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Estimating a DSGE Model for Japan: Evaluating and Modifying a CEE/SW/LOWW Model

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•The views expressed here are those of the authors, and should not be interpreted as reflecting the views of the Bank of Japan.

Outline

- Motivation
- Model
- Estimation results
- Effect of monetary policy shock on inflation
- Conclusion

Motivation(1)

- Estimate a DSGE model for Japan
  - Avoid the Lucas critique. Use for policy analyses.
  - Middle-scale model incorporating many elements.
  - Few estimation has been done. Aim to provide a benchmark result.

- We also want to know
  - The driving force of the Japanese business cycles
  - The effect of monetary policy shock on inflation

Related literature

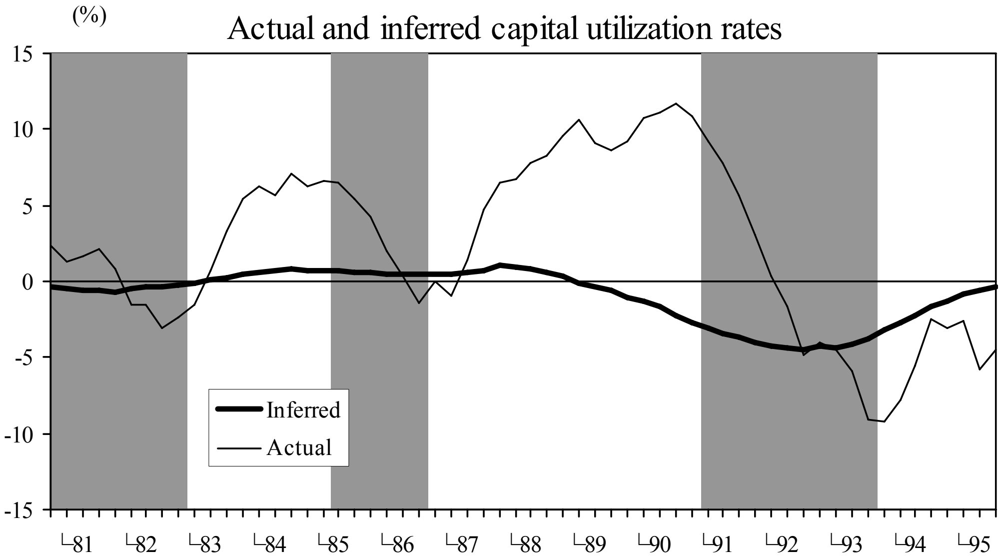
<Theory>

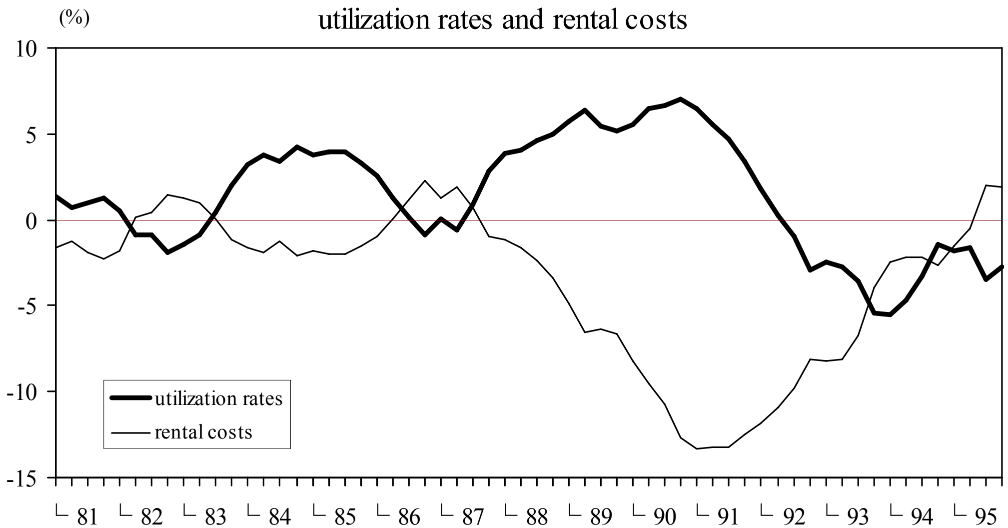
- Christiano, Eichenbaum, and Evans (CEE) (2005, JPE)
  - Construct the DSGE model

<Empirical papers>

- Smets and Wouters (SW) (2003, JEEA)
  - Estimate the Euro economy by Bayesian technique
- Levin, Onatski, Williams and Williams (LOWW) (2005, MA)
  - Estimate the U.S economy by Bayesian technique
- Iiboshi, Nishiyama, Watanabe (INW) (2006, mimeo)
  - Estimate the Japanese economy by Bayesian technique

Motivation(2): capital utilization rates





- Inferred capital utilization from CEE/SW model is very different from actual one in terms of their movements and their amplitude.

- Utilization rates and rental costs are negatively correlated, while CEE model assumes the positive correlation between capital utilization and rental costs.

⇒ need to modify the canonical model by CEE/SW

Bottom Line

- We use actual capital utilization rate data for estimation, and modify the formalization of utilization.
- We succeed in incorporating a negative correlation between capital utilization and rental cost.
- Japanese business cycles are driven by investment adjustment cost shock in the short run and by productivity shock in the long run.
- We find a hump-shaped and persistent behavior of inflation rates in response to a monetary policy shock.

Model

Household preferences

- A household *h* maximizes the following:

$$\Xi_t(h) = E_t \sum_{j=0}^{\infty} \beta_{t+j}^{j} V_{t+j}(h),$$

where $\beta_{t+j}^{j} = \prod_{s=0}^{j} \beta_{t+s}$ and $\beta_{t+s} = \beta Z_t^b$

- Utility function: separable and habit formation

$$V_t = \frac{\left(C_t(h) - \theta C_{t-1}(h)\right)^{1-\sigma}}{1-\sigma} - \frac{Z_t^L \left(L_t(h)\right)^{1+\chi}}{1+\chi}.$$

- The household *h*'s budget constraint:

$$\frac{B_{t-1}(h)}{P_t} + W_t(h)L_t(h) + R_t^k U_t(h) K_{t-1}(h) + \Pi_t(h) \geq C_t(h) + I_t(h) + b_t \frac{B_t(h)}{P_t}.$$

Capital utilization and accumulation

- Capital depreciation rates depend on capital utilization rates (Greenwood, Hercowitz, and Huffman[1988]):
  - Different from CEE/SW

$$\delta(U_t(h)) = \delta\Psi(Z_t^U U_t(h)).$$

- A higher utilization rates leads to high depreciation:

$$\Psi(X) = 1 + \mu \frac{X^{1+\psi^{-1}} - 1}{1+\psi^{-1}}.$$

- Capital accumulation:

$$K_t(h) = \{1 - \delta(U_t(h))\} K_{t-1}(h) + \left\{ 1 - \zeta^{-1} \left(\frac{Z_t^I I_t(h)}{I_{t-1}(h)} - 1 \right)^2 \right\} I_t(h).$$

Production and Prices/Wages

- Production technology:

$$Y_t(j) = A_t \left(\widetilde{K}_t(j)\right)^{\alpha} L_t(j)^{1-\alpha} - \Phi.$$

- Monopolistic competitive firms/households determine prices/wages in the Calvo manner
  - With indexation to the past inflation rates

- Market clearing condition:

$$Y_t = C_t + G_t + I_t.$$

Monetary policy rule

- Monetary policy rule:

$$r_t = r_i r_{t-1} + (1 - r_i)\bar{\pi}_t + r_\pi(\pi_{t-1} - \bar{\pi}_t) + r_y(y_{t-1} - y^*_{t-1})$$
$$+ r_{\Delta\pi}(\pi_t - \pi_{t-1}) + r_{\Delta y}\big((y_t - y^*_t) - (y_{t-1} - y^*_{t-1})\big) + \eta^r_t .$$

Log-linearized equations (1)

$$c_t = E_t \frac{1}{1+\theta+\beta\theta^2}\{\theta c_{t-1} + (1+\beta\theta^2+\beta\theta)c_{t+1} - \beta\theta c_{t+2}$$

$$-\frac{1-\theta}{\sigma}((1-\beta\theta)(r_t - \pi_{t+1}) - \varepsilon_t^b + (1+\beta\theta)\varepsilon_{t+1}^b - \beta\theta\varepsilon_{t+2}^b)\}$$

$$q_t = -(r_t - E_t\pi_{t+1}) + \frac{1}{1-\delta+\overline{R}^k}\{(1-\delta)E_t q_{t+1} + \overline{R}^k E_t r_{t+1}^k\}$$

$$i_t = \frac{1}{1+\beta}E_t(i_{t-1} + \beta i_{t+1} + \zeta q_t + \beta\varepsilon_{t+1}^i - \varepsilon_t^i)$$

$$k_t = (1-\delta)k_{t-1} + \delta i_t - \overline{R}^k(u_t + \varepsilon_t^u)$$

$$u_t = \psi(r_t^k - q_t - \varepsilon_t^u) - \varepsilon_t^u$$

$$l_t = -w_t + r_t^k + u_t + k_{t-1}$$

Log-linearized equations (2)

$$y_t = c_y c_t + g_y \varepsilon_t^g + \delta k_y i_t$$

$$y_t = \phi[\varepsilon_t^a + \alpha(u_t + k_{t-1}) + (1-\alpha) l_t]$$

$$w_t = \frac{1}{1+\beta} E_t \{\beta w_{t+1} + w_{t-1} + \beta \pi_{t+1} - (1+\beta\gamma_w)\pi_t + \gamma_w \pi_{t-1}$$

$$- \frac{\lambda_w (1-\beta\xi_w)(1-\xi_w)}{(\lambda_w + (1+\lambda_w)\chi)\xi_w} (w_t - \chi l_t - \varepsilon_t^l + \frac{\beta\theta}{1-\beta\theta}(\varepsilon_t^b - \varepsilon_{t+1}^b) - \eta_t^w$$

$$- \frac{\sigma}{(1-\theta)(1-\beta\theta)} ((1+\beta\theta^2) c_t - \theta c_{t-1} - \beta\theta c_{t+1}))\}$$

$$\pi_t = \frac{1}{1+\beta\gamma_p} \{\beta E_t \pi_{t+1} + \gamma_p \pi_{t-1} + \frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p} (w_t + \alpha(l_t - u_t - k_{t-1}) - \varepsilon_t^a + \eta_t^p)\}$$

$$\varepsilon_t^x = \rho_x \varepsilon_{t-1}^x + \nu_t^x \quad \text{where} \quad x = \{a, b, g, i, l, u\}$$

$$\overline{\pi}_t = \rho_\pi \overline{\pi}_{t-1} + \nu_t^\pi$$

Estimation results

Data and estimation method

- Estimation period: 1981:1Q～ 1995:4Q
- Data: real GDP, real consumption, real investment, real wage, hours worked, capital utilization, inflation, call rates
  - Detrend real variables with kinked linear trends (1991:2Q and 2001:1Q)
  - Demean the rest of variables
- Bayesian estimation

Prior distributions of parameters

		Distribution	Mean	S. D.
Structural parameters				
θ	consumption habit	beta	0.7	0.15
σ	inverse of the elasticity of substitution	normal	1	0.375
χ	inverse of the elasticity of work	normal	2	0.75
$1/\zeta$	investment adjustment costs	normal	4	1.5
Ψ	inverse of the elasticity of capital utilization costs	normal	5	0.5
φ-1	a fixed-cost share	gamma	0.075	0.0125
ξ_p	price no-revise probability	beta	0.375	0.1
ξ_w	wage no-revise probability	beta	0.375	0.1
γ_p	price indexation	beta	0.5	0.25
γ_w	wage indexation	beta	0.5	0.25
Policy parameters				
r_i	lagged interest rate	normal	1	0.15
r_π	inflation	normal	0.5	0.2
r_y	output	normal	0.01	0.01
$r_{\triangle\pi}$	change in inflation	normal	0.1	0.1
$r_{\triangle y}$	change in output	normal	0.1	0.1

Estimation result: Posterior distribution

	SW	OW	LOWW	INW	This paper			
Parameters	mean	mean	mean	mean	mean	90% interval		
Structural parameters								
θ	0.592	0.4	0.294	0.641	0.102	0.042	-	0.164
σ	1.391	2.178	2.045	2.041	1.249	0.960	-	1.522
χ	2.503	3	1.405	2.427	2.149	1.764	-	2.532
$1/\zeta$	6.962	6.579	1.822	8.338	6.319	4.297	-	8.266
Ψ	4.975	2.800	0.198	0.182	2.370	1.398	-	3.336
φ-1	0.417	0.8	0.082	0.581	0.084	0.061	-	0.106
ξ_p	0.905	0.93	0.824	0.65	0.875	0.884	-	0.914
ξ_w	0.742	0.704	0.807	0.367	0.516	0.428	-	0.599
γ_p	0.477	0.323	0.116	0.613	0.862	0.740	-	0.995
γ_w	0.728	0	0.773	0.578	0.246	0.011	-	0.458
Policy parameters								
r_i	0.956	0.962	0.832	0.682	0.842	0.725	-	0.957
r_π	0.074	0.152	0.460	0.505	0.606	0.481	-	0.729
r_y	0.004	0.004	0.000	0.017	0.110	0.046	-	0.170
$r_{\triangle\pi}$	0.151	0.14	0.285	-	0.250	0.133	-	0.366
$r_{\triangle y}$	0.158	0.159	0.481	-	0.647	0.445	-	0.864

- An average contract duration of price setting is about 8 quarters.
- Monetary policy has a very high inertia.

Capital adjustment utilization

- Explain a sizable decline in utilization rates in the early 1990's and a recovery in 1994-1995.

Variance decomposition

Output

	T=1	T=4	T=10	T=30
productivity shock	43.7	56.6	84.0	94.9
preference shock	7.0	0.3	1.7	2.9
investment adjustment cost shock	36.7	32.1	10.3	1.5
external demand shock	6.2	2.2	1.1	0.4
utilization adjustment cost shock	3.3	2.7	2.1	0.3
labor supply disutility shock	1.0	0.2	0.1	0.0
price markup shock	1.0	5.2	0.5	0.0
wage markup shock	0.0	0.1	0.1	0.0
interest rate shock	0.4	0.1	0.0	0.0
target inflation shock	0.7	0.6	0.1	0.1

Hours worked

	T=1	T=4	T=10	T=30
productivity shock	16.5	0.3	0.2	48.7
preference shock	4.7	0.1	24.6	6.2
investment adjustment cost shock	41.9	57.3	4.6	17.3
external demand shock	16.2	12.6	65.6	27.0
utilization adjustment cost shock	3.6	0.6	0.5	0.4
labor supply disutility shock	8.0	1.9	0.8	0.0
price markup shock	1.2	21.7	0.1	0.2
wage markup shock	2.4	2.0	3.2	0.1
interest rate shock	2.3	0.5	0.0	0.0
target inflation shock	3.3	3.1	0.5	0.1

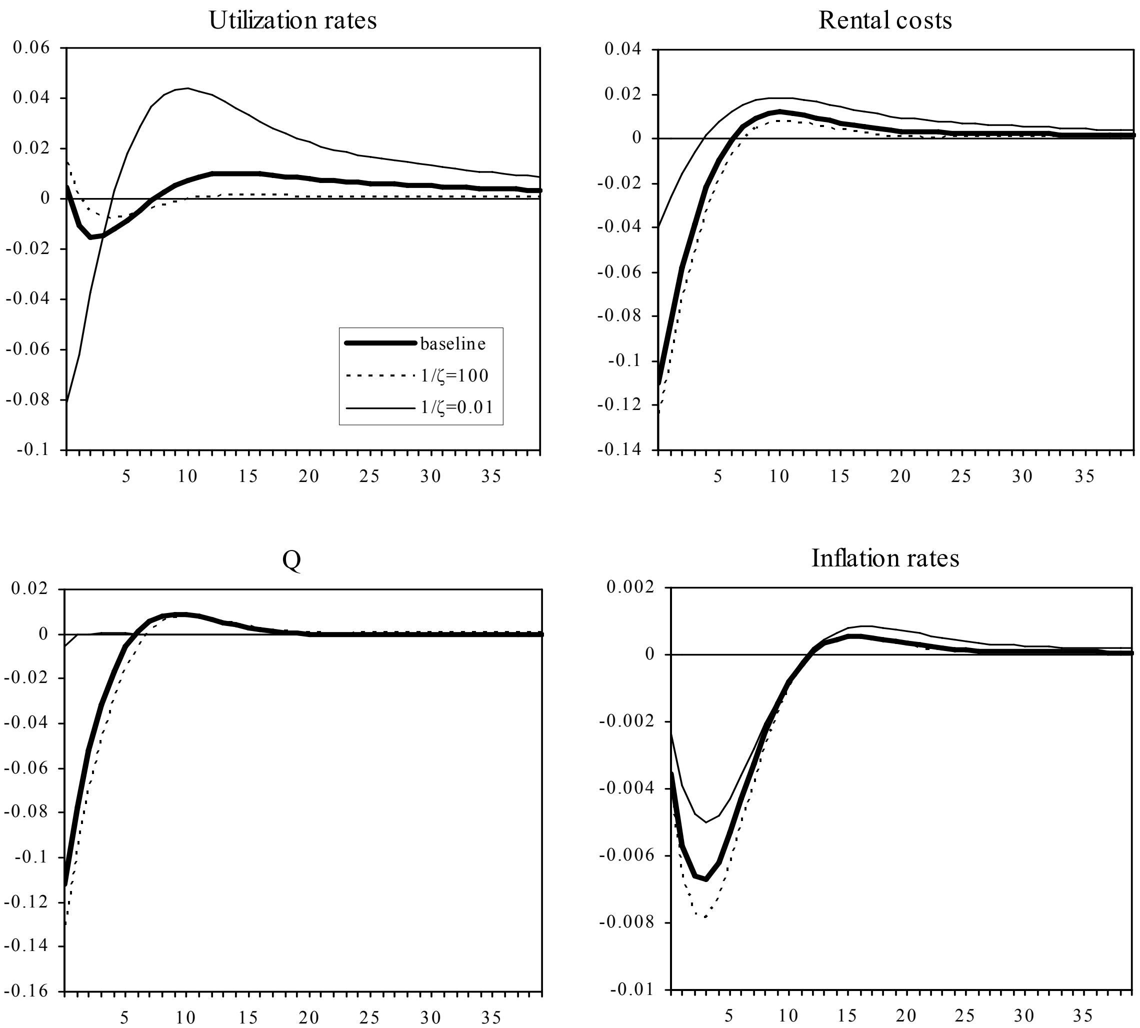
- In the short run, an increase in output and hours worked is caused mainly by the investment adjustment cost shock.
- In the long run, a productivity shock is a dominant driving force.

Effect of monetary policy shock on inflation

Argument by CEE (2005)

- Capital utilization costs should be treated not as capital depreciation but as additional spending to explain the hump-shaped inflation behavior.
- If the cost of capital utilization is treated as additional spending, then tightening monetary policy causes a fall in capital utilization rates.
  - This makes a modest fall in the rental rate of capital and a hump-shaped behavior of inflation rates.
- If the cost of capital utilization is modeled as a higher capital depreciation rate, then tightening monetary policy causes a rise in capital utilization rates.
  - This is because policy tightening decreases the value of capital (Q), and encourages the capital utilization.
  - Hump-shaped behavior of inflation rates cannot be explained.

Effects of tightening monetary policy shock



- True, utilization rates increase on impact, as CEE point out.
- However, this increase is only temporary, and our model can explain a hump-shaped response of inflation rates.
- If adjustment costs are small, utilization rates drop on impact and rental costs fall mildly (close to CEE).
- If adjustment costs are large, rental costs drop by large amounts. But the response of inflation rate is still hump-shaped.
- This is a response to an i.i.d. interest rate shock. To a longer-run target inflation shock, the responses of utilization as well as inflation become the same as CEE.

Conclusion

Conclusion

- We succeed in incorporating a negative correlation between capital utilization and rental costs by assuming that adjustment cost depreciates the capital.

- Japanese business cycles are driven by a investment adjustment cost shock in the short run and by a productivity shock in the long run.

- We find a hump-shaped and persistent behavior of inflation rates in response to a monetary policy shock.

Future research

- Introduce a model of effective labor (e.g. labor hoarding or overhead labor) to explain the movement of productivity growth
- Combine unemployment with the RBC or New Keynesian models (Blanchard and Gali (2006))
- Study an optimal monetary policy and social welfare in the framework of middle-scale DSGE model