Monetary and Exchange Rate Policies in a Dual-Exchange Rate Area: The Case of Iran

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Introduction

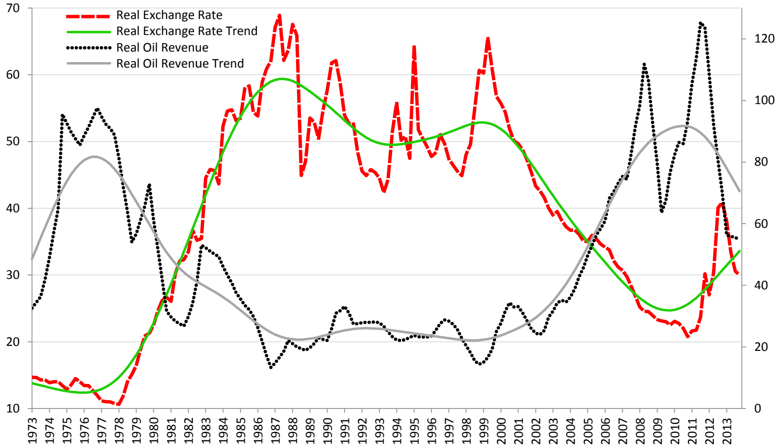
- There are many studies covering monetary and exchange rate policies in DSGE models for developing countries.
- Among these, however, small numbers model oil-exporting countries with their specific characteristics.
- High degree of fiscal dominance, different channel of influencing oil price shocks on economic growth and the effects of oil price shocks on exchange rate regime are among the specific characteristics in such countries.

Introduction

- A property that some oil dependent countries have and is absent in conventional DSGE models is that exchange rate regime is highly affected by oil price shocks.
- Whenever there are high oil revenues and massive foreign reserves, the central bank is able to overvalue the national currency.
- Although the real exchange rate is affected by different factors, but without doubt oil revenue fluctuation, either caused by changes in oil production levels or oil prices, is the main factor in real exchange rate fluctuation and deviation of nominal exchange rate from Purchasing Power Parity (PPP) trend.

Introduction

Figure: Real exchange rate and real oil revenues in Iran



Household Problem

The economy is populated by a continuum of identical households seeking to maximize their utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \Big[\frac{(C_t C_{Gt}^{\gamma})^{1-\sigma}}{1-\sigma} + \frac{\kappa_m}{1-b_m} \left(\frac{M_t}{P_t} \right)^{1-b_m} + \frac{\kappa_s}{1-b_s} \left(\frac{S_{St} M_{St}}{P_t} \right)^{1-b_s} - \chi \frac{L_t^{1+\eta}}{1+\eta} \Big] \tag{1}$$

Household Problem

Subject to budget constraint

$$C_t + \frac{M_t}{P_t} + \mathcal{P}_{It} I_t + \frac{B_t}{P_t} + \frac{S_{St} M_{St}}{P_t} + T_t = w_t L_t + R_t u_t K_{t-1}$$
$$-\Psi(u_t) K_{t-1} + \frac{M_{t-1}}{P_t} + D_t + (1 + r_{t-1}) \frac{B_{t-1}}{P_t} + \frac{S_{St} M_{St-1}}{P_t} + TA_t \tag{2}$$

and the law of motion for private capital

$$K_t = (1-\delta) K_{t-1} + \left[1 - F\left(\frac{I_t}{I_{t-1}}\right)\right](1 - b_I) I_t z_t \tag{3}$$

Household Problem

Solving this problem we get labour supply, demand for real money balances, demand for real amount of foreign currency, conventional consumption Euler equation, an investment Euler equation and capital pricing dynamics

$$w_t = \frac{\chi L_t^{\eta}}{C_{Gt}^{\gamma}\left(C_t C_{Gt}^{\gamma}\right)^{-\sigma}} \tag{4}$$

$$\kappa_m m_t^{-b_m} = \left(\frac{r_t}{1+r_t}\right) C_{Gt}^{\gamma}\left(C_t C_{Gt}^{\gamma}\right)^{-\sigma} \tag{5}$$

$$\kappa_s (e_{St} m_{St})^{-b_s} = \left[1 - E_t\left(\frac{e_{St+1}\pi_{t+1}}{\pi_{t+1}^{*}(1+r_t)}\right)\right] C_{Gt}^{\gamma}\left(C_t C_{Gt}^{\gamma}\right)^{-\sigma} \tag{6}$$

Household Problem

$$C_{Gt}^{\gamma}\left(C_t C_{Gt}^{\gamma}\right)^{-\sigma} = \beta E_t \frac{(1+r_t) C_{Gt+1}^{\gamma}\left(C_{t+1} C_{Gt+1}^{\gamma}\right)^{-\sigma}}{\pi_{t+1}} \tag{7}$$

$$\begin{aligned} \mathcal{P}_{It} = {} & (1-b_I) q_t z_t \left[1 - F\left(\frac{I_t}{I_{t-1}}\right) - F'\left(\frac{I_t}{I_{t-1}}\right) \cdot \frac{I_t}{I_{t-1}}\right] \\ & + (1-b_I) E_t \frac{\pi_{t+1}}{1+r_t} q_{t+1} z_{t+1} F'\left(\frac{I_{t+1}}{I_t}\right) \cdot \left(\frac{I_{t+1}}{I_t}\right)^2 \end{aligned} \tag{8}$$

$$q_t = E_t \frac{\pi_{t+1}}{1+r_t}\left[(1-\delta) q_{t+1} + u_{t+1} R_{t+1} - \Psi(u_{t+1})\right] \tag{9}$$

Domestic and Imported Consumption and Investment

Aggregate consumption is assumed to be given by a CES index of domestically produced and imported goods according to

$$C_t = \left(a_C^{\frac{1}{\theta_c}} C_{Dt}^{\frac{\theta_c - 1}{\theta_c}} + (1 - a_C)^{\frac{1}{\theta_c}} C_{Nt}^{\frac{\theta_c - 1}{\theta_c}} \right)^{\frac{\theta_c}{\theta_c - 1}} \tag{10}$$

$$C_{Nt} = \left(a_{C_N}^{\frac{1}{\theta_{C_N}}} (C_{Nt}^F)^{\frac{\theta_{C_N} - 1}{\theta_{C_N}}} + (1 - a_{C_N})^{\frac{1}{\theta_{C_N}}} (C_{Nt}^S)^{\frac{\theta_{C_N} - 1}{\theta_{C_N}}} \right)^{\frac{\theta_{C_N}}{\theta_{C_N} - 1}} \tag{11}$$

$$I_t = \left(a_I^{\frac{1}{\theta_I}} I_{Dt}^{\frac{\theta_I - 1}{\theta_I}} + (1 - a_I)^{\frac{1}{\theta_I}} I_{Nt}^{\frac{\theta_I - 1}{\theta_I}} \right)^{\frac{\theta_I}{\theta_I - 1}} \tag{12}$$

Domestic and Imported Consumption and Investment

$$P_t = \left(a_C P_{Dt}^{1-\theta_C} + (1 - a_C)(P_{C_N t})^{1-\theta_C} \right)^{\frac{1}{1-\theta_C}} \tag{13}$$

$$P_{C_N t} = \left(a_{C_N} (P_{Nt}^F)^{1-\theta_{C_N}} + (1 - a_{C_N})(P_{Nt}^S)^{1-\theta_{C_N}} \right)^{\frac{1}{1-\theta_{C_N}}} \tag{14}$$

$$P_{It} = \left(a_I P_{Dt}^{1-\theta_I} + (1 - a_I) P_{Nt}^{1-\theta_I} \right)^{\frac{1}{1-\theta_I}} \tag{15}$$

Final Good Producers

Good is produced using the following aggregate CES technology, where intermediate goods, $y_t(i)$, are indexed by $i \in [0, 1]$:

$$Y_{Dt} = \left(\int_0^1 y_t(i)^{\frac{1}{\theta_t}} di \right)^{\theta_t} \tag{16}$$

The profit maximization first order condition can be written in the form of a demand function for the intermediate good, $y_t(i)$

$$y_t(i) = \left(\frac{P_{Dt}(i)}{P_{Dt}} \right)^{-\frac{\theta_t}{\theta_t - 1}} Y_{Dt} \tag{17}$$

Final Good Producers

Introducing (17) in (16) and simplifying it is readily seen that the domestic goods price index is:

$$P_{Dt} = \left(\int_0^1 P_{Dt}(i)^{\frac{1}{1-\theta_t}} di \right)^{1-\theta_t} \tag{18}$$

Intermediate Good Producer

Each firm, indexed by $i \in [0, 1]$, produces $y_t(i)$ units of differentiated output using the following Cobb-Douglas production technology:

$$Y_t^{no}(i) = a_t \left[\tilde{K}_{t-1}(i) K_{Gt-1}^{\psi}\right]^{\alpha} L_{Yt}(i)^{1-\alpha}, \qquad 0 < \alpha < 1 \tag{19}$$

Following Kim and Lougani (1992), de Walque, etal. (2005) and Medina and Soto (2005), it is assumed aggregate output is generated by the following CES technology in which X_{et} is the use of energy (oil) in the production of $y_t(i)$:

$$y_t(i) = \left[\gamma_y^{\frac{1}{\theta_y}} \left(Y_t^{no}\right)^{\frac{1-\theta_y}{\theta_y}} + (1-\gamma_y)^{\frac{1}{\theta_y}} \left(X_{et}\right)^{\frac{1-\theta_y}{\theta_y}}\right]^{\frac{\theta_y}{1-\theta_y}} - \varrho \tag{20}$$

It is also assumed that energy price is determined by:

$$P_{et} = (S_{Ft} P_{Ot})^{\tau_e} \tag{21}$$

where $0 < \tau_e < 1$ is the rate of transfer payment on domestic consumption of energy.

Intermediate Good Producer

There is also a price rigidity type of Calvo (1983). Each period only a fraction $1-\xi$ of them, randomly chosen, can optimally readjust their prices. For the remaining ξ fraction of firms, prices are indexed to past inflation as follows:

$$P_{Dt}(i) = \pi^{\tau}_{Dt-1} P_{Dt-1}(i) \tag{22}$$

From firms that get to maximizes the expected discounted sum of profit we get the hybrid New Keynesian Phillips Curve in log-linearized form as:

$$\hat{\pi}_{Dt} = \frac{\beta}{1+\beta\tau} E_t \hat{\pi}_{Dt+1} + \frac{\tau}{1+\beta\tau}\hat{\pi}_{Dt-1} + \frac{(1-\beta\xi)(1-\xi)}{(1+\beta\tau)\xi}(\hat{mc}_t + \hat{\theta}_t) \tag{23}$$

Oil Exporting Sector

Based on the model proposed byBalke et al. (2010), state-owned enterprises use labor, L_{Ot} and oil reserves, X_{Ot} to produce oil, Y_{Ot} utilizing the following technology:

$$Y_{Ot} = a_{Ot} \left[\gamma_O X_{Ot}^{1-\theta_O} + (1-\gamma_O) L_{Ot}^{1-\theta_O} \right]^{\frac{1}{1-\theta_O}} \tag{24}$$

The next period oil reserves include both additions to reserves and the depletion due to production:

$$X_{Ot+1} = X_{Ot} + G_{Ot} - Y_{Ot} \tag{25}$$

Gross additions to reserves are defined as:

$$G_{Ot} = \Phi_O \left(\frac{I_{Xt}}{X_{Ot}} \right) X_{Ot} \tag{26}$$

$$I_{Xt} = A_{Xt}^{I} \left[\gamma_{IX} (b_{IG} I_{Gt})^{1-\theta_{IX}} + (1-\gamma_{IX})(b_I I_t)^{1-\theta_{IX}} \right]^{\frac{1}{1-\theta_{IX}}} \tag{27}$$

Non-oil Exporting Sector

For simplicity it is assumed that the exports of domestic economy or foreign demand for home goods, Y_{Xt} is given by the following expression

$$Y_{Xt} = a_X \left(\frac{P_{Dt}}{P_t^*} \right)^{-\theta_X} Y_t^* = a_X \left(\frac{\mathcal{P}_{Dt}}{\mathcal{P}_t^*} \right)^{-\theta_X} Y_t^* \tag{28}$$

Central Bank and Public Sector

The flow budget constraint of the CB is:

$$\begin{aligned} M_t - DC_t - S_{Ft}FR_t + S_{St}\hbar_t FR_t &= M_{t-1} - DC_{t-1} - S_{Ft}FR_{t-1} \\ +S_{St}\hbar_{t-1}FR_{t-1} &= M_{t-1} - DC_{t-1} - S_{Ft-1}FR_{t-1} \\ +S_{St-1}\hbar_{t-1}FR_{t-1} - RCB_t \end{aligned} \tag{29}$$

In terms of domestic goods, the CB balance, for all t, is:

$$m_t = dc_t + e_{Ft}fr_t - e_{St}\hbar_t fr_t \tag{30}$$

where $dc_t = \frac{DC_t}{P_t}$, $fr_t = \frac{FR_t}{P_t^*}$ and $e_{St} = \frac{S_{St}P_t^*}{P_t}$.

Central Bank and Public Sector

In period t the government budget constraint is

$$\mathcal{P}_{CGt}C_{Gt} + \mathcal{P}_{IGt}I_{Gt} + (1+r_{t-1})\frac{B_{t-1}}{P_t} + TA_t = T_t + \frac{B_t}{P_t} + \frac{DC_t - DC_{t-1}}{P_t} + e_{Ft}\mathcal{P}^*_{Ot}Y^X_{Ot} + \mathcal{P}_{et}X_{et} \tag{31}$$

$$C_{Gt} = \left(a_{CG}^{\frac{1}{\theta_{CG}}} \left(C^D_{Gt}\right)^{\frac{\theta_{CG}-1}{\theta_{CG}}} + (1-a_{CG})^{\frac{1}{\theta_{CG}}} \left(C^N_{Gt}\right)^{\frac{\theta_{CG}-1}{\theta_{CG}}} \right)^{\frac{\theta_{CG}}{\theta_{CG}-1}} \tag{32}$$

$$I_{Gt} = \left(a_{IG}^{\frac{1}{\theta_{IG}}} \left(I^D_{Gt}\right)^{\frac{\theta_{IG}-1}{\theta_{IG}}} + (1-a_{IG})^{\frac{1}{\theta_{IG}}} \left(I^N_{Gt}\right)^{\frac{\theta_{IG}-1}{\theta_{IG}}} \right)^{\frac{\theta_{IG}}{\theta_{IG}-1}} \tag{33}$$

Central Bank and Public Sector

Following Leeper, Walker and Tang (2010), I model the delay between when government investment is authorized and when it becomes available as public capital by letting the budget authorized for government investment at time t be A_{It} and the number of quarters to complete an investment project be N. The law of motion for public capital, K_{Gt}, is then

$$K_{Gt} = (1-\delta_G)K_{Gt-1} + A_{It} \tag{34}$$

$$\log A_{It} = (1-\rho_A)\log A_I + \rho_A \log A_{It-1} + \iota\varepsilon_{\pi_o^* t} + \varepsilon_{At} \tag{35}$$

Central Bank and Public Sector

It is also assumed that the government investment implemented (or outlaid) at time t is given by

$$I_{Gt} = \sum_{n=0}^{N-1} \varphi_n A_{It-n} \tag{36}$$

fiscal policy is assumed to be exogenous and follow an AR(1) process

$$C_{Gt} = (C_G)^{1-\rho_G} (C_{Gt-1})^{\rho_G} \exp(\varepsilon_{Gt}), \qquad \varepsilon_{Gt} \sim i.i.d.N(0, \sigma_G^2) \tag{37}$$

The aggregate resource constraint

The real GDP identity can be described as

$$Y_t = (C_{Dt} + C_{Nt}) + (I_{Dt} + I_{Nt}) + \left(C_{Gt}^D + C_{Gt}^N\right) + \left(I_{Gt}^D + I_{Gt}^N\right) + Y_{Ot} + Y_{Xt} - \aleph_t \quad (38)$$

where

$$\aleph_t \equiv C_{Nt} + I_{Nt} + C_{Gt}^N + I_{Gt}^N \quad (39)$$

is total imports.
The domestic goods market clearing condition is

$$Y_t^{no} = C_{Dt} + I_{Dt} + C_{Gt}^D + I_{Gt}^D + Y_{Xt} + \Psi(u_t)K_{t-1} \quad (40)$$

The evolution of CB's net foreign reserves (in terms of domestic currency) satisfies

$$(1 - \hbar_t)FR_t = (1 - \hbar_{t-1})FR_{t-1} + P_{Ot}^* Y_{Ot}^X - P_t^*(C_{Nt}^F + I_{Nt} + C_{Gt}^N + I_{Gt}^N) \quad (41)$$

Spot exchange market equilibrium

Consolidating household budget constraint with government budget constraint and considering aggregate resource constraint and the evolution of net foreign reserves, the equilibrium condition in spot exchange market would be

$$\hbar_t FR_t - \hbar_{t-1} FR_{t-1} + P_t^* Y_{Xt} = M_{St} - M_{St-1} + P_t^* C_{Nt}^S \tag{42}$$

The CBI seeks to minimize the deviation of spot and official exchange rates. Therefore, CB responds to deviations of the ratio of depreciation of spot exchange rate to official exchange rate $\left(\frac{S_{St}}{S_{Ft}}\right)$ by changing the fraction $\hbar_t$. This reaction function can be shown by the following relation

$$\hbar_t = 1 - \exp[\nu_t (1 - \frac{S_{St}}{S_{Ft}})] \tag{43}$$

Spot exchange market equilibrium

Therefore, $\hbar_t = 0$ if $\frac{S_{St}}{S_{Ft}} = 1$, that is, the fraction of foreign reserves supplied in foreign exchange spot market is zero, if there is just one exchange rate in the economy. In this situation

$$m_{St} = \frac{m_{St-1}}{\pi_t^*} + Y_{Xt} - C_{Nt}^S \tag{44}$$

That is, foreign currency accumulation in households' portfolio is affected by non-oil exports and unofficial imports. I consider this situation as unified exchange rate system in which spot exchange rate is equal to official exchange rate.

Monetary and exchange rate policies

In this paper, a managed exchange rate regime is assumed in which the CB uses two different policy rules. In domestic money market, the CB intervenes to achieve an operational target for monetary growth. To achieve this target, the CB responds to deviations of the inflation rate (π_t) from a time-varying inflation target (π_{Tt}) and to deviations of GDP from its steady state value.

$$\left(\frac{\dot{m}_t}{\dot{m}}\right) = \left(\frac{\dot{m}_{t-1}}{\dot{m}}\right)^{\rho_{\dot{m}}} \left(\frac{\pi_t/\pi}{\pi_{Tt}/\pi_T}\right)^{\omega_\pi} \left(\frac{Y_t^{no}}{Y^{no}}\right)^{\omega_y} e^{\vartheta_t} \tag{45}$$

Monetary and exchange rate policies

At the same time, the rate of depreciation of official exchange rate responds to the same variables and additionally to the deviations of the CB's net foreign reserves ratio to GDP from a target (Υ_{fr})

$$\left(\frac{d_{Ft}}{d_F}\right) = \left(\frac{d_{Ft-1}}{d_F}\right)^{\rho_F} \left(\frac{\pi_t/\pi}{\pi_{Tt}/\pi_T}\right)^{\varpi_\pi} \left(\frac{Y_t^{no}}{Y^{no}}\right)^{\varpi_y} \left(\frac{e_{Ft}}{e_F}\right)^{\varpi_e} \left(\frac{e_{Ft} fr_t / Y_t}{\Upsilon_{fr}}\right)^{\varpi_{fr}} e^{\zeta_t} \tag{46}$$

The time-varying inflation target is assumed to follow the process

$$\log \pi_{Tt} = (1-\rho_\pi) \log \pi_T + \rho_\pi \log \pi_{Tt} + \varepsilon_{\pi t} \tag{47}$$

Foreign Economy

The foreign country is specified by three equations of international oil price inflation π_{Ot}, foreign economy consumer price inflation π^*_t and and foreign economy's income Y^*_t.

$$\log \pi_{Ot} = (1-\rho_{\pi_O}) \log \pi_O + \rho_{\pi_O} \log \pi_{Ot-1} + \varepsilon^{\pi o}_t \ \varepsilon^{\pi o}_t \sim i.i.d.N(0, \sigma^2_{\pi_O}) \quad (48)$$

$$\log \pi^*_t = (1-\rho_{\pi^*}) \log \pi^* + \rho_{\pi^*} \log \pi^*_{t-1} + \varepsilon^{\pi^*}_t \qquad \varepsilon^{\pi^*}_t \sim i.i.d.N(0, \sigma^2_{\pi^*}) \quad (49)$$

$$\log Y^*_t = (1-\rho_{Y^*}) \log Y^* + \rho_{Y^*} \log Y^*_{t-1} + \varepsilon^{Y^*}_t \qquad \varepsilon^{Y^*}_t \sim i.i.d.N(0, \sigma^2_{Y^*}) \quad (50)$$

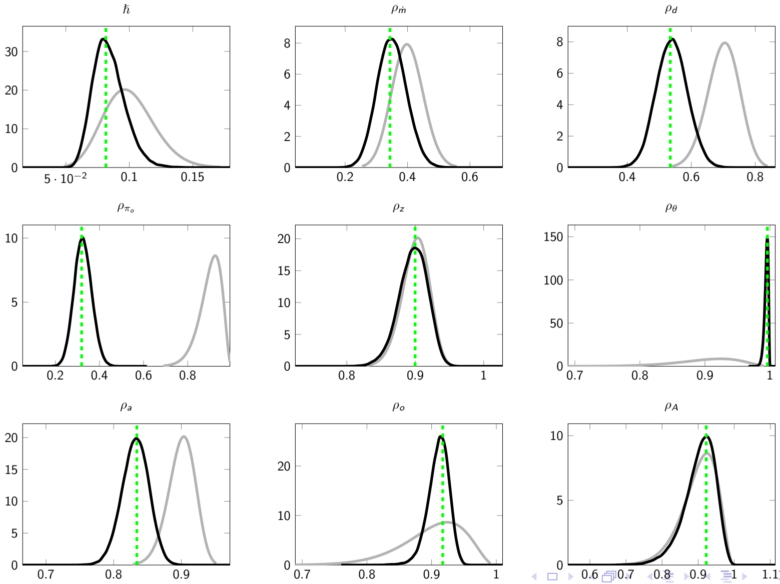
Table: Estimated Parameters

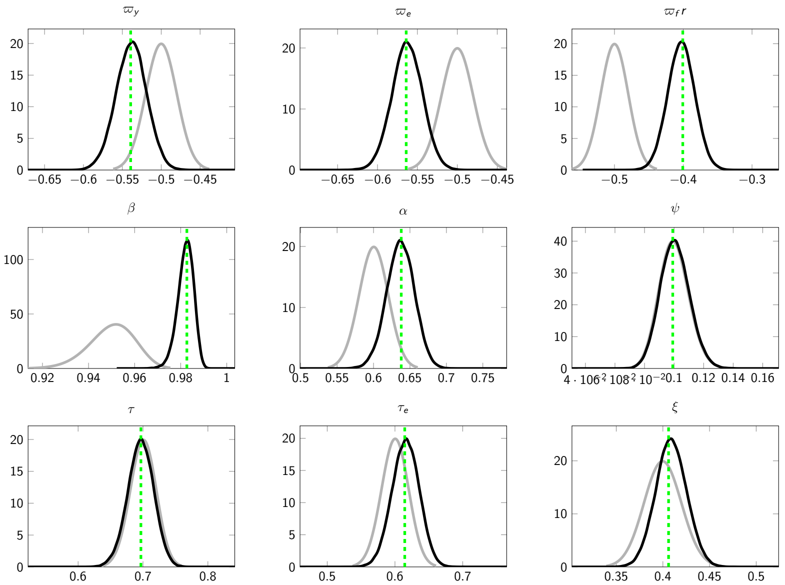
Params	type	prior mean	post std	post mean	10%	90%
η	Gamma	2.89	2.8875	0.3	2.4177	3.3598
σ	Gamma	1.165	1.4176	0.1	1.2648	1.5696
γ	Gamma	0.193	0.1932	0.01	0.1765	0.20960
b_m	Gamma	1.0720	0.7581	0.05	0.6850	0.8295
b_s	Gamma	1.3	1.3923	0.05	1.3125	1.4717
ϵ	Gamma	0.2	0.2593	0.05	0.2106	0.3068
ϱ	Gamma	0.4	0.4495	0.05	0.3592	0.5392
$\varkappa$	Gamma	4	4.2494	0.2	3.9235	4.5742
θ_y	Gamma	0.5	0.3973	0.03	0.3571	0.4370
θ_o	Gamma	0.5	0.5460	0.03	0.4940	0.5991
$\mathcal{P}_{OX}$	Gamma	6	6.0427	0.3	5.5425	6.5341
ϕ_o	Gamma	1	1.0009	0.1	0.8372	1.1642
θ_x	Gamma	0.9	0.8895	0.03	0.8439	0.9377
$\frac{Y_X}{\hbar fr}$	Gamma	0.6	0.6028	0.03	0.5590	0.6477
$\frac{m_S}{\hbar fr}$	Gamma	0.8	0.7853	0.03	0.7373	0.8325
$\frac{C_N^S}{\hbar fr}$	Gamma	0.6	0.7098	0.03	0.6567	0.7612
θ_C	Gamma	0.9	0.8069	0.05	0.7349	0.8778

Params	type	prior mean	post std	post mean	10%	90%
θ_{CG}	Gamma	0.9	0.8389	0.05	0.7617	0.9134
θ_{I}	Gamma	0.295	0.2495	0.05	0.1800	0.3163
θ_{IG}	Gamma	0.505	0.4706	0.05	0.3938	0.5448
β	Beta	0.95	0.9820	0.01	0.9764	0.9876
α	Beta	0.6	0.6367	0.02	0.6062	0.6686
ψ	Beta	0.1	0.1004	0.01	0.0842	0.1165
τ	Beta	0.7	0.6960	0.02	0.6636	0.7295
τ_e	Beta	0.6	0.6153	0.02	0.5828	0.6480
ξ	Beta	0.4	0.4087	0.02	0.3823	0.4367
$\hbar$	Beta	0.1	0.0840	0.02	0.0637	0.1034
$\rho_{\dot{m}}$	Beta	0.4	0.3495	0.05	0.2718	0.4267
ρ_d	Beta	0.7	0.5386	0.05	0.4609	0.6192
ρ_{π_o}	Beta	0.9	0.3246	0.05	0.2587	0.3897
ρ_z	Beta	0.9	0.8964	0.02	0.8629	0.9311
ρ_θ	Beta	0.9	0.9943	0.05	0.9898	0.9988
ρ_a	Beta	0.9	0.8317	0.02	0.7987	0.8639
ρ_O	Beta	0.9	0.9102	0.05	0.8847	0.9361
ρ_A	Beta	0.9	0.9027	0.05	0.8372	0.9722
ρ_{CG}	Beta	0.9	0.6103	0.05	0.4695	0.7497

Params	type	prior mean	post std	post mean	10%	90%
ρ_{ν}	Beta	0.9	0.9009	0.05	0.8281	0.9804
ρ_{ϑ}	beta	0.9	0.6606	0.5585	0.7672	
ρ_{ζ}	Beta	0.9	0.3299	0.05	0.2574	0.4011
ρ_{π_T}	Beta	0.9	0.9885	0.02	0.9804	0.9972
ρ_{π^*}	Beta	0.9	0.8412	0.02	0.7543	0.9309
ρ_{y^*}	Beta	0.9	0.8880	0.02	0.8313	0.9492
σ_{π^*}	InvGamma	0.01	0.0017	∞	0.0015	0.0019
σ_{y^*}	InvGamma	0.01	0.0052	∞	0.0046	0.0058
σ_{π_O}	InvGamma	0.01	0.1328	∞	0.1174	0.1481
σ_z	InvGamma	0.01	0.0101	∞	0.0022	0.0188
σ_{θ}	InvGamma	0.01	0.5984	∞	0.4780	0.7196
σ_a	InvGamma	0.01	0.3086	∞	0.2520	0.3644
σ_o	InvGamma	0.01	1.1157	∞	0.8965	1.3342
σ_A	InvGamma	0.01	0.0090	∞	0.0022	0.0165
σ_{CG}	InvGamma	0.01	0.0727	∞	0.0632	0.0823
$\sigma_{\hbar}$	InvGamma	0.01	0.0096	∞	0.0022	0.0181
$\sigma_{\dot{m}}$	InvGamma	0.01	0.1235	∞	0.1022	0.1448
σ_d	InvGamma	0.01	0.5325	∞	0.4648	0.5983
σ_{π_T}	InvGamma	0.01	0.1437	∞	0.1069	0.1807

Figure: Prior and posterior distribution of parameters





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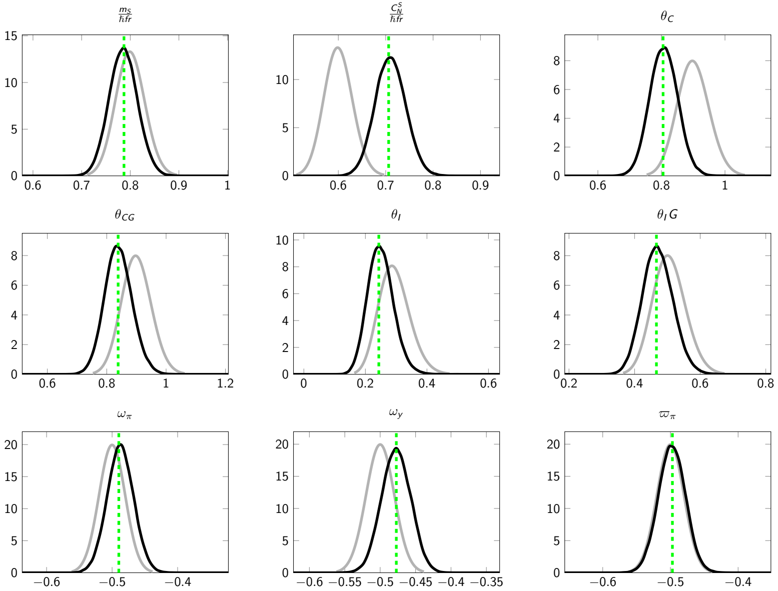
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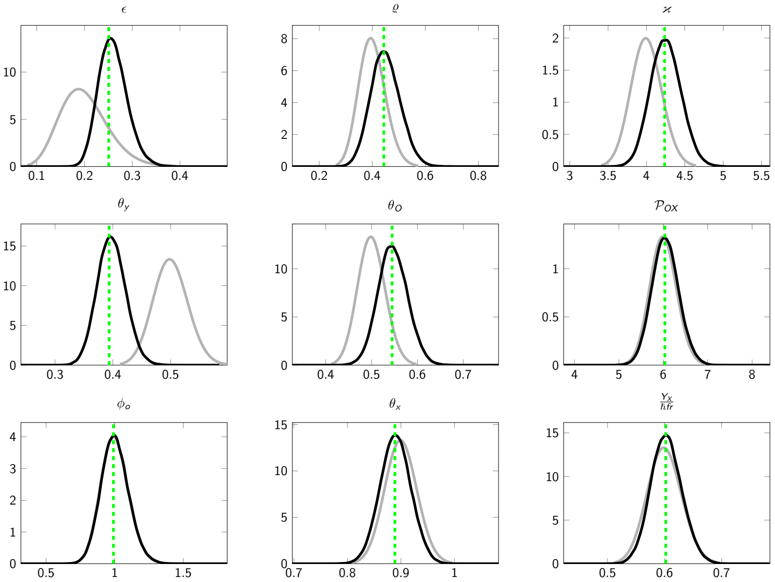
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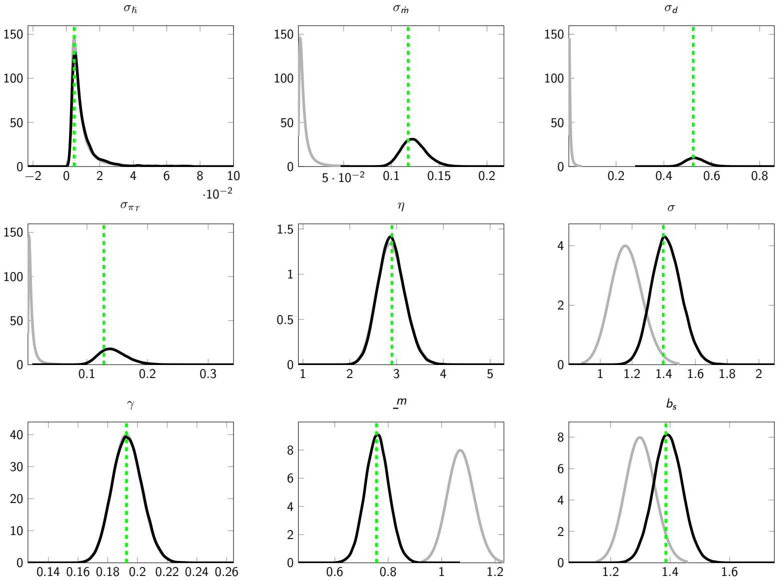
θ_x
$\frac{Y_x}{\hbar fr}$



$\sigma_{\hbar}$
150
100
50
0
−2 0 2 4 6 8 10
$\cdot 10^{-2}$
$\sigma_{\dot{m}}$
150
100
50
0
$5 \cdot 10^{-2}$ 0.1 0.15 0.2
σ_d
150
100
50
0
0.2 0.4 0.6 0.8
σ_{π_T}
150
100
50
0
0.1 0.2 0.3
η
1.5
1
0.5
0
1 2 3 4 5
σ
4
2
0
1 1.2 1.4 1.6 1.8 2
γ
40
30
20
10
0
0.14 0.16 0.18 0.2 0.22 0.24 0.26
$\_m$
8
6
4
2
0
0.6 0.8 1 1.2
b_s
8
6
4
2
0
1.2 1.4 1.6

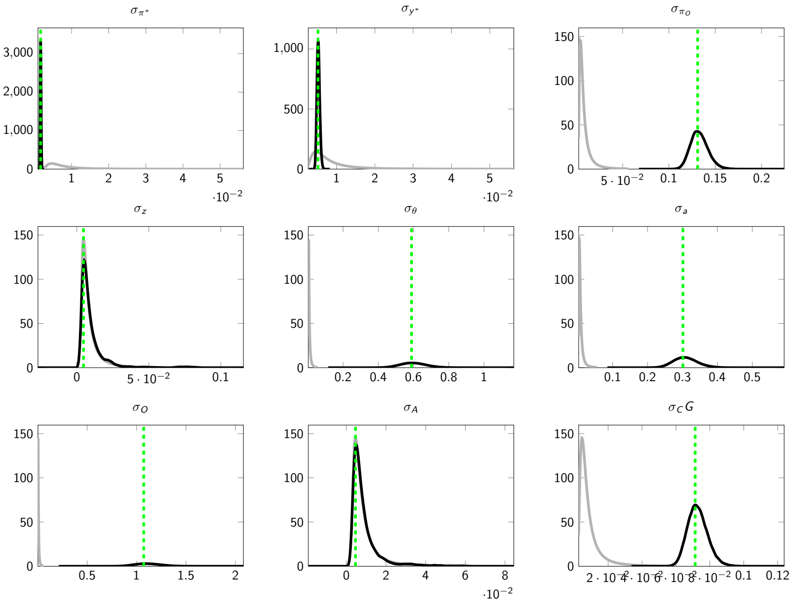

σ_{π^*}
3,000
2,000
1,000
0
1 2 3 4 5
$\cdot 10^{-2}$
σ_{y^*}
1,000
500
0
1 2 3 4 5
$\cdot 10^{-2}$
σ_{π_O}
150
100
50
0
$5 \cdot 10^{-2}$ 0.1 0.15 0.2
σ_z
150
100
50
0
0 $5 \cdot 10^{-2}$ 0.1
σ_θ
150
100
50
0
0.2 0.4 0.6 0.8 1
σ_a
150
100
50
0
0.1 0.2 0.3 0.4 0.5
σ_O
150
100
50
0
0.5 1 1.5 2
σ_A
150
100
50
0
0 2 4 6 8
$\cdot 10^{-2}$
$\sigma_C G$
150
100
50
0
0.1 0.12

Figure: Impulse Response to $\varepsilon_{\dot{m}}$

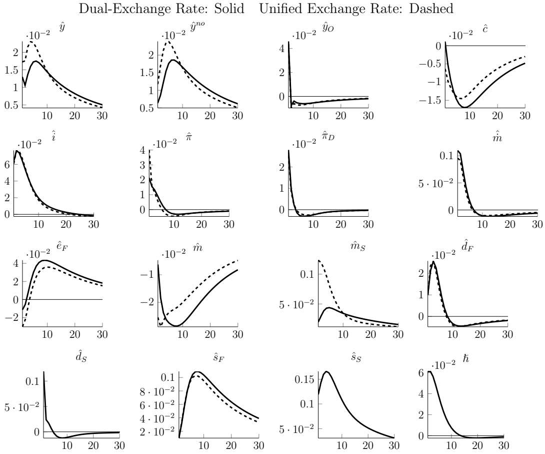


Figure: Impulse Response to ε_d

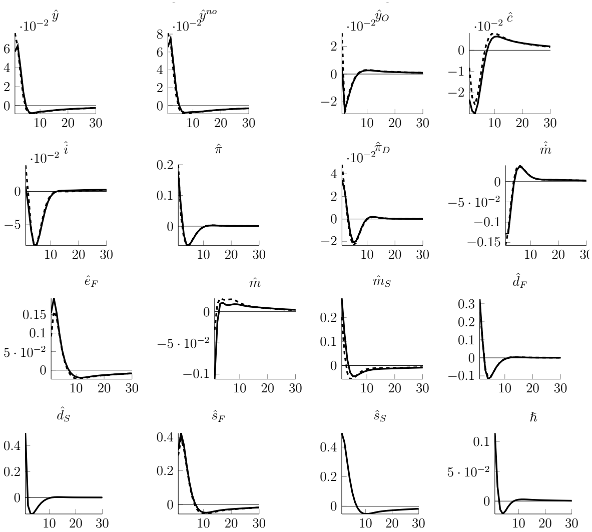


Figure: Impulse Response to $\varepsilon_\hbar$

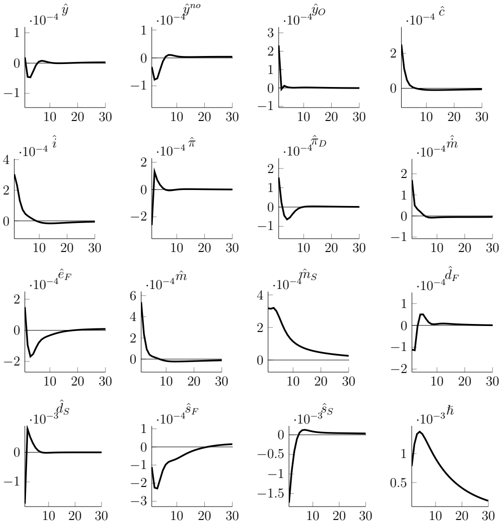


Figure: Impulse Response to ε_{π_o}

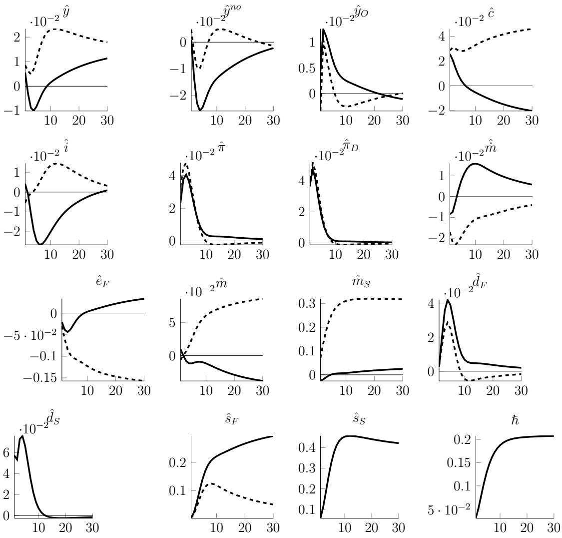


Figure: Impulse Response to ε_a

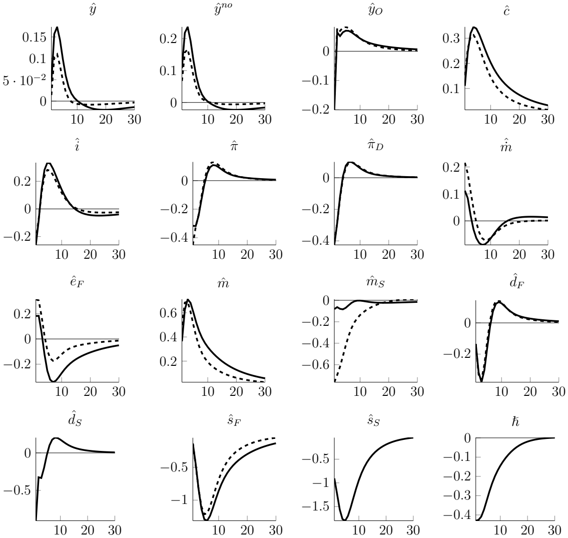
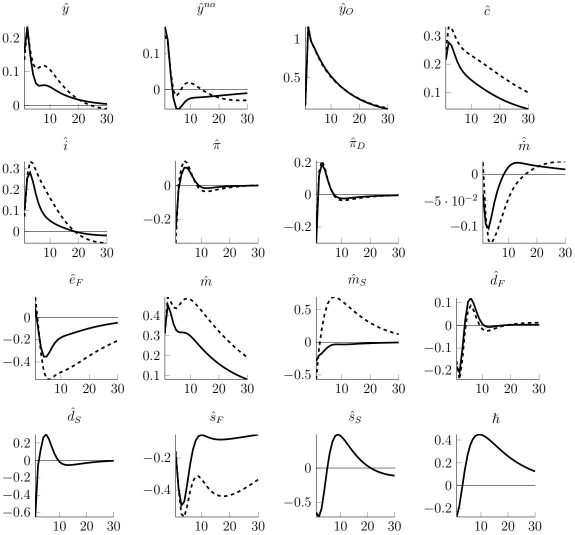


Figure: Impulse Response to ε_O



Thank You