Exiting from QE

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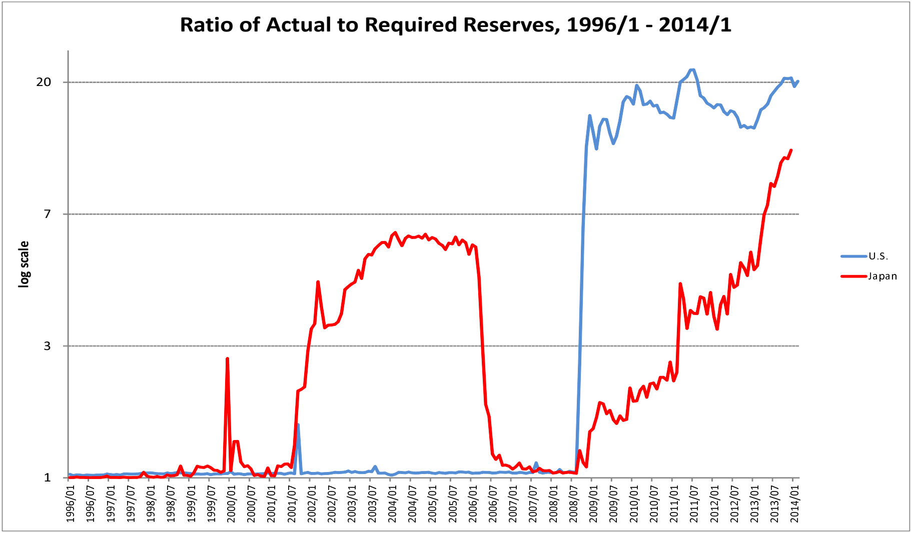
To get started...



What This Paper Does

- Study the effect of QE on macro variables (inflation and GDP) on Japanese data using SVAR (structural VAR)
  - Japan has, by our count, 130 QE months (as of Dec. 2012)
  - Includes actual lift-off.
- Unique in two respects:
  - Observable and endogenous regimes (unlike in the hidden-state Markov switching model)
  - IR (impulse response) to regime changes.

Plan of Talk

- Identifying the Regime
- The Model
- Estimation Results
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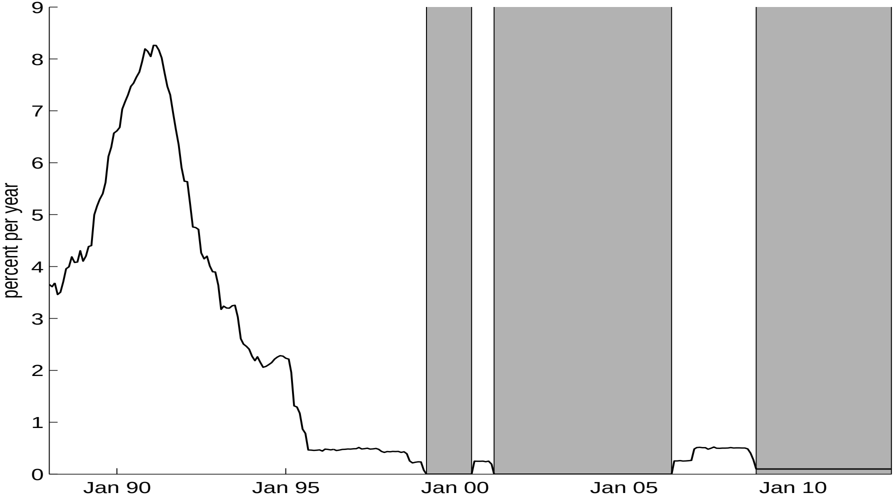
- Conclusions about BOJ's Zero-Rate/QE Policy

Three QE Spells

- **Z** (zero-rate regime) if r (the policy rate) $< 0.05\%$ (5 basis points). **P** (normal regime) otherwise.
- **Z** $=$ QE because excess reserves > 0 when **Z**.
- Periods of **Z** (Zero-Rate/QE) Regime
  - QE1: March 1999 - July 2000
  - QE2: March 2001 - June 2006
  - QE3: December 2008 to date
- Agrees with BOJ annoucements. For example,
  - July 14, 2006: "... the BOJ decided ... to change the guideline for money market operations.... The BOJ will encourage the uncollateralized overnight rate to remain at around 0.25 percent."

Policy Rate (r) in Japan, 1988 - 2012



The Exit Condition

- (to repeat) Periods of Zero-Rate/QE Regime
  - QE1: March 1999 - July 2000
  - QE2: March 2001 - June 2006
  - QE3: December 2008 to date

- During QE's, BOJ made the inflation commitment. For example
  - September 21, 1999: "The BOJ ... is explicitly committed to continue this policy [the zero-rate policy] until deflationary concerns subside."

The Model, step 1 of 4: a textbook block-recursive SVAR

- Point of departure: textbook 3-variable SVAR (see Stock and Watson, *J. of Econ. Perspectives*, 2001)
  - (p, x, r), $p =$ inflation rate, $x =$ output gap, $r =$ policy rate.
  - The first two equations are reduced forms in (p, x).
  - The third equation is the Taylor rule, relating r to contemporaneous (p, x).

- Taylor rule: with $\pi_t \equiv \frac{1}{12}(p_t + \cdots + p_{t-11})$,

$$r_t = \rho_r r_t^* + (1 - \rho_r) r_{t-1} + \sigma_r v_{rt}, \quad r_t^* \equiv \underbrace{\alpha_r^* + \underset{(1\times 2)}{\beta_r^{*\prime}} \begin{bmatrix} \pi_t \\ x_t \end{bmatrix}}_{\text{“desired Taylor rate”}}, \quad v_{rt} \sim \mathcal{N}(0, 1).$$

  - The inflation rate in the Taylor rule is the year-on-year (12-month) inflation rate π.

The Model, step 2 of 4: Add the Zero Lower Bound

- Impose the lower bound:

$$r_t = \max\Big[\underbrace{\rho_r r_t^* + (1-\rho_r) r_{t-1} + \sigma_r v_{rt}}_{\text{“shadow Taylor rate”}}, 0\Big], \quad v_{rt} \sim \mathcal{N}(0,1).$$

  Equivalently,

$$r_t = \begin{cases} \text{shadow Taylor rate} & \text{if } s_t = \mathbf{P}, \\ 0 & \text{if } s_t = \mathbf{Z}. \end{cases} \quad s_t = \begin{cases} \mathbf{P} & \text{if shadow Taylor rate} > 0, \\ \mathbf{Z} & \text{otherwise.} \end{cases}$$

- Note:
  - The regime s_t is endogenous.
  - $s_t = \mathbf{Z}$ if and only if $r_t = 0$ (the econometrician doesn't have to observe the shadow Taylor rate).

The Model, step 3 of 4: Introduce Exit Condition

- If $s_{t-1} = \mathbf{Z}$,

$$s_t = \begin{cases} \mathbf{P} & \text{if shadow Taylor rate} > 0 \ \ \textbf{and} \ \ \pi_t > \underbrace{\overline{\pi} + \sigma_{\overline{\pi}} v_{\overline{\pi} t}}_{\text{target inflation rate}}, \\ \mathbf{Z} & \text{otherwise.} \end{cases}$$

- If $s_{t-1} = \mathbf{P}$, as before, i.e.,

$$s_t = \begin{cases} \mathbf{P} & \text{if shadow Taylor rate} > 0, \\ \mathbf{Z} & \text{otherwise.} \end{cases}$$

- (reminder) $\pi_t \equiv \frac{1}{12}(p_t + \cdots + p_{t-11})$,

$$\text{shadow Taylor rate} = \rho_r r_t^* + (1-\rho_r) r_{t-1} + \sigma_r v_{rt}, \quad r_t^* \equiv \underbrace{\alpha_r^* + \underset{(1\times 2)}{\beta_r^{*\prime}} \begin{bmatrix} \pi_t \\ x_t \end{bmatrix}}_{\text{“desired Taylor rate”}}.$$

The Model, step 4 of 4: Add m

- Add m to (p, x, r).

$$m_t = \begin{cases} 0 & \text{if } s_t = \mathbf{P}, \\ \max\left[m_{st}, 0\right], \quad v_{mt} \sim \mathcal{N}(0,1) & \text{if } s_t = \mathbf{Z}, \end{cases}$$

where

$$m_{st} \equiv \alpha_s + \boldsymbol{\beta}_s{}' \begin{bmatrix} \pi_t \\ x_t \end{bmatrix} + \gamma_s m_{t-1} + \sigma_s v_{st},$$

- (reminder)
  - $p \equiv$ monthly inflation rate, $\pi_t \equiv \frac{1}{12}(p_t + \cdots + p_{t-11})$,
  - $x \equiv$ output gap,
  - $m \equiv \log\left(\frac{\text{actual reserves}}{\text{required reserves}}\right)$.

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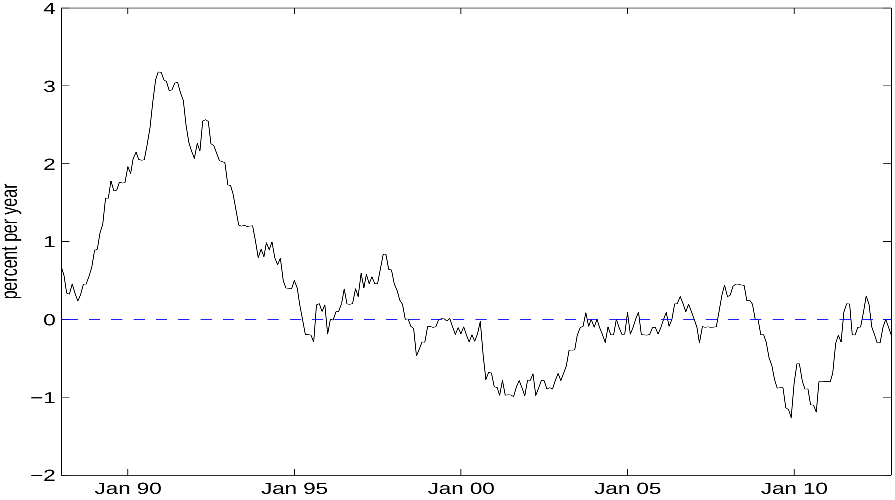
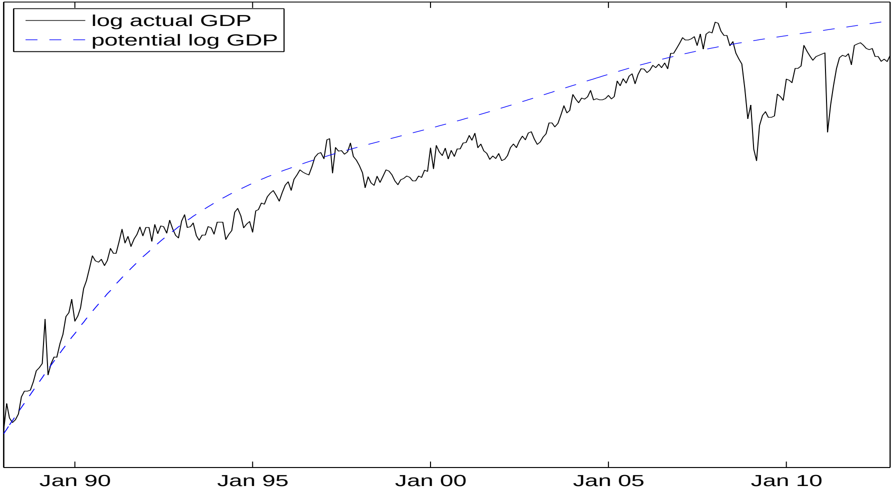
Estimation: The Monthly Data

- p (monthly CPI inflation rate)
- π (12-month inflation rate)
- m (excess reserve rate): $m_t \equiv 100 \times \log \left(\frac{\text{actual reserves}_t}{\text{required reserves}_t} \right)$.
- r (policy rate): collateralized overnight interbank rate.
- x (GDP gap): monthly interpolation of official quarterly estimate.

12-Month Inflation Rate (π), 1988-2012



GDP, 1988-2012



Estimation: The Equations

- bivariate (p, x) reduced form: allowed to shift between (lagged) $\mathbf{P}$ (normal regime) and (lagged) $\mathbf{Z}$ (zero-rate/QE regime) by Lucas.
- Taylor rule: estimated on $\mathbf{P} + \mathbf{Z}$, regime endogeneity taken into account.
- Excess reserve supply equation: on $\mathbf{Z} = \{\text{QE1, QE2, QE3}\}$, but QE1 dropped because QE1 looks different.

Estimation: (p, x) Reduced Form (t value in brackets)

sample period is January 1992 - December 2012

subsample **P** (s_{t-1} = **P**, sample size = 123)						
dep. var.	const.	p_{t-1}	x_{t-1}	r_{t-1}	m_{t-1}	R^2
p_t	−0.23 [−0.9]	0.10 [1.1]	0.14 [1.7]	0.39 [3.4]		0.19
x_t	−0.20 [−1.4]	−0.00 [−0.1]	0.93 [21]	0.02 [0.3]		0.80

subsample **Z** (s_{t-1} = QE2+QE3 , sample size = 112)						
dep. var.	const.	p_{t-1}	x_{t-1}	r_{t-1}	m_{t-1}	R^2
p_t	0.15 [0.3]	0.22 [2.4]	0.16 [1.8]		0.0002 [0.1]	0.11
x_t	−1.21 [−3.3]	−0.02 [−0.3]	0.77 [14]		0.0052 [2.6]	0.75

Things to Note about Estimated Reduced Form

- subsample $s_{t-1} = \mathbf{P}$:
  - lagged r coefficient in p_t equation *positive* and significant.
- subsample $s_{t-1} = \mathbf{Z}$ (QE2+QE3):
  - lagged m coefficient in p_t and x_t equations positive.
  - Intercepts lower for $\mathbf{Z}$ than for $\mathbf{P}$.

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m-IR and r-IR

- m-IR (IR to a change in m):

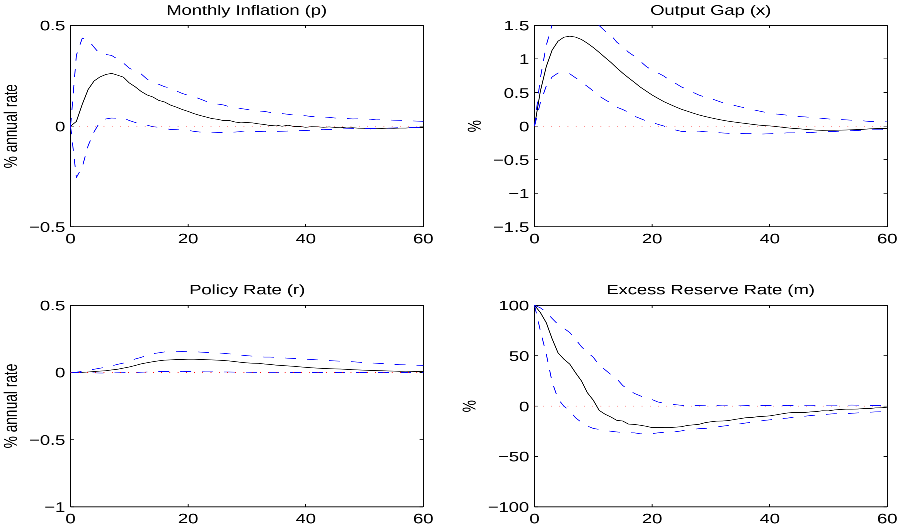
$$\mathrm{E}\big(y_{t+k}\,|\,s_t=\mathbf{Z},\quad \underbrace{(p_t,x_t,0,m_t+\delta_m),}_{(p_t,\,x_t,\,r_t,\,m_t)\text{ in alternative history}}\quad \ldots\big)$$
$$-\,\mathrm{E}\big(y_{t+k}\,|\,s_t=\mathbf{Z},\quad \underbrace{(p_t,x_t,0,m_t),}_{(p_t,\,x_t,\,r_t,\,m_t)\text{ in baseline history}}\quad \ldots\big),\;\; y=p,x,r,m.$$

- r-IR (IR to a change in r):

$$\mathrm{E}_t\big(y_{t+k}\,|\,s_t=\mathbf{P},\quad \underbrace{(p_t,x_t,r_t+\delta_r,0),}_{(p_t,\,x_t,\,r_t,\,m_t)\text{ in alternative history}}\quad \ldots\big)$$
$$-\,\mathrm{E}_t\big(y_{t+k}\,|\,s_t=\mathbf{P},\quad \underbrace{(p_t,x_t,r_t,0),}_{(p_t,\,x_t,\,r_t,\,m_t)\text{ in baseline history}}\quad \ldots\big),\;\; y=p,x,r,m.$$

- Adaptation of GRT (Gallant-Rossi-Tauchen, *Econometrica*, 1993) IR.

m-IR, February 2004



Focus on Exiting from QE2 (March 2001 - June 2006)

- Winding-down of QE2, March to August 2006:

	March	April	May	June	July	August
regime (**P** for normal, **Z** for zero-rate/QE)	**Z**	**Z**	**Z**	**Z**	**P**	**P**
ratio of actual to required reserves	4.5	2.7	1.7	1.6	1.0	1.0
m, log of the above ratio (%)	151	100	55	46	0	0
r, the policy rate (% per year)	≈ 0	≈ 0	≈ 0	≈ 0	0.26	0.25
π, year-on-year inflation rate (%)	0.1	-0.1	0.0	0.2	0.2	0.3
x, output gap (%)	-0.7	-0.3	-0.6	-0.4	-0.7	-0.4
shadow Taylor rate (% per year)	0.04	0.02	0.03	0.07	0.08	0.29

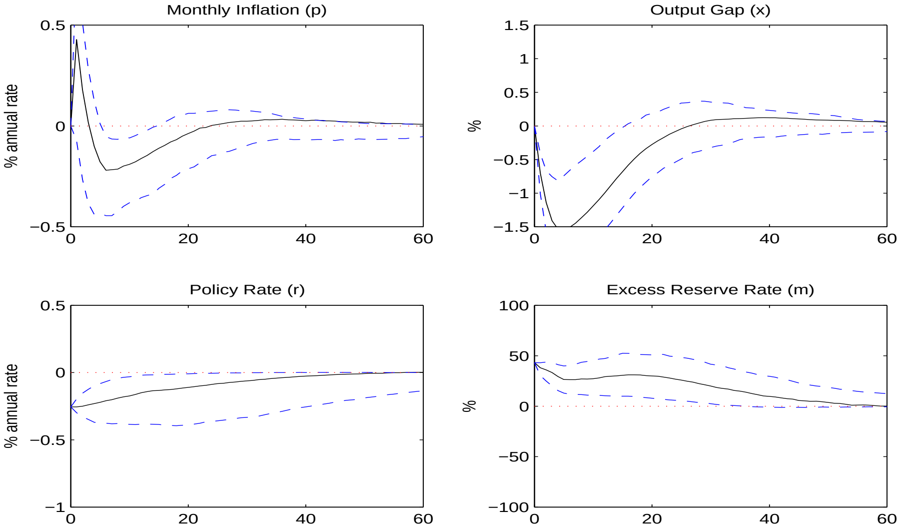
IR with Regime Change

$$
\begin{aligned}
&\mathrm{E}\big(y_{t+k} \,|\, s_t = \mathbf{Z}, \quad \underbrace{(p_t, x_t, 0, m_t^e),}_{(p_t,\, x_t,\, r_t,\, m_t) \text{ in alternative history}} \quad \dots\big) \\
&-\mathrm{E}\big(y_{t+k} \,|\, s_t = \mathbf{P}, \quad \underbrace{(p_t, x_t, r_t, 0),}_{(p_t,\, x_t,\, r_t,\, m_t) \text{ in baseline history}} \quad \dots\big)
\end{aligned}
$$

- $m_t^e \equiv$ the m to be expected given history up to (p_t, x_t).
  - Can be calculated from the estimated excess reserve equation.

- Set $t =$ July 2006 (BOJ exited from QE2 in July 2006).

If BOJ hadn't exited in July 2006...

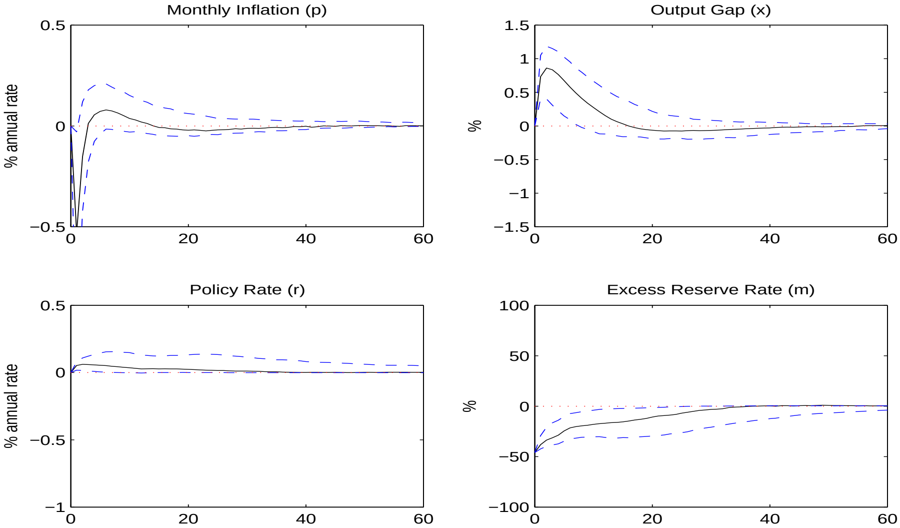


IR with Regime Change, in opposite direction

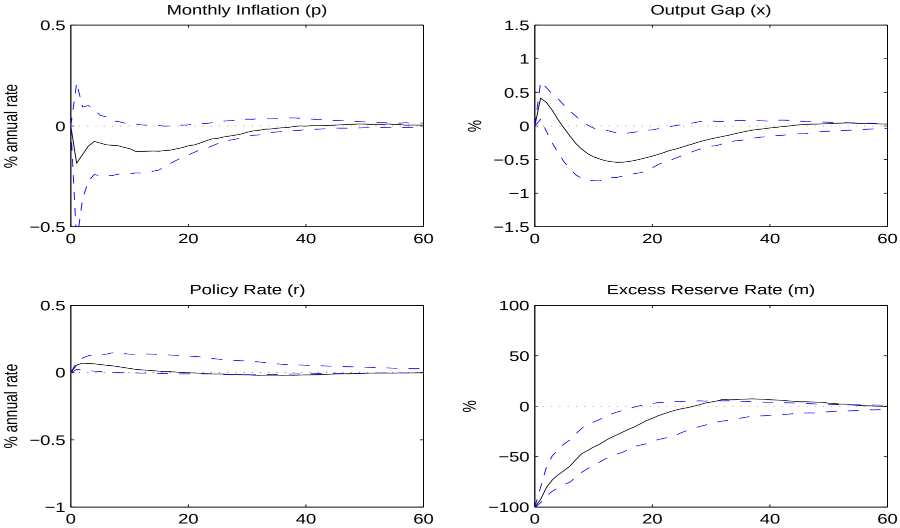
$$
\begin{aligned}
&\mathrm{E}\big(y_{t+k} \,|\, s_t = \mathbf{P}, \qquad \underbrace{(p_t, x_t, 0, 0),}_{(p_t,\, x_t,\, r_t,\, m_t) \text{ in alternative history}} \qquad \ldots\,\big) \\
&-\mathrm{E}\big(y_{t+k} \,|\, s_t = \mathbf{Z}, \qquad \underbrace{(p_t, x_t, 0, m_t),}_{(p_t,\, x_t,\, r_t,\, m_t) \text{ in baseline history}} \qquad \ldots\,\big)
\end{aligned}
$$

- Here, m_t in baseline is the actual m.

If BOJ had exited one month earlier, in June 2006...



If BOJ had exited in April 2006...



Conclusions about BOJ's Zero-Rate/QE Policy

- Increases in reserves under QE raise both inflation and output.
- Exiting from QE2 on July 2006 was *expansionary*.
- Better to have ended QE2 earlier, in April 2006 or May 2006, even though the ratio of actual to required reserves was as high as 1.7∼2.7.
- Caveats:
  - The price puzzle
  - Winding-down takes time.

r-IR, January 1992