Real Fluctuations at the Zero Lower Bound

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April 2014

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Paul Krugman, September 2011

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Answer depends on assumptions about policy **in future**

How does economy at the zero lower bound respond to shocks?

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Depends on assumptions about policy **in future**

Common Assumption at Zero Lower Bound

Taylor (1993)-type policy rule

$$r_t^d = r + \phi_\pi \Big(\pi_t - \pi \Big) + \phi_x x_t$$

$$r_t = \max \Big(0, r_t^d \Big)$$

Conduct of future policy does not depend on history

Central bank stops responding to economy at zero lower bound

Taylor Rule Inconsistent With FOMC Behavior

"The Committee will continue to assess the economic outlook and is prepared to employ its tools to promote a stronger economic recovery."

FOMC Statement, December 2011

Assume policy uses forward guidance to help stabilize economy

Reasonable Alternative Assumption

Reifschneider & Williams (2000) policy rule

$$r_t^d = r + \phi_\pi\Big(\pi_t - \pi\Big) + \phi_x x_t + \phi_d\Big(r_{t-1}^d - r_{t-1}\Big)$$

$$r_t = \mathsf{max}\,\Big(0, r_t^d\Big)$$

Offsets shocks using expectations about future policy

Central bank responds to economy at zero lower bound

Lift-off date depends on historical evolution of economy

Real Fluctuations at the Zero Lower Bound

Simulate prolonged zero lower bound episode

Show effects of real shocks under two policy assumptions:

1. Standard Taylor (1993) rule ($\phi_d = 0$)
2. History-dependent rule ($\phi_d = 0.9$)

Examine technology, government spending, & markup shocks

Assumptions about policy matter *even at zero lower bound*

Responses to shocks may not differ from normal times

Model Summary

Standard New-Keynesian model without capital

Solve nonlinear model using policy function iteration method

Illustrate results using linearized AS-AD framework

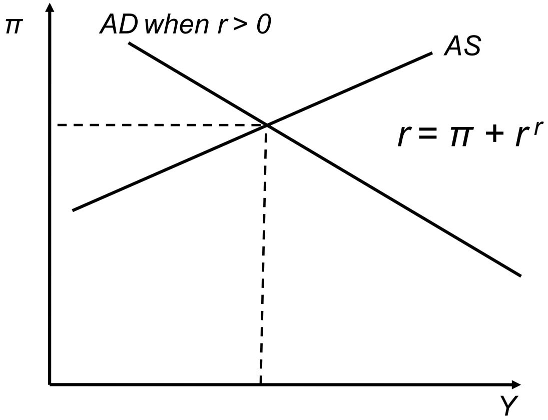
$$\pi_t = \beta E_t \pi_{t+1} + \psi_y y_t - \omega_t - (1-\eta)\psi z_t - \psi a_t + \psi_g (g_t - g)$$

$$y_t = E_t y_{t+1} - (1 - s_g)\left(r_t^r + (1-\rho_a) a_t + s_g (g_t - g)\right)$$

$$r_t = E_t \pi_{t+1} + r_t^r$$

Aggregate Demand Away From Zero Lower Bound

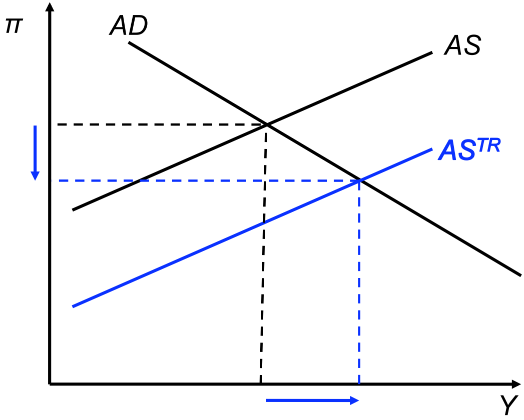
$$\left(1+\phi_y+\frac{\psi_y}{\beta}\right)y_t \quad = \quad E_t y_{t+1} - \left(\phi_\pi - \frac{1}{\beta}\right)\pi_t + \left(\text{Shocks}\right)$$



Declines in π_t offset with lower real rates which raises Y_t

Supply Shock Away From Zero Lower Bound

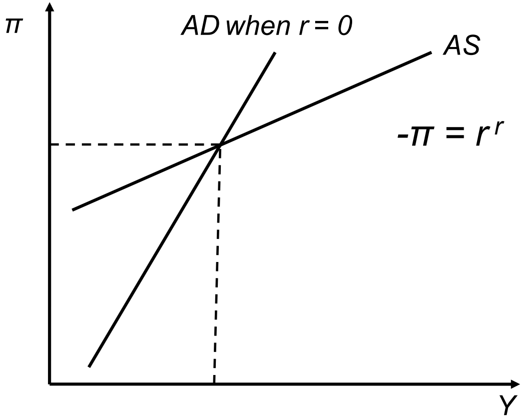
$$\left(1+\phi_y+\frac{\psi_y}{\beta}\right)y_t \quad = \quad E_t y_{t+1}-\left(\phi_\pi-\frac{1}{\beta}\right)\pi_t+\left(\text{Shocks}\right)$$



Supply shock lowers π_t & raises Y_t with policy accommodation

Aggregate Demand At Zero Lower Bound

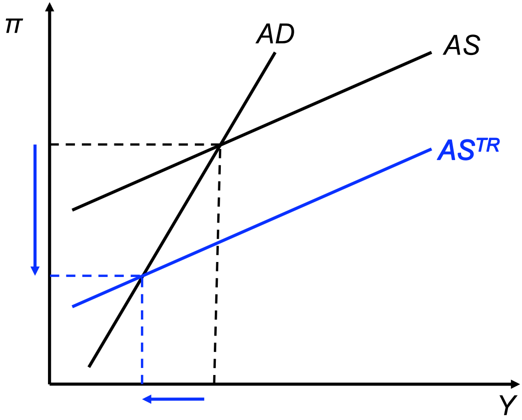
$$\left(1+\frac{\psi_y}{\beta}\right) y_t = E_t y_{t+1} + \frac{1}{\beta}\pi_t + \left(\text{Shocks}\right)$$



Declines in π_t cannot be initially offset which raises real rates

Supply Shock At Zero Lower Bound

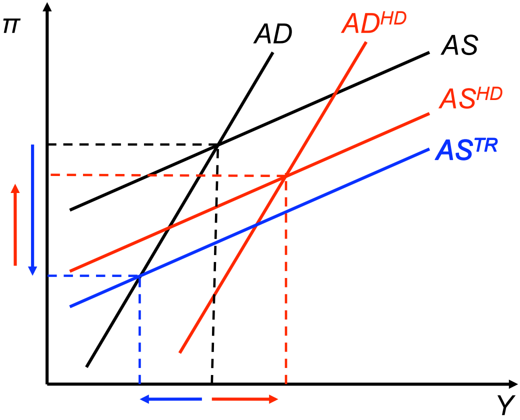
$$\left(1+\frac{\psi_y}{\beta}\right)y_t \quad = \quad E_t y_{t+1} + \frac{1}{\beta}\pi_t + \Big(\text{Shocks}\Big)$$



Supply shock can cause larger disinflation & output losses

Response to Shock Under History-Dependent Rule

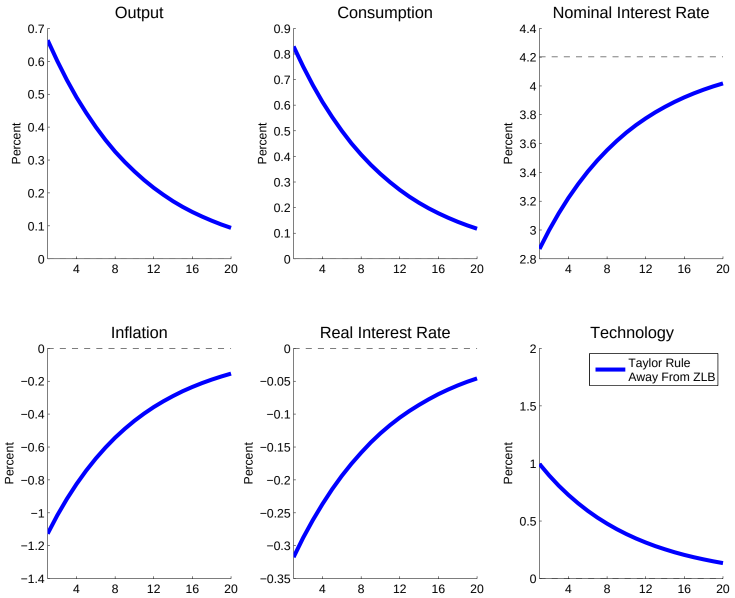
$$\left(1+\frac{\psi_y}{\beta}\right)y_t \quad = \quad E_t y_{t+1} + \frac{1}{\beta}\pi_t + \Big(\text{Shocks}\Big)$$



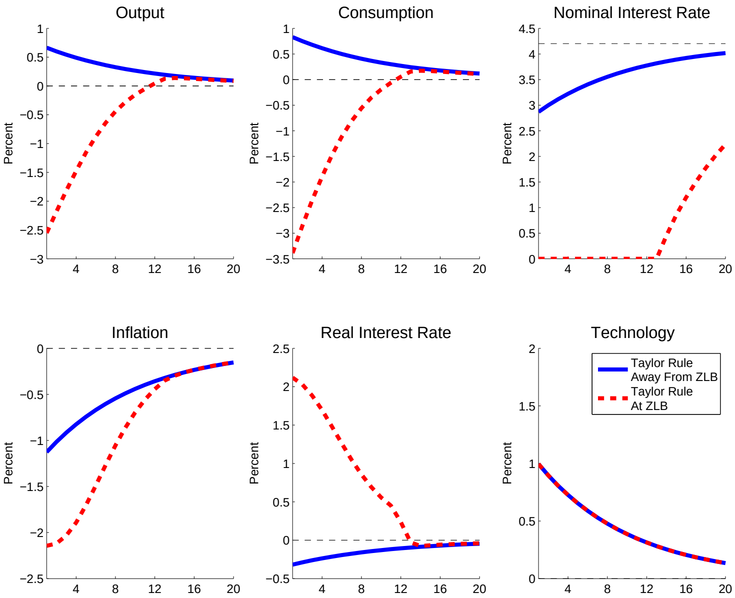
Declines in π_t offset with expansionary policy in future

Are technological improvements highly contractionary?

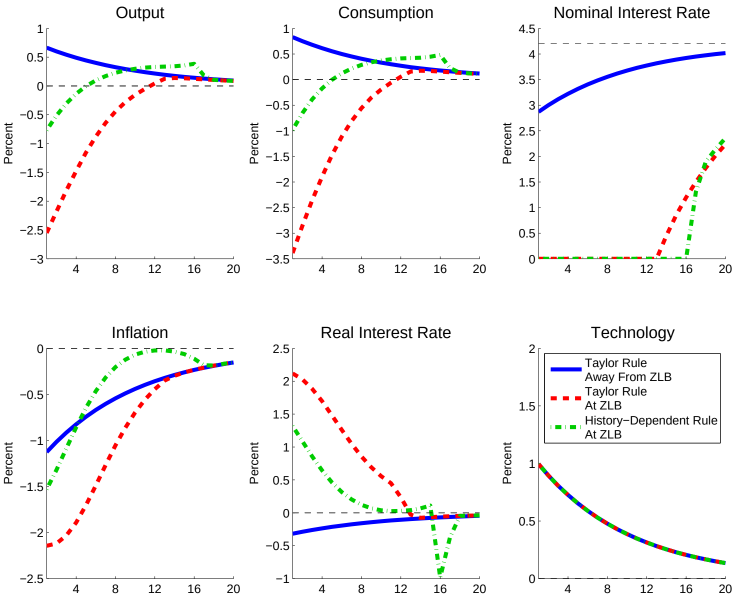
Increase in Productivity Away From Zero Lower Bound



Increase in Productivity At Zero Lower Bound



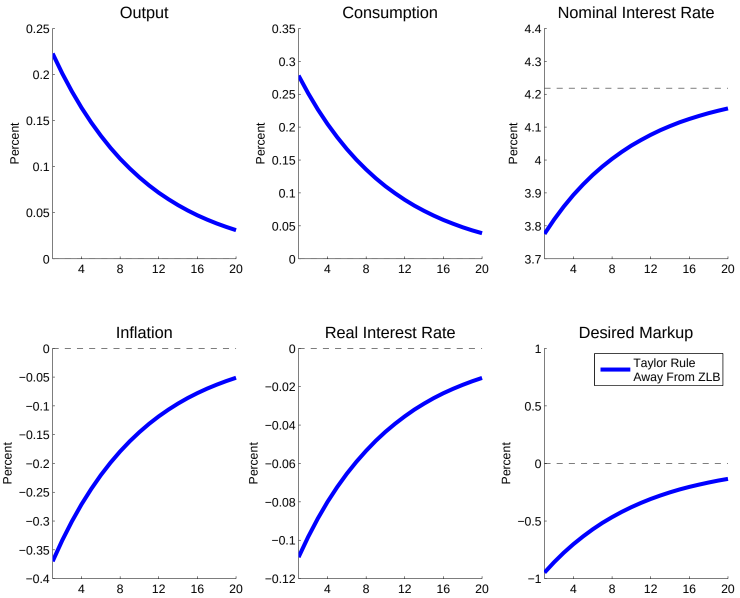
Increase in Productivity Under History-Dependent Policy



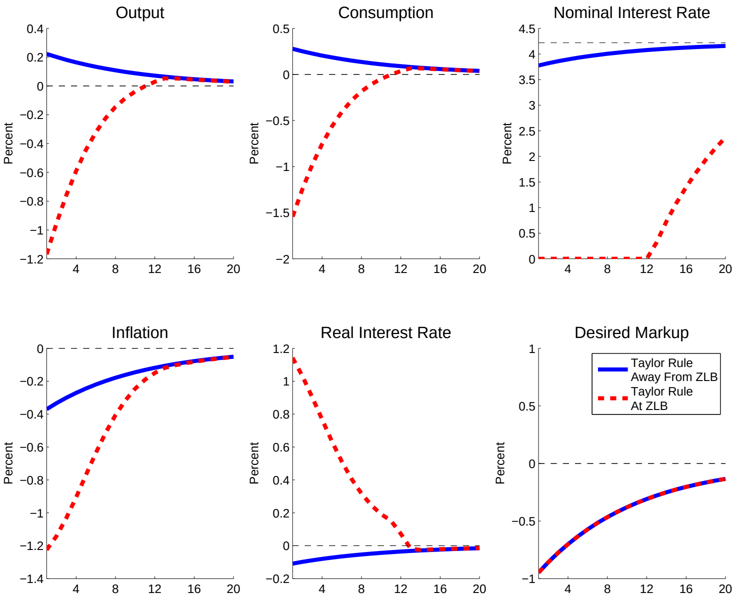
Are structural reforms that increase competition bad for Europe?

Do decreases in firm market power depress output?

Fall in Desired Markups Away From Zero Lower Bound



Fall in Desired Markups At Zero Lower Bound



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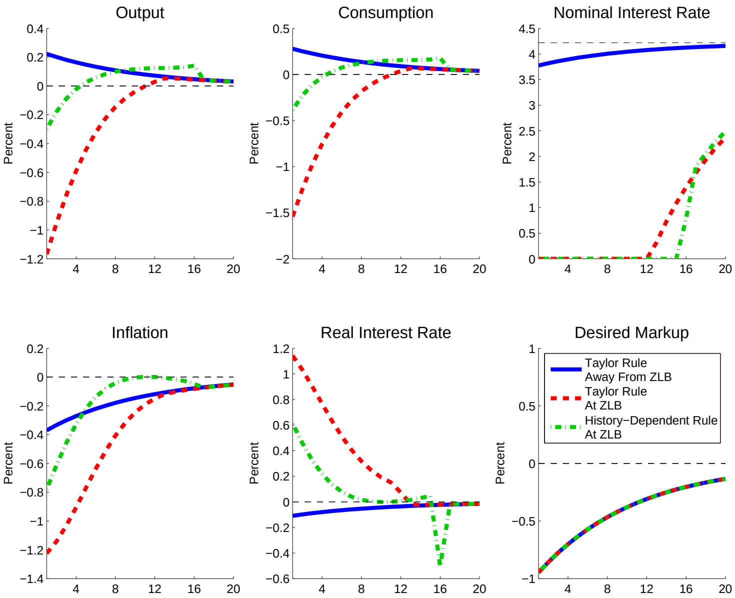
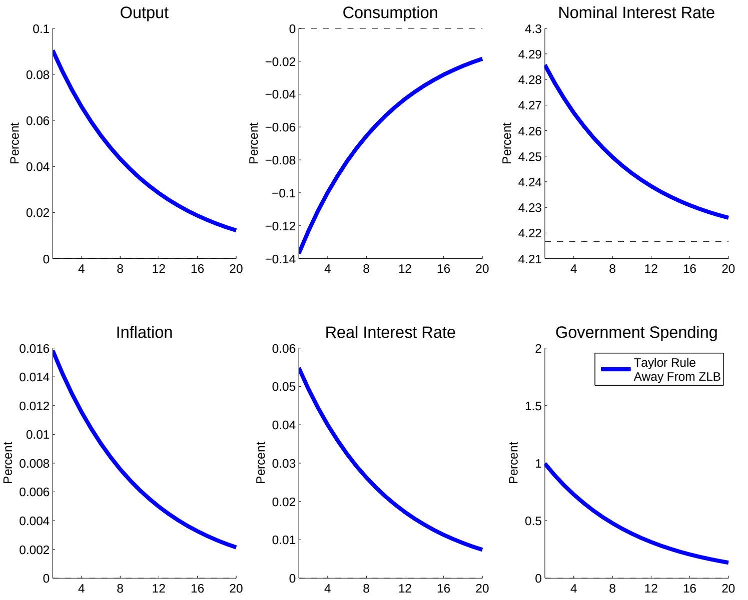


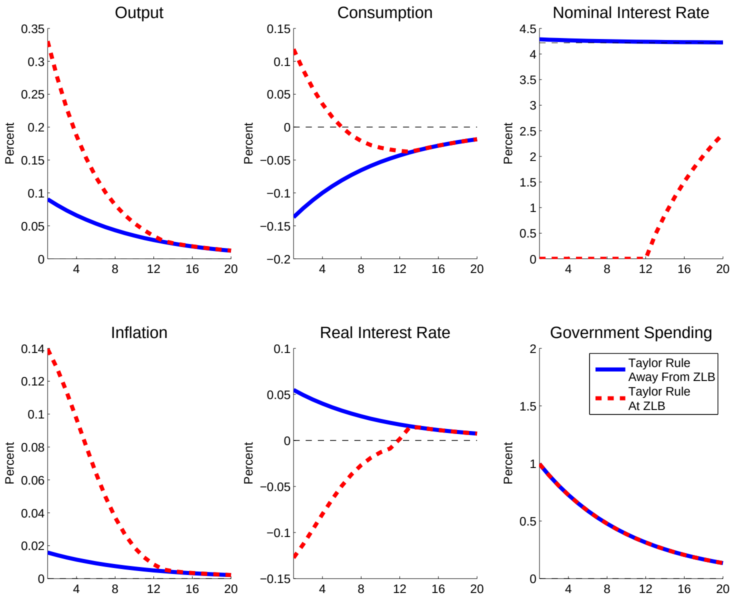
Are government spending multipliers bigger than one?

Does consumption rise after increase in government spending?

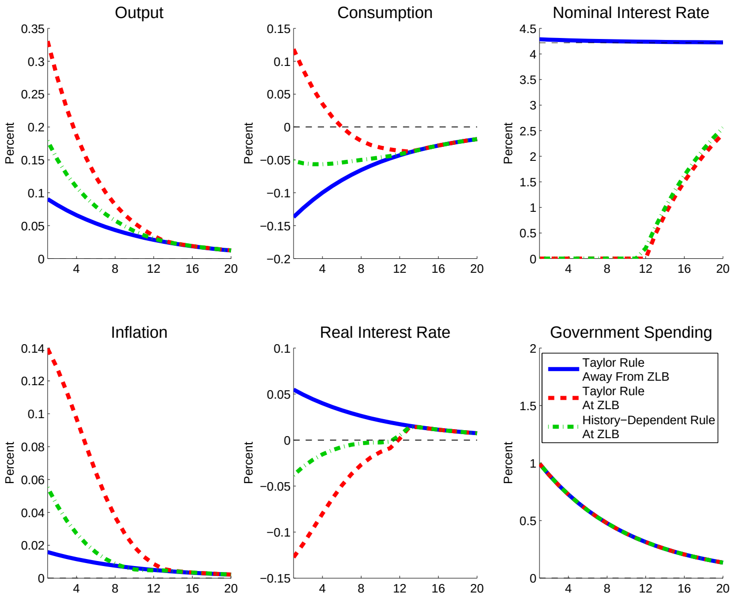
Government Spending Away From Zero Lower Bound



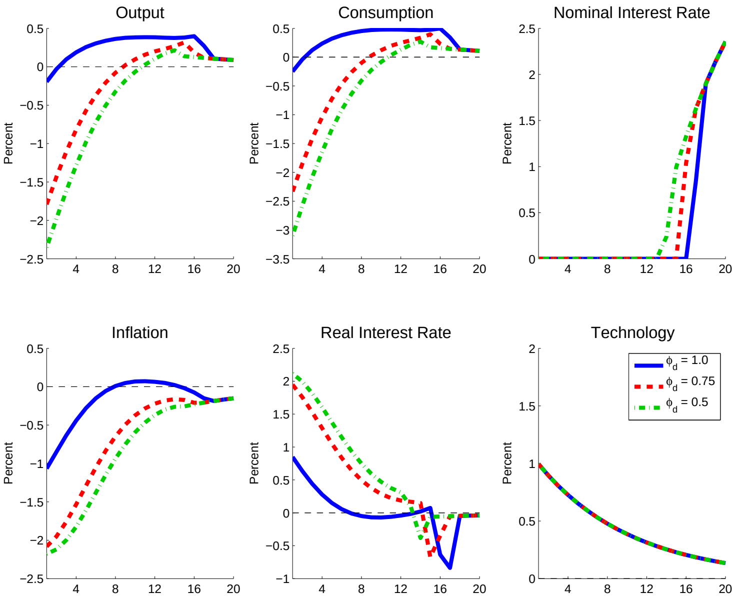
Government Spending At Zero Lower Bound



Government Spending Under History-Dependent Policy



Comparing Amounts of History-Dependence



History-Dependence and Memory

Assume economy constrained by zero lower bound for n periods

$$r_t^d = r + \phi_\pi \pi_t + \phi_x x_t + \phi_d r_{t-1}^d$$

$$r_t^d = r + \phi_\pi \pi_t + \phi_x x_t + \phi_d \Big(r + \phi_\pi \pi_{t-1} + \phi_x x_{t-1} + \phi_d r_{t-2}^d \Big)$$

$$r_t^d = r + \phi_\pi \pi_t + \phi_x x_t + \sum_{i=1}^{n} \phi_d^i \Big(r + \phi_\pi \pi_{t-i} + \phi_x x_{t-i} \Big)$$

ϕ_d controls the memory of the policy rule

Alternative Forms and Evidence

History-dependent policy responds to backward-looking state variable

Gust, Lopez-Salído, & Smith (2013) estimate following rule

$$r_t^d = \Big(1 - \phi_r\Big) r + \phi_r r_{t-1}^d + \phi_\pi \Big(\pi_t - \pi\Big) + \phi_x \Delta y_t$$

95% confidence interval for ϕ_r is $\Big(0.79, 0.92\Big)$

Gorodnichenko & Shapiro (2007) argues weight on price-level in 90s

$$r_t = \Big(1 - \phi_r\Big) r + \phi_r r_{t-1} + \phi_\pi \Big(\pi_t - \pi\Big) + \phi_p \Big(p_t - p_t^*\Big) + \phi_x x_t$$

Significant evidence of price-level targeting

Responding to Unemployment & History-Dependence

"The [FOMC] anticipates that this exceptionally low range for the federal funds rate will be appropriate at least as long as the unemployment rate remains above 6-1/2 percent, ..."

FOMC Statement, December 2012

Response to unemployment implies history-dependence in DMP

$$N_t = (1-\psi) N_{t-1} + m_t$$

$$u_t = 1 - N_t$$

$$u_t = 1 - \sum_{i=0}^{\infty} (1-\psi)^i m_{t-i}$$

Conclusions

Assumptions about policy matter even at zero lower bound

Does policy continue to react to state of economy?

Is a standard Taylor rule accurately describing current policy?

Additional Details

Representative Household

Household maximizes lifetime utility from consumption and leisure

$$\max E_t \sum_{i=0}^{\infty} a_t \beta^i \left(\frac{C_{t+i}^{\eta} (1 - N_{t+i})^{1-\eta}}{1-\sigma} \right)^{1-\sigma}$$

Household budget constraint

$$C_t + \frac{B_t}{P_t R_t} \leq \frac{W_t}{P_t} N_t + \frac{B_{t-1}}{P_t} + \frac{D_t}{P_t}$$

Household stochastic discount factor

$$M_{t+1} = \left(\beta \frac{a_{t+1}}{a_t} \right) \left(\frac{C_{t+1}^{\eta} \left(1 - N_{t+1}\right)^{1-\eta}}{C_t^{\eta} \left(1 - N_t\right)^{1-\eta}} \right)^{1-\sigma} \left(\frac{C_t}{C_{t+1}} \right)$$

Representative Goods-Producing Firm

Firm i chooses $N_t(i)$ and $P_t(i)$ to maximize cash flows

$$\max E_t \left\{ \sum_{s=0}^{\infty} M_{t+s} \left(\frac{D_{t+s}(i)}{P_{t+s}} \right) \right\}$$

Definition of firm cash flows

$$\frac{D_t(i)}{P_t} = \left[\frac{P_t(i)}{P_t} \right]^{1-\theta} Y_t - \frac{W_t}{P_t} N_t(i) - \frac{\phi_P}{2} \left[\frac{P_t(i)}{\Pi P_{t-1}(i)} - 1 \right]^2 Y_t$$

Quadratic cost of changing nominal price $P_t(i)$

$$\frac{\phi_P}{2} \left[\frac{P_t(i)}{\Pi P_{t-1}(i)} - 1 \right]^2 Y_t$$

Cobb-Douglas production function subject to fixed costs

$$Y_t(i) = N_t(i) - \Phi$$

Aggregation & National Income Accounting

All users of final output assemble the final good Y_t using the range of varieties $Y_t(i)$ in a CES aggregator

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}}$$

Aggregate production function

$$Y_t = N_t - \Phi$$

National income accounting

$$Y_t = C_t + \frac{\phi_P}{2} \left(\frac{\Pi_t}{\Pi} - 1 \right)^2 Y_t$$

Model Summary

Model summarized by consumption Euler equation and NK Philips Curve

$$1 = \mathbb{E}_t \left\{ M_{t+1} \left(\frac{R_t}{\Pi_{t+1}} \right) \right\}$$

$$\phi_P \left(\frac{\Pi_t}{\Pi} - 1 \right) \left(\frac{\Pi_t}{\Pi} \right) = (1-\theta) + \theta \Xi_t$$
$$+ \phi_P E_t \left\{ M_{t+1} \frac{Y_{t+1}}{Y_t} \left(\frac{\Pi_{t+1}}{\Pi} - 1 \right) \left(\frac{\Pi_{t+1}}{\Pi} \right) \right\}$$