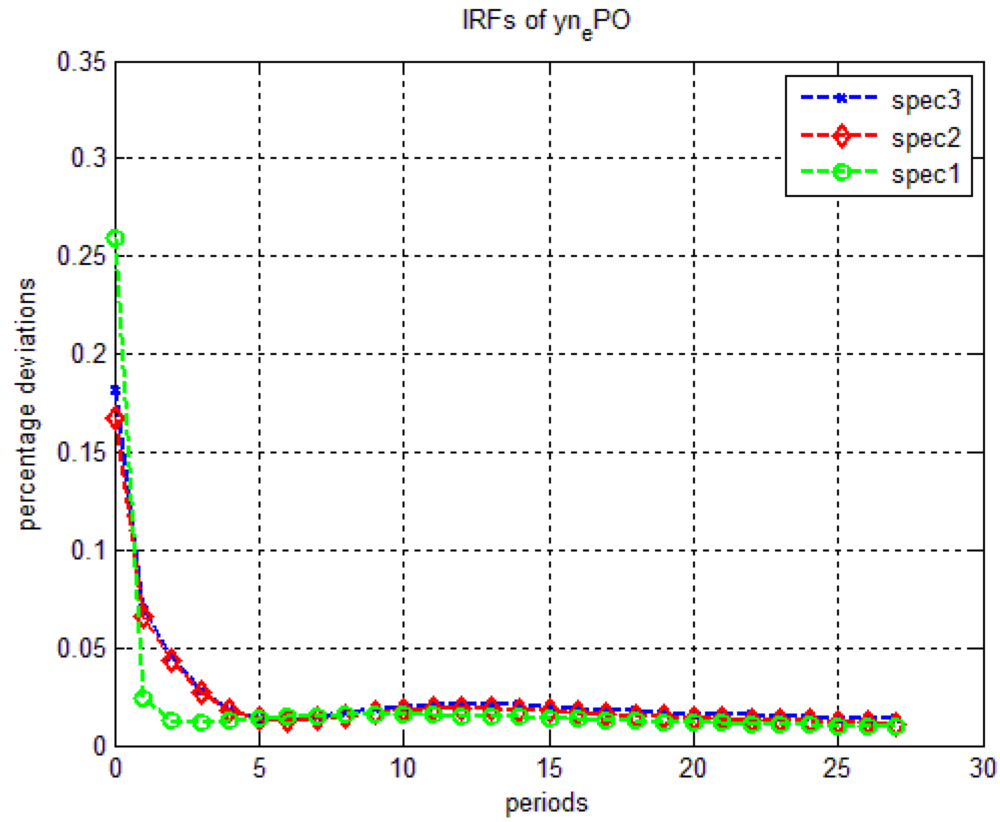


Figure 27. Capital stock

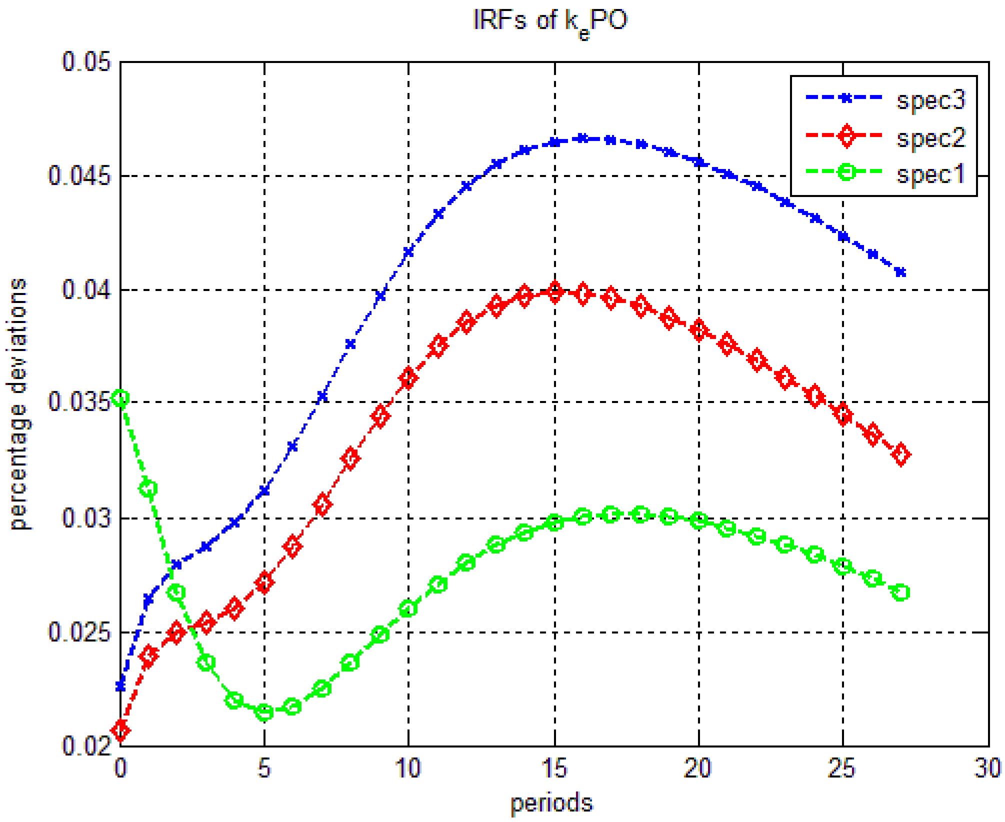


Figure 28. Fund transfers

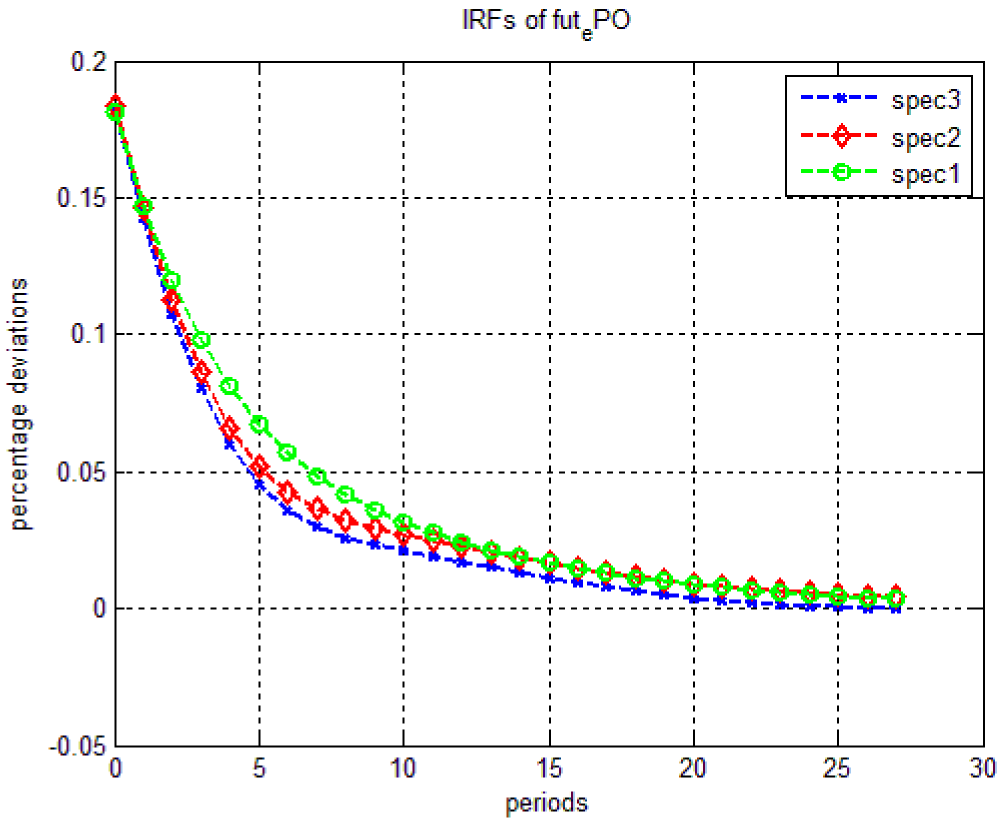


Figure 29. Exchange rate

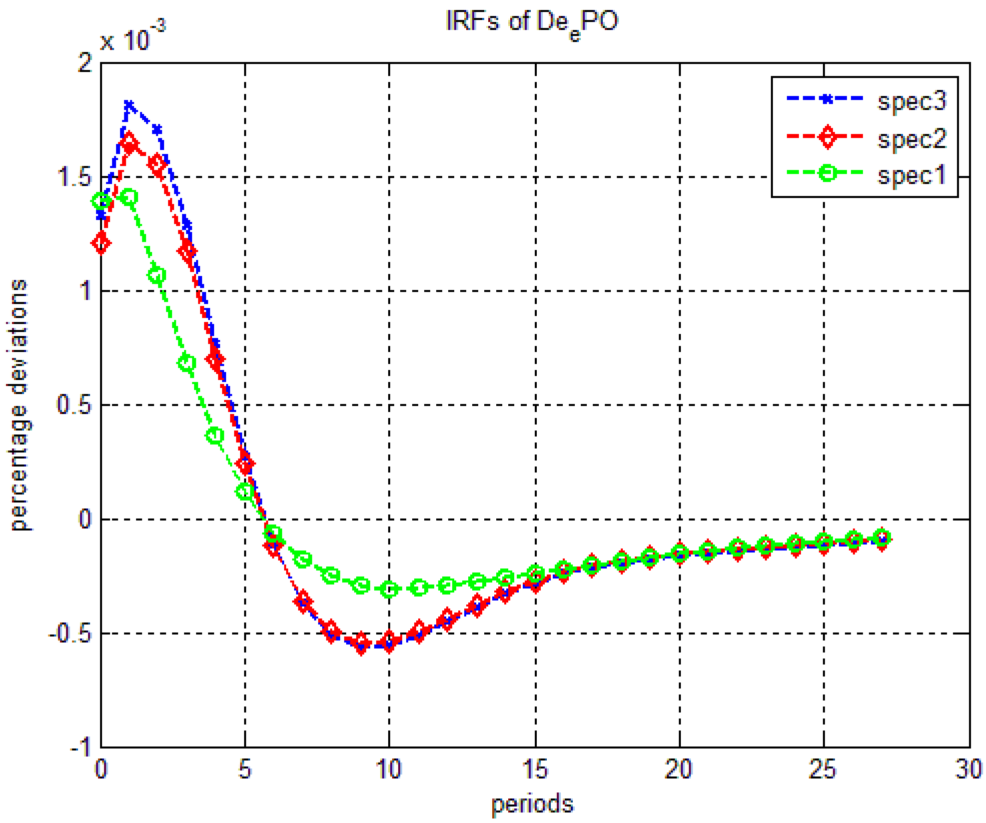


Figure 30. Interest rate

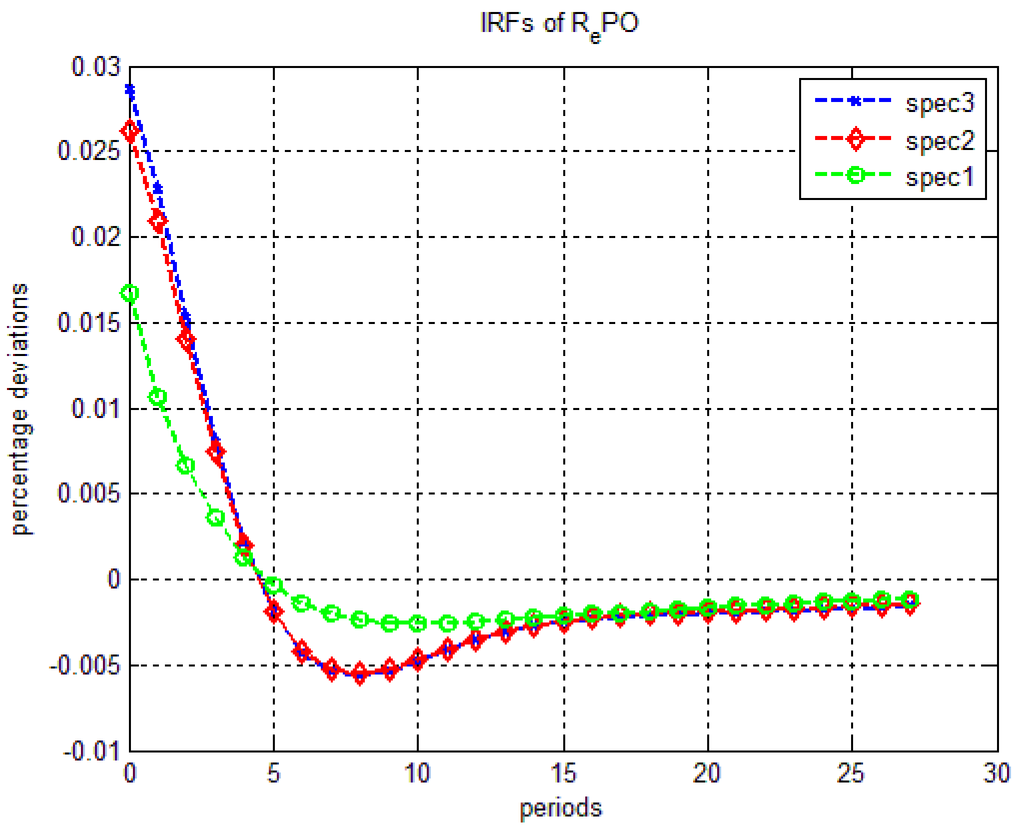


Figure 31. Domestic price

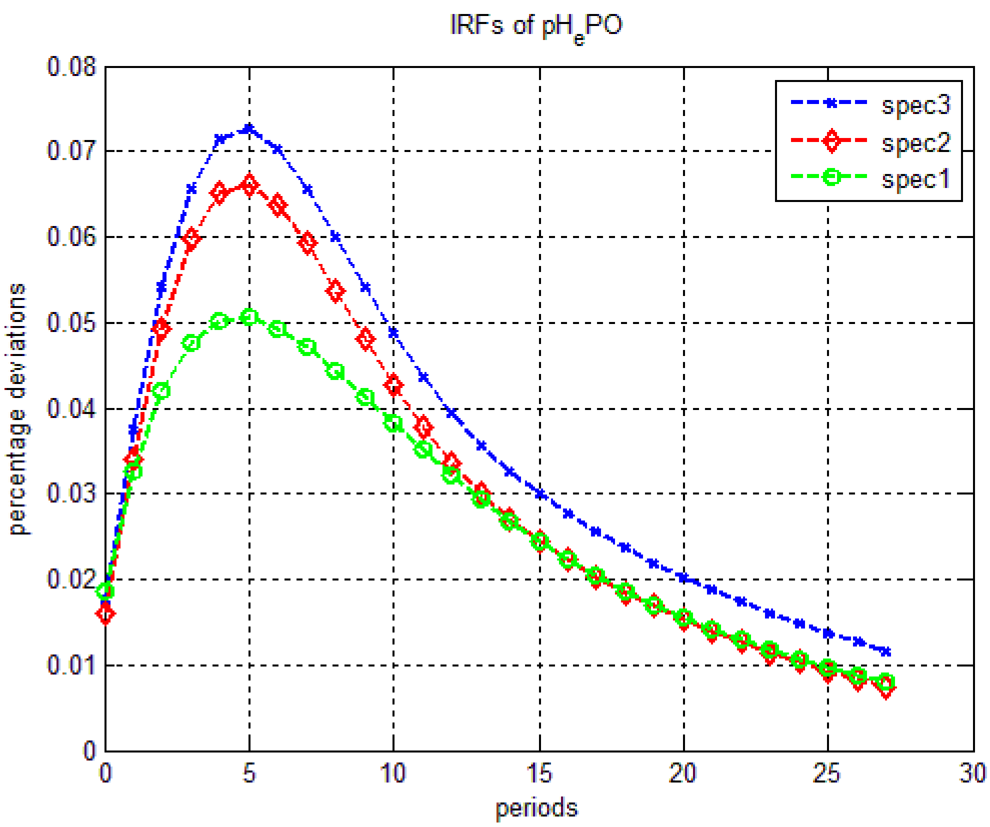


Figure 32. Import price

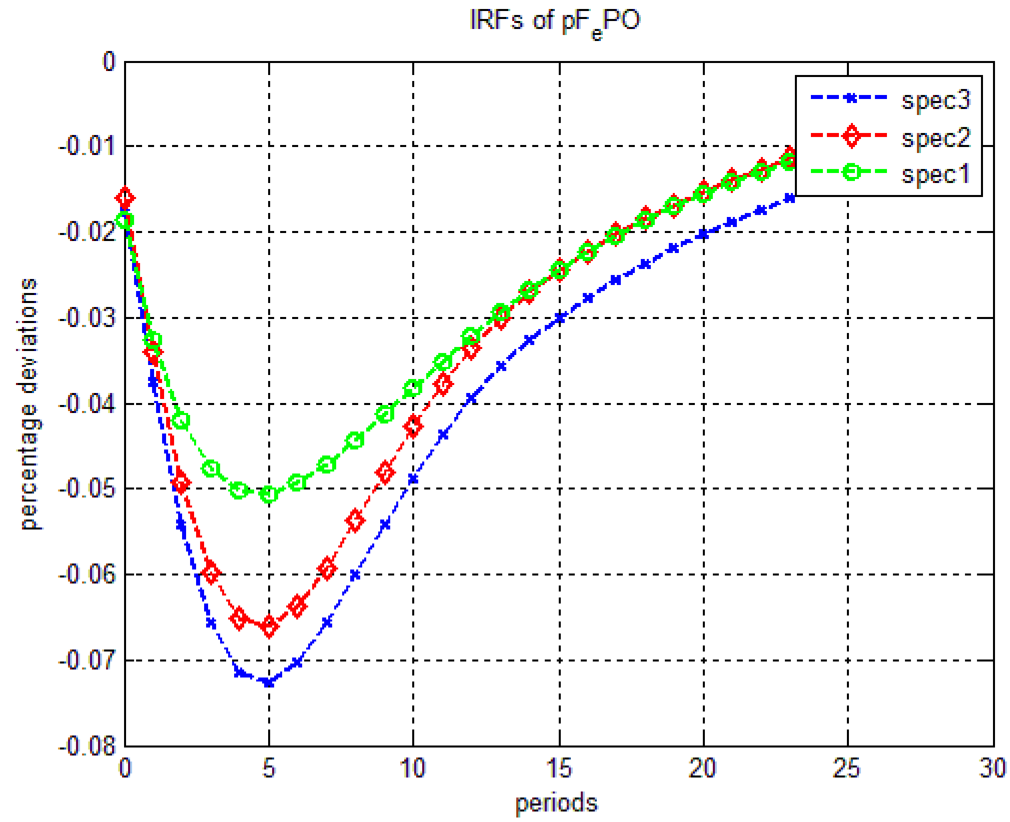
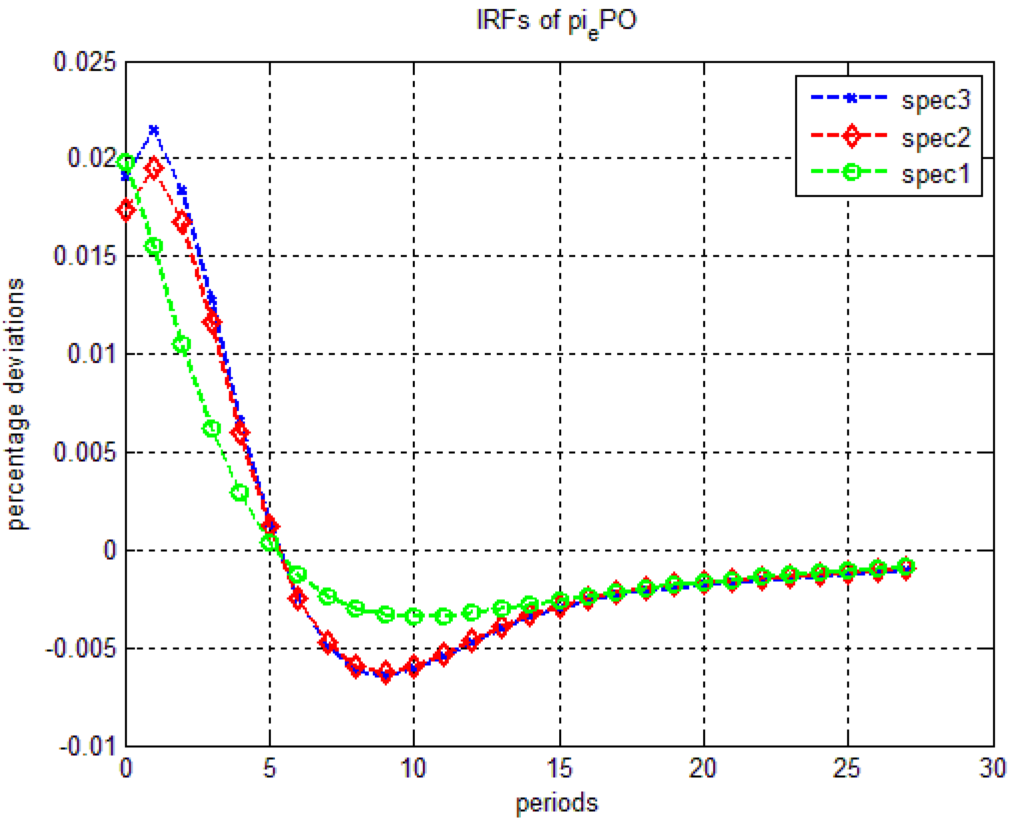


Figure 33. CPI



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