Oil Shocks and Monetary Policy in an Estimated DSGE for a Small Open Economy

Juan Pablo Medina
Central Bank of Chile

Claudio Soto
Central Bank of Chile

July 2006
Bank of Canada Workshop on Commodity Price Issues

The Paper

- Develops a DSGE model for a small open economy that explicitly introduces oil, both in consumption and in the production technology
- Key parameters of the model are estimated by a Bayesian approach
- The estimated model is utilized to analyze the counterfactual effects of an oil-price shock under different monetary frameworks
- Methodological approach should "alleviate" Luca's critique

Main Results

- An oil-price shock has a contractionary effect on output. An increase in the real price of oil by 13% (one standard deviation) leads to a fall in output of about 0.5% and an increase in inflation of about 0.4%
- The contractionary effect of the oil shock is due mainly to the endogenous tightening of the monetary policy
- A policy that counteracts wages rigidities delivers a aggregate real allocation that is closer to the second-best outcome at a cost of much higher inflation
- A policy rule that targets CPI inflation delivers an outcome that is very close to the one obtained under *core* inflation targeting. If the central bank tries to fully stabilize inflation there would be a considerably decrease in output

Model's Main Elements

- Small open economy setup
- Prices and wages are optimally adjusted infrequently, and they are partially indexed to past inflation
- Domestic households consume three types of goods: Home goods, Foreign goods, and Oil
- Consumption exhibits habit formation
- Each household has a monopolistic power over the type of labor service it provides
- Firms produce with a technology that combines labor and Oil in a flexible way
- Monetary policy is modelled as Taylor type rule

Households

- Representative household maximizes:

$$\sum_{t=0}^{\infty} \beta^t \left[log \left(C_t(j) - h(1+g_y)C_t \right) + \frac{a}{\mu} \left(\frac{\mathcal{M}_t(j)}{P_t} \right)^{\mu} - \frac{\zeta_t}{1+\sigma_L} l_t(j)^{1+\sigma_L} \right]$$

- Consumption bundle:

$$C_t = \left[\delta^{\frac{1}{\eta}} (O_{C,t})^{\frac{\eta-1}{\eta}} + (1-\delta)^{\frac{1}{\eta}} (Z_t)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

- *Core* Consumption:

$$Z_t = \left[\gamma^{\frac{1}{\theta}} \left(C_{F,t} \right)^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} \left(C_{H,t} \right)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}$$

Price Indices

- Consumer price index (CPI)

$$P_t = \left[\delta P_{O,t}^{1-\eta} + (1-\delta) P_{Z,t}^{1-\eta}\right]^{\frac{1}{1-\eta}}$$

- Core consumption price index

$$P_{Z,t} = \left[\gamma P_{F,t}^{1-\theta} + (1-\gamma) P_{H,t}^{1-\theta}\right]^{\frac{1}{1-\theta}}$$

Wages Setting

- Households face a $(1 - \phi_L)$ probability of re-optimizing wages
- If re-optimization is allowed, they chose $W_t(j)$ to maximize

$$E_t \left\{ \sum_{i=0}^{\infty} \phi_L^i \Lambda_{t,t+i} \left(\frac{W_t(j)\Gamma_{W,t}^i}{P_{t+i}} - \zeta_t MRS_{t+i} \right) l_{t+i}(j) \right\}$$

- If re-optimization is not allowed between t and $t+i$ then wage is set to

$$W_{t+i}(j) = \Gamma_{W,t}^i W_t = \prod_{j=1}^{i} (1 + \pi_{t+j-1})^{\xi_L} (1 + \overline{\pi}_{t+j})^{1-\xi_L} \left(1 + g_y\right) W_t$$

- Linearized real wages evolution

$$\frac{1 + \nu_L \phi_L + \sigma_L \epsilon_L (\phi_L + \nu_L)}{1 + \sigma_L \epsilon_L} \widehat{wr}_t - \phi_L \widehat{wr}_{t-1} - \nu_L E_t \widehat{wr}_{t+1} =$$
$$\frac{(1 - \nu_L)(1 - \phi_L)}{1 + \sigma_L \epsilon_L} \widehat{mrs}_t - (\phi_L + \nu_L \xi_L) \widehat{\pi}_t + \phi_L \xi_L \widehat{\pi}_{t-1} + \nu_L E_t \widehat{\pi}_{t+1} + \widehat{\zeta}_t$$

Firms

- Technology

$$Y_{H,t}\left(z_H\right) = A_{H,t}\left[(1-\alpha)^{\frac{1}{\omega}}\left(L_{H,t}\left(z_H\right)\right)^{1-\frac{1}{\omega}} + \alpha^{\frac{1}{\omega}}\left(O_{H,t}\left(z_H\right)\right)^{1-\frac{1}{\omega}}\right]^{\frac{\omega}{\omega-1}}$$

- Real marginal cost

$$\frac{MC_{H,t}}{P_t} = A_{H,t}^{-1}\left[(1-\alpha)\left(\frac{W_t}{P_t}\right)^{1-\omega} + \alpha\left(\frac{P_{O,t}}{P_t}\right)^{1-\omega}\right]^{\frac{1}{1-\omega}}$$

Price Setting

- A firm faces a $(1-\phi_H)$ probability of re-optimizing its price
- If re-optimization is allowed firms chose $P^{op}_{H,t}(z_H)$ to maximize

$$\sum_{i=0}^{\infty} \phi_H^i E_t \left\{ \Lambda_{t,t+i} \frac{\Gamma^i_{H,t} P^{op}_{H,t}(z_H) - MC_{H,t+i}}{P_{t+i}} Y_{H,t+i}(z_H) \right\}$$

- If re-optimization is not allowed between t and $t+i$ then price is set to

$$P_{H,t+i}(z_H) = \Gamma^i_{H,t} P_{H,t} = \prod_{j=1}^{i} \left(1+\pi_{H,t+j-1}\right)^{\xi_H} \left(1+\overline{\pi}_{t+j}\right)^{1-\xi_H} P_{H,t}$$

- Linearized Phillips curve

$$\widehat{\pi}_{H,t} = \frac{(1-\phi_H)(1-\beta\phi_H)}{\phi_H(1+\beta\xi_H)} \widehat{mc}_t + \frac{\beta}{1+\beta\xi_H} E_t \widehat{\pi}_{H,t+1} + \frac{\xi_H}{1+\beta\xi_H} \widehat{\pi}_{H,t-1}$$

Oil Price and Exogenous Processes

- Domestic currency real Oil price

$$\widehat{pr}_{O,t} = \widehat{rer}_t + \widehat{pr}^*_{O,t} + \widehat{\psi}_t$$

- Exogenous processes

$$\widehat{pr}^*_{O,t} = \rho_O \widehat{pr}^*_{O,t-1} + \varepsilon_{o,t}$$

$$\widehat{\psi}_t = \rho_\psi \widehat{\psi}_{t-1} + \varepsilon_{\psi,t}$$

$$\widehat{a}_{H,t} = \rho_a \widehat{a}_{H,t-1} + \varepsilon_{a,t}.$$

$$\widehat{\zeta}_t = \rho_\zeta \widehat{\zeta}_{t-1} + \varepsilon_{\zeta,t}$$

$$\widehat{\pi}^*_t = \rho_{\pi^*} \widehat{\pi}^*_{t-1} + \varepsilon_{\pi^*,t}$$

$$\widehat{y}_{S,t} = \rho_S \widehat{y}_{S,t-1} + \varepsilon_{S,t}$$

$$\widehat{c}^*_t = \rho_{c^*} \widehat{c}^*_{t-1} + \varepsilon_{c^*,t}$$

$$\widehat{i}^*_t = \rho_{i^*} \widehat{i}^*_{t-1} + \varepsilon_{i^*,t}$$

Output

- Gross output in Home goods sector

$$\widehat{y}_{H,t} = \widehat{a}_{H,t} + (1-\alpha)\,\widehat{l}_t + \alpha\widehat{o}_{H,t}$$

- Gross domestic product (GDP)

$$\widehat{y}_t = \frac{Y_H}{Y}(1-\alpha)\,\widehat{l}_t + \frac{Y_H}{Y}\left(\alpha - \frac{O_H}{Y_H}\right)\widehat{o}_{H,t} + \frac{Y_H}{Y}\widehat{a}_{H,t} + \frac{Y_S}{Y}\widehat{y}_{S,t}$$

Monetary Policy

- Monetary policy rule

$$\widehat{r}_t = \rho_i \widehat{r}_t + (1-\rho_i)\,\varpi_x g_{y,t} + (1-\rho_i)\,\varpi_\pi\left(\pi_t - \overline{\pi}_t\right) + \nu_t$$

Empirical Methodology

- Bayesian approach
- Log-likelihood function for the solved model is evaluated using the Kalman filter
- Mode of the posterior is obtained with a standard optimization routine
- Posterior distribution, $\mathbf{p}\left(\vartheta \mid \mathcal{Y}^T\right)$, is constructed using the Metropolis-Hasting algorithm, where

$$\mathbf{p}\left(\vartheta \mid \mathcal{Y}^T\right) = \frac{L(\vartheta \mid \mathcal{Y}^T)\mathbf{p}\left(\vartheta\right)}{\int L(\vartheta \mid \mathcal{Y}^T)\mathbf{p}\left(\vartheta\right) d\vartheta}$$

- Observable variables: $\mathbf{y}_t = \{\widehat{y}_t, \widehat{\pi}_{Z,t}, \widehat{r}_t, \Delta\widehat{e}_t, \widehat{rer}_t, \widehat{wr}_t, \widehat{l}_t, \widehat{o}_t, \widehat{pr}^*_{O,t}\}$

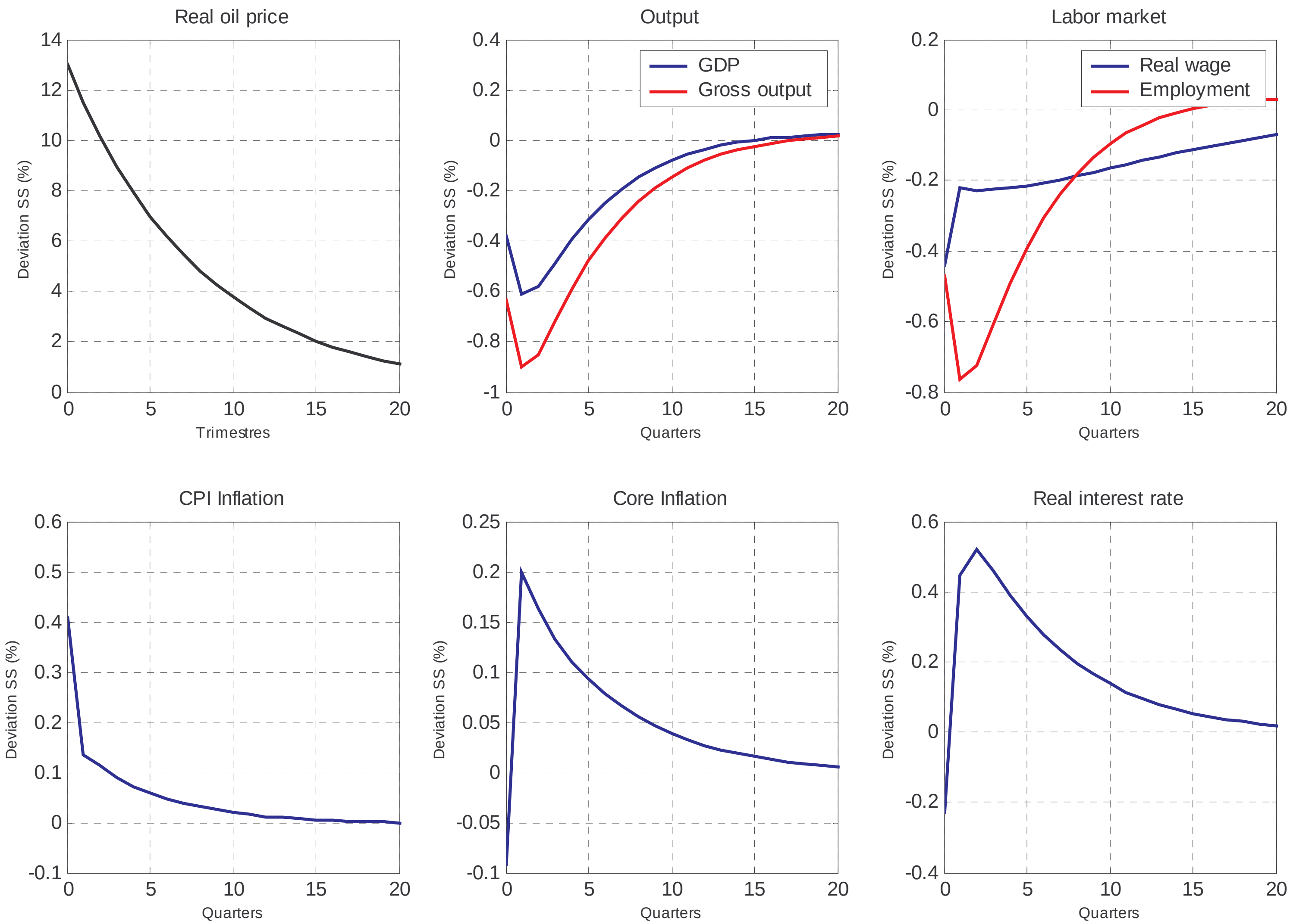
Table 1: Prior Densities

Param.	Description	Density	mean/moda	sd/df	90% interval	
σ_L	Inv. labor elasticity	Inverse Gamma	1.00	3.00	0.64	4.89
h	Habit coefficient	Beta	0.50	0.25	0.10	0.90
ϕ_H	Price rigidity	Beta	0.75	0.05	0.66	0.83
ϕ_L	Wage rigidity	Beta	0.75	0.05	0.66	0.83
θ	H/F elast. substit.	Inverse Gamma	1.00	3.00	0.64	4.89
η^*	Elast. frgn demand	Inverse Gamma	1.00	3.00	0.64	4.89
ϱ	Elast. risk. premium	Inverse Gamma	0.10	4.00	0.06	0.37
ξ_L	Weight past inflation	Beta	0.50	0.25	0.10	0.90
ξ_H	Weight past inflation	Beta	0.50	0.25	0.10	0.90
η	*Core*/oil elast. subst.	Inverse Gamma	0.20	4.00	0.13	0.73
ω	Labor/oil elasticity	Inverse Gamma	0.20	4.00	0.13	0.73
ρ_i	AR policy rule	Beta	0.75	0.20	0.35	0.99
ϖ_π	Inf. weight pol. rule	Normal	0.75	0.15	0.50	1.00
ϖ_x	Out. weight pol. rule	Normal	0.50	0.15	0.25	0.75

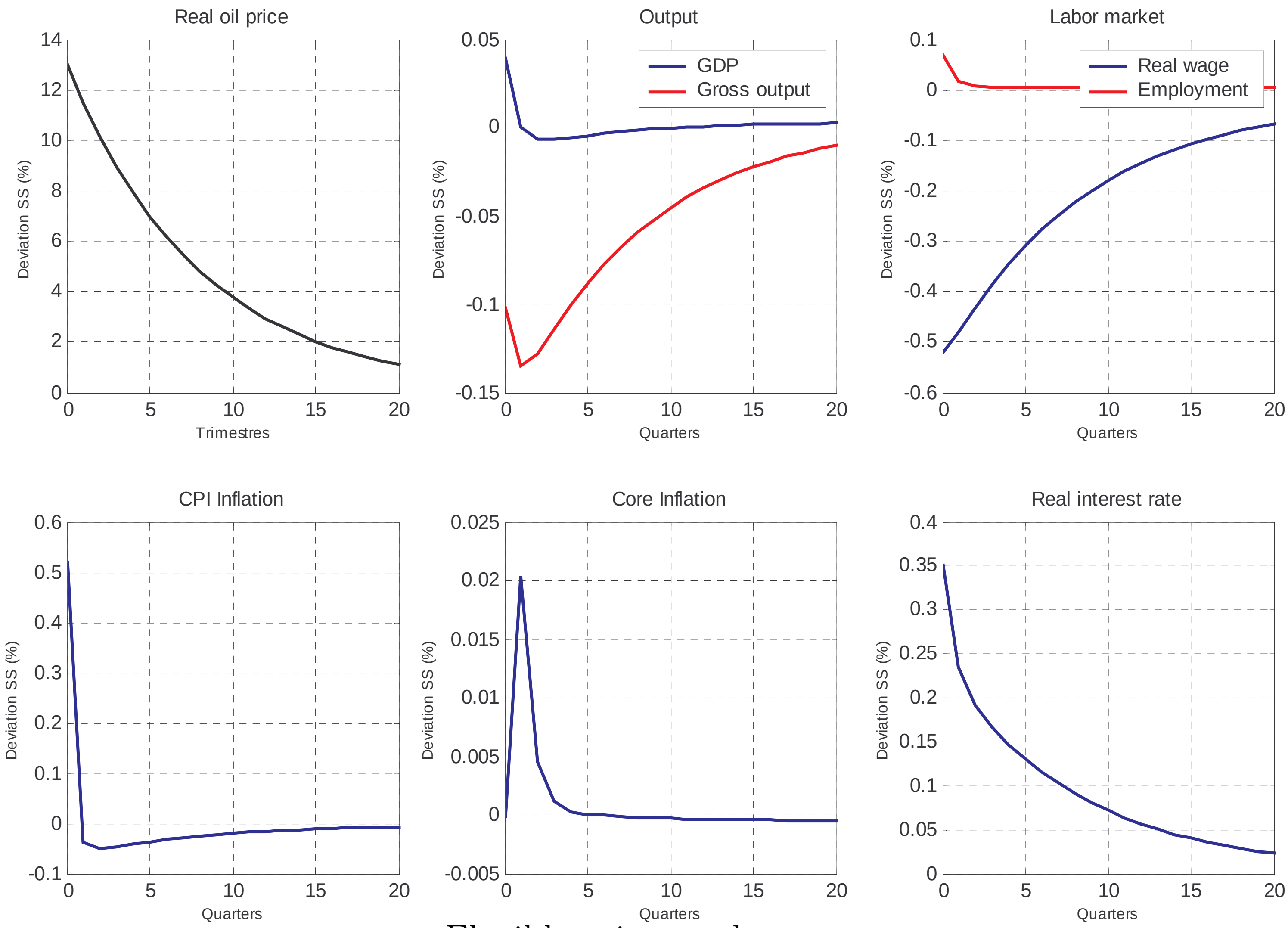
For inverse gamma distribution, mode and degrees of freedom are presented

Table 2: Posterior distributions

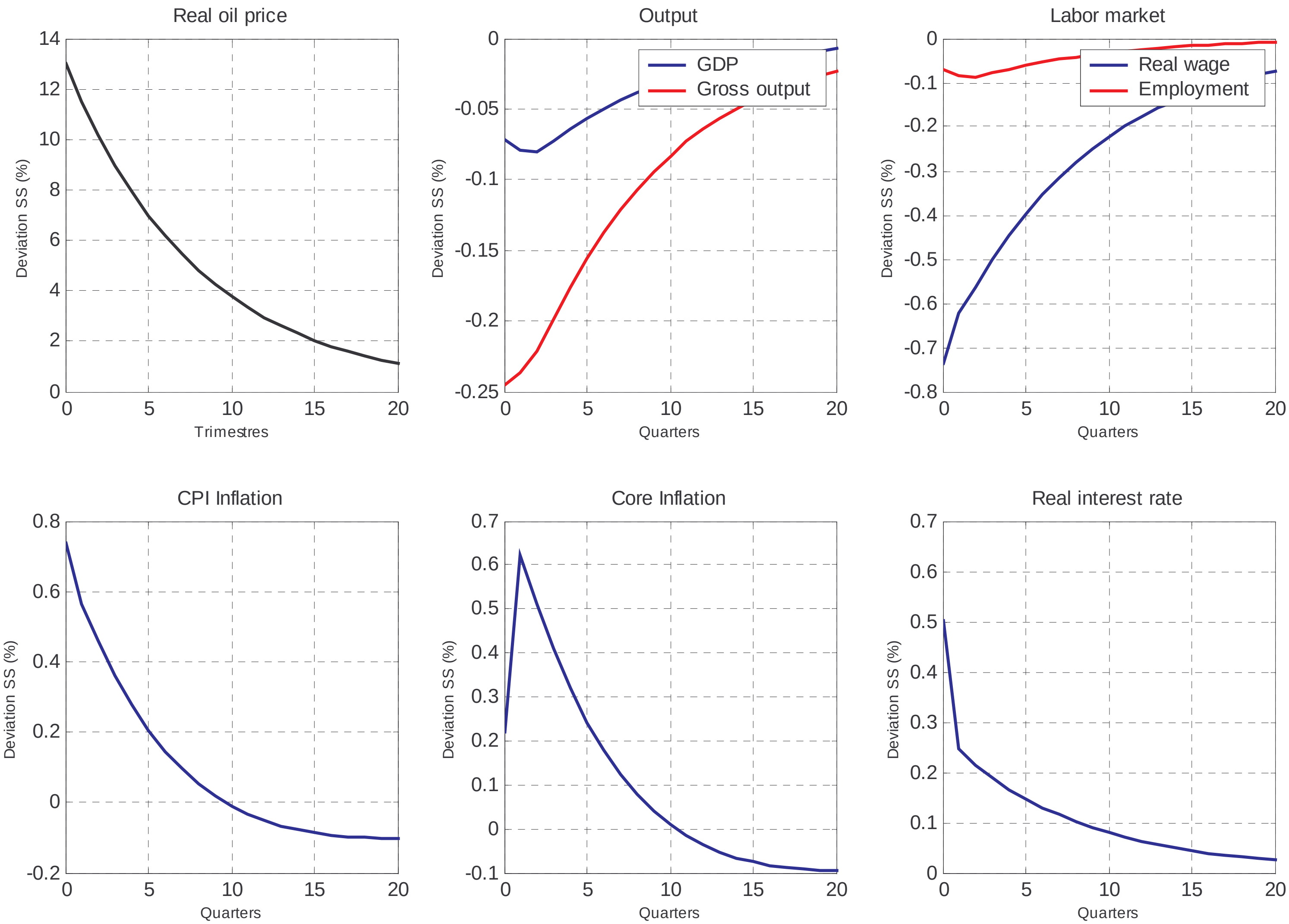
Param.	Description	Monetary Policy reacts to CPI Inflation		Monetary Policy reacts to core Inflation	
		mean	st. Dev.	mean	st. Dev.
σ_L	Inv. labor elasticity	0.781	0.141	0.959	0.102
h	Habit coefficient	0.324	0.104	0.254	0.040
ϕ_H	Price rigidity	0.166	0.013	0.159	0.026
ϕ_L	Wage rigidity	0.819	0.019	0.804	0.005
θ	H/F elast. substit.	0.616	0.183	0.612	0.143
η^*	Elast. frgn demand	1.140	0.174	1.052	0.178
ϱ	Elast. risk. premium	0.012	0.004	0.010	0.001
ξ_L	Weight past inflation	0.908	0.079	0.920	0.028
ξ_H	Weight past inflation	0.257	0.143	0.276	0.081
η	*Core*/oil elast. subst.	0.656	0.006	0.568	0.010
ω	Labor/oil elasticity	0.507	0.045	0.660	0.095
ρ_i	AR policy rule	0.331	0.256	0.247	0.112
ϖ_π	Inf. weight pol. rule	0.850	0.032	0.835	0.028
ϖ_x	Out. weight pol. rule	0.120	0.263	-0.004	0.147
Log marginal likelihood		-3049.3		-3021.9	



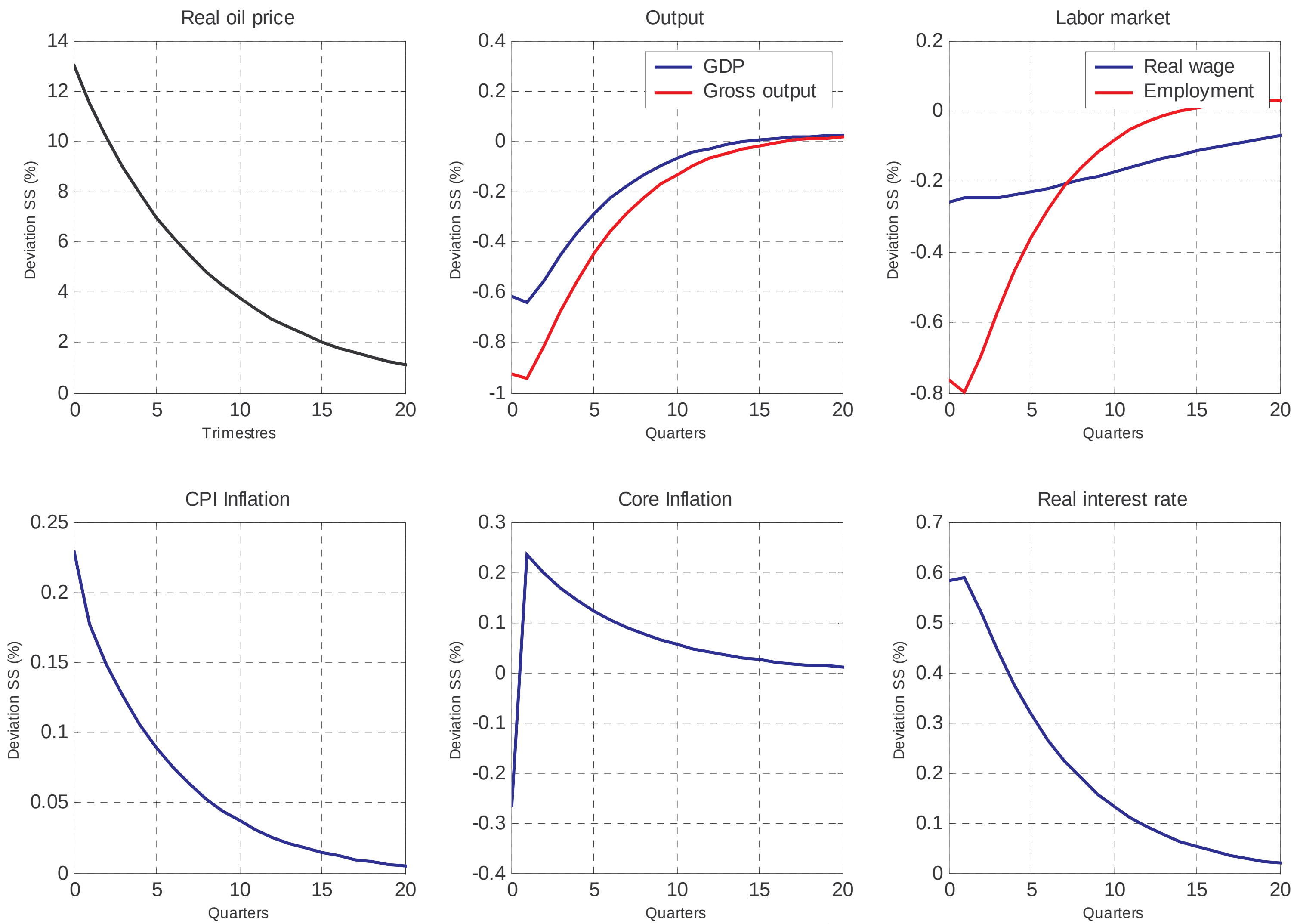
Baseline policy rule



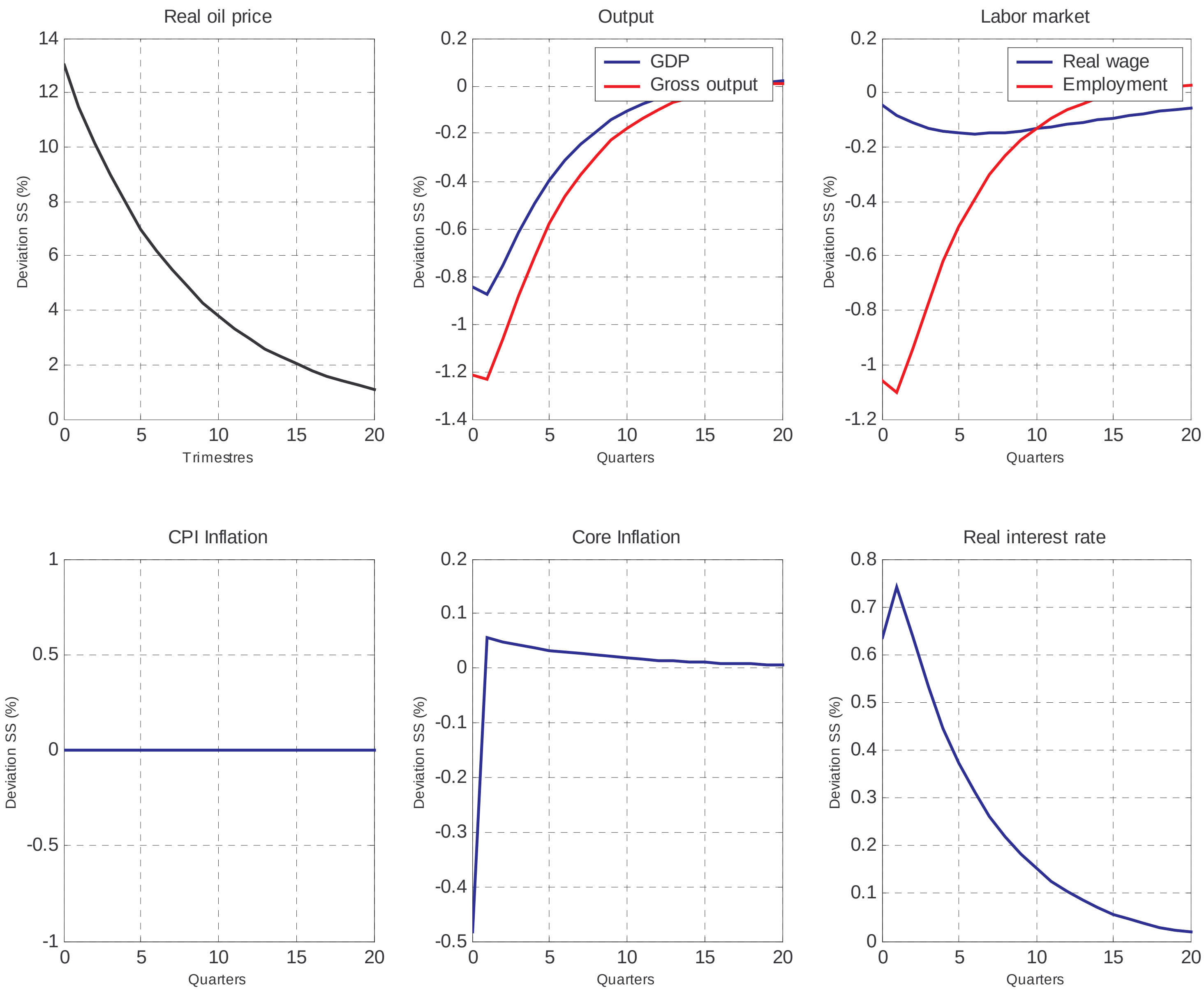
Flexible prices and wages



Policy that undoes wages rigidity



Policy that reacts to CPI deviations from the target



CPI full stabilization

Current Work

- Model
  - Introduce imperfect exchange rate pass-through
  - Introduce copper price shocks
- Estimation
  - Enhance the set of observable variables
  - Structural foreign block: endogenous response of foreign interest rate, foreign inflation and foreign output to oil-price shock
- Optimal monetary policy