Expectations Formation, Sticky Prices, and the ZLB[1]

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[1] These views are those of the authors, and not necessarily those of the Board of Governors of the Federal Reserve System, or of the Deutsche Bundesbank.

Introduction

- unusual macro phenomena occur at the ZLB with RE
  1. fiscal multipliers can be extremely large
  2. small delay in ELB liftoff can be very effective policy tool
  3. delaying liftoff for too many quarters can be a disaster
  4. to stabilize economy at ELB, may raise nominal rate
- expectations are crucial for all of these results
- we study these issues in a simple model of belief formation

Departures from RE: level-k thinking

- follow framework of Farhi and Werning (2018)
- framework is similar to Garcia-Schmitt and Woodford (2017)
- concept is called level-k thinking
- this is a plausible model for the process of belief revision
- mimics what might be going on in people's mind
- expectations formed iteratively
- start from "partial" equilibrium effects of policy interventions
- add future general equilibrium effects imperfectly

The macro questions we address

- Use a model of bounded rationality to study
  1. optimal monetary policy at the ZLB
  2. effects of a delayed liftoff from the ZLB
  3. the fiscal multiplier under a transient peg

Temporary equilibrium

Definition

A temporary equilibrium in period t is a collection of choices such that

1. given beliefs about future variables, household and firms optimize
2. goods, labor and asset markets clear
3. budget constraints for all agents are satisfied

A temporary equilibrium in period t is the outcome of a mapping from beliefs $\{B_{t+j}\}_{j=1}^{\infty}$ about relevant variables $\{X_{t+j}\}_{j=1}^{\infty}$ into equilibrium values X_t that satisfies the assumptions above.

Temporary equilibrium, level-k equilibrium

Temporary equilibrium

$$X_t = \Phi\left(\{B_{t+j}\}_{j=1}^{\infty}, X_{t-1}\right) \tag{1}$$

Definition

A level-k equilibrium is a temporary equilibrium where beliefs $\{B_{t+j}\}_{j=1}^{\infty}$ are given by the level $k-1$ equilibrium sequences for $\{X_{t+j}\}_{j=1}^{\infty}$. These are generated recursively given an initial belief

$$X_t^k = \Phi\left(\left\{X_{t+j}^{k-1}\right\}_{j=1}^{\infty}, X_{t-1}^k\right). \tag{2}$$

Further assumptions

- agents know the correct structure of the economy
- perfect foresight about exogenous government policies
- initial beliefs: RE equilibrium prior to policy intervention
- allows for fair comparison with RE (same baseline outlook)

What level of belief revision k ?

- experimental evidence, $k \leq 3$ (Mauersberger et al. 2018)
- survey of firm managers $k < 5$ (Coibion et al. 2018)

Baseline New Keynesian model

For arbitrary expectations, the equilibrium conditions are

$$y_t = \mathbf{E}_t \sum_{s=0}^{\infty} \beta^s [(1-\beta) y_{t+1+s} - \frac{1}{\sigma}(i_{t+s} - r_{t+s} - \pi_{t+1+s})] \quad (3)$$

$$\pi_t = \mathbf{E}_t \sum_{s=0}^{\infty} (\beta\varphi)^s \left[\beta(1-\varphi)\pi_{t+1+s} + \kappa y_{t+s}\right] \quad (4)$$

where π_t is inflation, y_t is output, i_t is nominal interest rate
Under RE we use law of iterated expectations to obtain:

$$\pi_t = \kappa y_t + \beta \mathbb{E}_t \pi_{t+1} \quad (5)$$

$$y_t = \mathbb{E}_t y_{t+1} - \frac{1}{\sigma}\left(i_t - r_t - \mathbb{E}_t \pi_{t+1}\right) \quad (6)$$

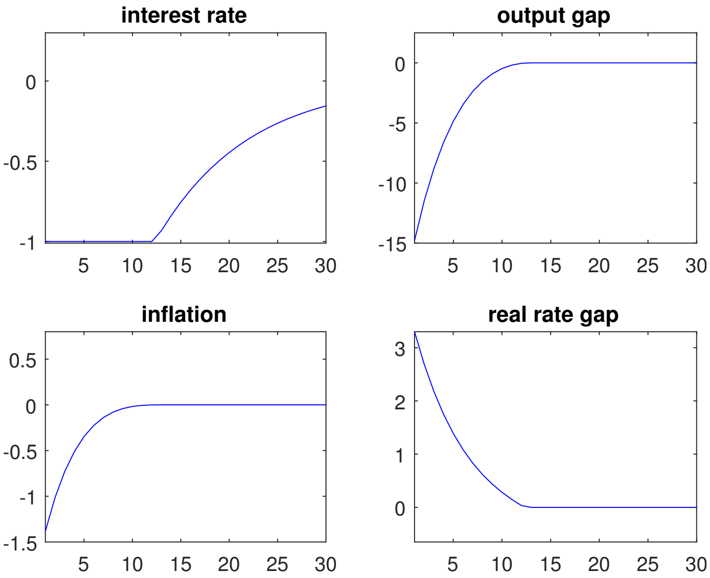
Part I: Optimal Policy at the ZLB

- assume a natural rate shock r_t with persistence $\rho = 0.9$.
- benchmark Taylor rule: $i_t = max(r_t + 1.5\pi_t + 0.5y_t, ZLB)$
- prices are fixed on average for about 7 quarters $\varphi = 0.85$
- other parameters also standard

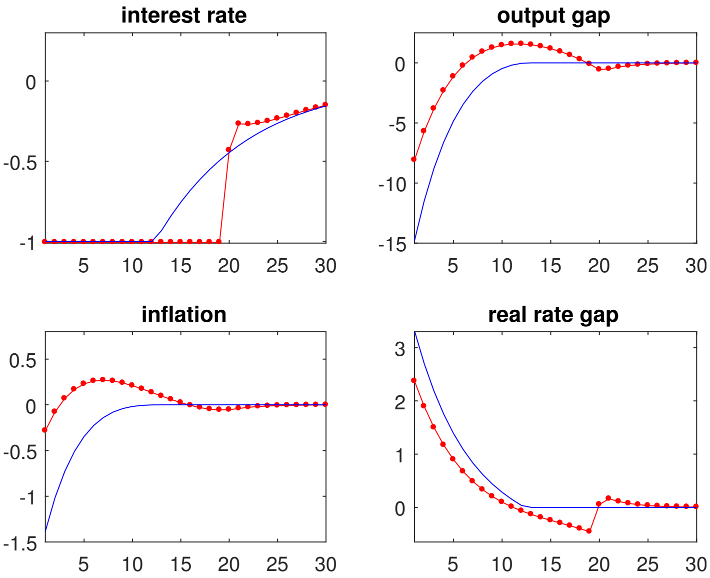
Compute optimal policy with commitment

- central bank loss function $\mathcal{L} = \sum_{j=0}^{\infty} \beta^j \left(\pi_{t+j}^2 + \alpha y_{t+j}^2 \right)$
- CASE 1: welfare based weight ($\alpha \sim 0.0025$)
- CASE 2: equal weight ($\alpha = 1$)

The benchmark outcome under a Taylor rule



Optimal policy with rational expectations



Model under level-k thinking

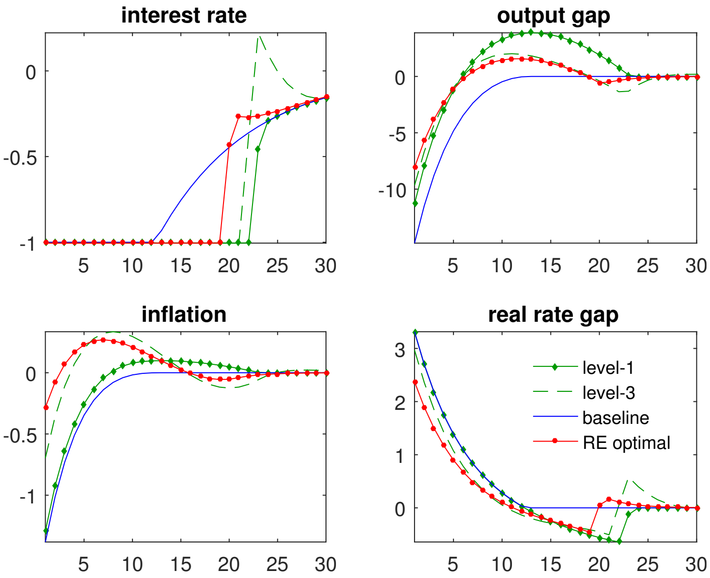
Recursions for updating beliefs:

$$y_t^k = \sum_{s=0}^{\infty} \beta^s [(1-\beta) y_{t+1+s}^{k-1} - \frac{1}{\sigma}(i_{t+s} - r_{t+s} - \pi_{t+1+s}^{k-1})]$$

$$\pi_t^k - \kappa y_t^k = \sum_{s=0}^{\infty} (\beta\varphi)^s \left[\beta(1-\varphi)\pi_{t+1+s}^{k-1} + \kappa\beta\varphi y_{t+1+s}^{k-1}\right]$$

- initialize beliefs at RE under baseline Taylor rule
- this initialization makes for a fair comparison with RE
- policymaker knows how private sector forms belief and set policy optimally under commitment

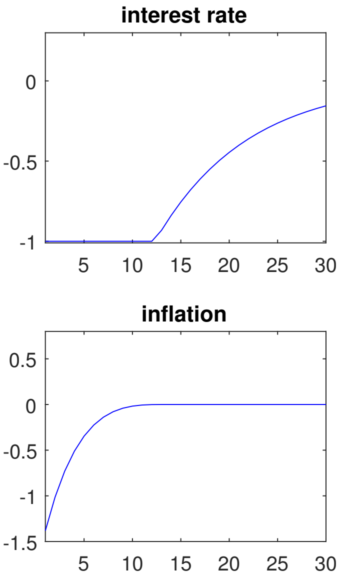
Optimal policy with level 1 and 3 thinking



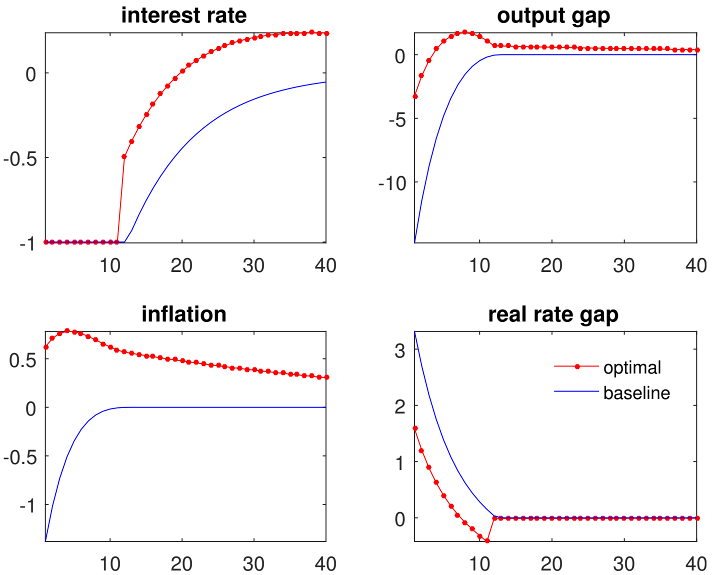
Discussion of CASE 1

- both settings give qualitatively similar results
- prescription is to delay liftoff relative to Taylor rule
- improvements in π and y smaller under level-k
- required stay at the ZLB is longer than under RE
- "*central bankers need to work harder*"
- consistent with Nakata (2018) work on ueber discounting

CASE 2: equal weights, same Taylor rule benchmark



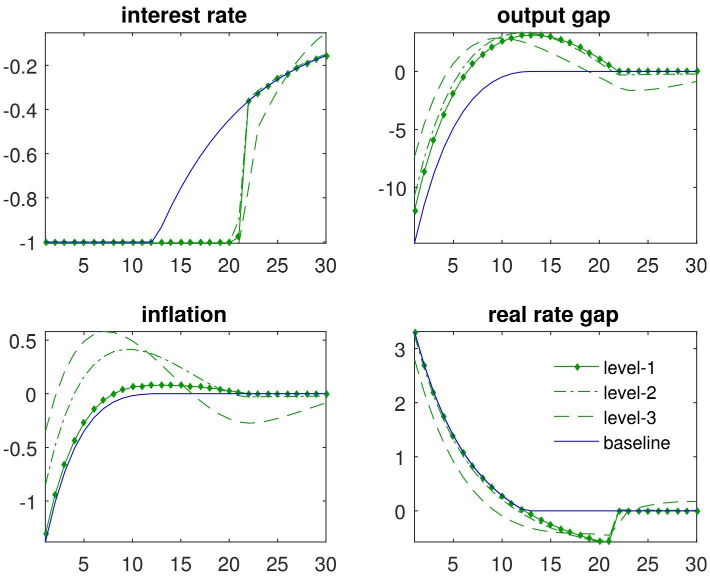
Optimal policy under RE with equal weights



Discussion of Case 2

- optimal policy has a neo-Fisherian flavor
- liftoff from ELB occurs earlier than under Taylor rule
- nominal rate is higher post liftoff than under simple rule
- but real interest rate is lower
- lower real rate stimulates demand and raises inflation
- higher expected inflation raises nominal rate
- prescription at odds with policy seen in practice
- instantaneous move in inflation expectations crucial

Optimal policy under level 1-3 thinking (equal weights)



Discussion

- optimal policy stays at ZLB "lower for longer"
- delay in liftoff date not very sensitive to level k
- no neo-Fisherian feature
- macro outcomes worse than under RE
- worsening is substantial for low level of k

Convergence to rational expectations for high k?

- yes, level-k converges to RE for high k
- that was surprising to me - why?
- RE interest rate path is above Taylor rule
- any uniformly higher rate path achieves worse outcomes
- but .... under RE, interest rate is below baseline in $T = 100$
- monetary easing in final period is tiny, but crucial
- Neo-Fisherian feature is entirely Keynesian

Part II: The reversal puzzle

- Adding indexation to past inflation to the model
- Under arbitrary expectations, Phillips curve given by

$$
\begin{aligned}
p_t^* + \pi_t =& (1-\beta\varphi)\mathbf{E}_t \sum_{s=0}^{\infty} (\beta\varphi)^s [\pi_{t+s} + (\omega + \sigma^{-1}) y_{t+s}] \\
p_t^* =& \frac{\varphi}{1-\varphi}(\pi_t - \pi_{t-1}),
\end{aligned}
$$

- p_t^* is price of adjusting firms relative to aggregate price index
- with RE this amounts to well known Phillips curve

$$\pi_t = \frac{1}{1+\beta}\pi_{t-1} + \frac{\beta}{1+\beta}\mathbb{E}_t \pi_{t+1} + \frac{1}{1+\beta}\kappa y_t \tag{7}$$

The policy experiment - time dependent forward guidance

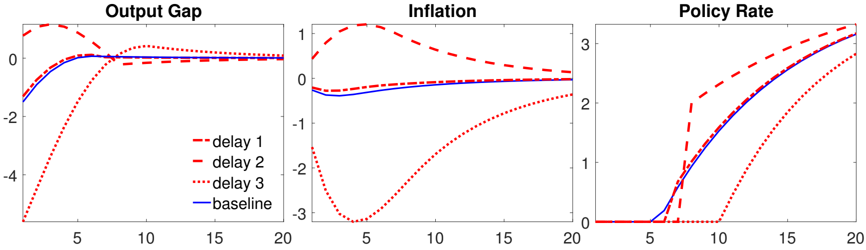
- adverse demand shock drives the economy to ZLB
- stay at ZLB for t^* periods under Taylor rule
- delay liftoff for additional k periods
- return to Taylor rule from period $t^* + k + 1$ onwards
- central bank announces the following interest rate rule:

$$i_t = \begin{cases} ZLB & t = 1, 2, ..., t^*.t^{*+1}, ..., t^{*+k} \\ max(ZLB, r_t + \phi_\pi \pi_t + \phi_y y_t) & t \geq t^{*+k+1} \end{cases}$$

- calibration: $\phi_\pi = 1.5$ and $\phi_y = 0.5$
- initial innovation is $r_1 = -0.015$

Reversal puzzle

- stay at ZLB for 5 quarters under Taylor rule (blue)
- delay liftoff by 1,2,3 quarters

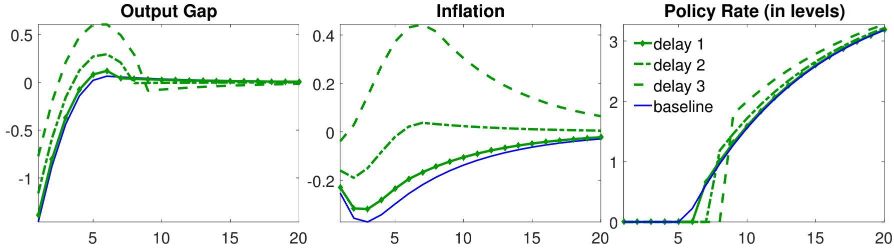


Reversal puzzle

- common sense says that delay in liftoff should be stimulative
- this is true for short delay by 1 and 2 quarters
- delay by 3 quarters is contractionary !
- hence ZLB is binding for longer, have to delay by 5 quarters
- see in Carlstrom, Fuerst, Paustian JME (2015)
- would the same reversal occur with level-k thinking?

Level-2 thinking

delayed liftoff by 1, 2, and 3 quarters:



qualitatively similar results for higher levels

Discussion

- no reversal puzzle with level-k thinking
- level-k converges to RE for small delay (conventional case)
- level-k does not converge to RE for large delay (perverse case)
- macro effect of delay grows without bound as k increases
- bottom line: can discard reversal puzzle as implausible
- feature not shared by bounded rationality even in the limit

Part III: Fiscal multiplier with constant interest rates

- fiscal multiplier can be large under an interest rate peg
- mechanism is well understood, but magnitude is surprising
  - in Christiano et. al. (2011) simple model fiscal multiplier is 3.7
  - same parametrization but with separable preferences it is 4.9
- how sensitivity is the multiplier to bounded rationality (BR)?

Answer:

- when RE multiplier is huge, BR multiplier very different.
- when RE multiplier is modest, BR multiplier is more similar.

The experiment

We follow Christiano et. al (2011), use three equation NK model

- model a joint monetary-fiscal expansion regime
- i.e. regime with fixed rates and high government spending
- p is the probability of being in an expansion regime
  - regime continues with probability p
  - exits with probability $1 - p$ into an absorbing state
  - after exit, we are back in steady state
  - expected duration the regime is $T = \frac{1}{1-p}$
- $p < p^*$: determinate case ("fundamental equilibrium")
- $p > p^*$: indeterminate case ("expectations driven trap")

The model

Under arbitrary expectations, model is given by

$$c_t = \mathbf{E}_t \sum_{s=0}^{\infty} \beta^s p^{s+1} [(1-\beta) c_{t+1+s} - \frac{1}{\sigma}(i_{t+s} - \pi_{t+1+s})]$$

$$\pi_t = \mathbf{E}_t \sum_{s=0}^{\infty} (\beta\varphi)^s \left[p^{s+1} \beta (1-\varphi) \pi_{t+1+s} + p^s \kappa (\sigma c_{t+s} + \omega^{-1} y_{t+s}) \right]$$

$$y_t = (1-s) c_t + s g_t$$

Under RE we have :

$$\begin{aligned} i_t - pE_t \pi_{t+1} &= -\sigma (c_t - p\mathbb{E}_t c_{t+1}) \\ \pi_t &= \beta p \mathbb{E}_t \pi_{t+1} + \kappa m c_t \\ m c_t &= \sigma c_t + \omega^{-1} y_t \\ y_t &= (1-s) c_t + s g_t \end{aligned}$$

Rational expectations multiplier

Under RE, fiscal multiplier during the peg is given by:

$$\frac{dY}{dG} \equiv \left(\frac{1}{s}\right)\frac{dy_t}{dg_t} = \left[\frac{\sigma\left[(1-p)(1-\beta p)-\kappa p\right]}{\Delta}\right]$$

where

$$\Delta \equiv \sigma(1-p)(1-\beta p) - \kappa\left[\sigma + \omega^{-1}(1-s)\right]p.$$

Unique stable equilibrium whenever $\Delta > 0$.
$\beta =$ 0.99, $\kappa = 0.028$, $\omega^{-1} = 0.5$, $\sigma = 2$, $s = 0.2$ and $p = 5/6$.
Under this calibration, fiscal multiplier is 4.9

Fiscal Multiplier under level-k thinking: $p = 5/6$

level-k	1	2	5	10	50	100	200	500
multiplier (% of RE)	1 (20)	1.03 (20)	1.2 (24)	1.46 (30)	3.02 (62)	4.02 (82)	4.7 (96)	4.9 (100)

- convergence to RE is extremely slow
- when RE multiplier is huge, BR multiplier is plausible

Fiscal Multiplier under level-k thinking: $p = 0.8$

level-k	1	2	5	10	50
multiplier (% of RE)	1 (77)	1.02 (78)	1.14 (88)	1.24 (95)	1.3 (100)

- convergence to RE is much faster
- when RE multiplier is plausible, BR multiplier is similar

An expectations driven trap

- Mertens and Ravn (2014) focus on expectations driven trap
- use non-linear NK model, but nonlinearity is really minor
- when $p > p^*$, model is indeterminate
- sunspot equilibria (pessism) can bring us to ZLB
- how large is fiscal multiplier in expectations driven trap?
- Mertens and Ravn (2014) focus on MSV solution under RE
- under level-k, equilibrium unique for given initial belief

Fiscal multiplier as a function of p

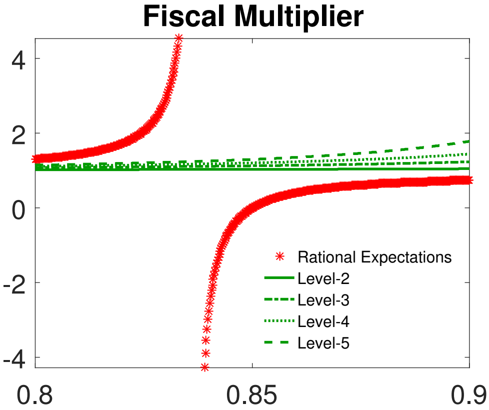


Figure: Fiscal multiplier as a function of the probability p

Conclusion

Expectations formation matter! Level-k thinking does...

- ... support *lower for longer* strategies at ZLB
- ... not support neo-Fisherian strategies
- ... not support worries about reversals
- ... suggest fiscal multipliers at ZLB only mildly $>$1
- ... not suggest fiscal policy less effective in expectations trap