Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound

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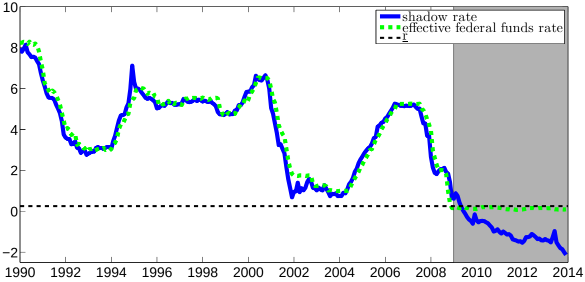
Key question

What is the macroeconomic impact of monetary policy at the ZLB?

Conventional approach before ZLB

- VAR with the fed funds rate

But since December 2008, the fed funds rate has been near zero



Challenges of zero lower bound

Challenges

- Conventional monetary policy doesn't work. Fed has implemented unconventional policy tools
  - large-scale asset purchases
  - forward guidance
- What framework to study unconventional monetary policy?
- Gaussian ATSM allows negative interest rates

Shadow rate term structure model: Black (1995)

- Non-negative short rate: $r_t = max(\underline{r}, s_t)$
- Analytical solution does not exist in general

Contributions

This paper

- an analytical approximation for SRTSM

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- an analytical approximation for SRTSM
- shadow rate has similar dynamic correlations with macro variables as the fed funds rate did previously
- our shadow rate updated monthly by Atlanta Fed
  www.frbatlanta.org/cqer/researchcq/shadow_rate.cfm

Outline

1. Model
2. Shadow rate
3. Macroeconomic Implications
4. Conclusion

Bond pricing

Risk-neutral factor dynamics:

$$X_{t+1} = \mu^{\mathbb{Q}} + \rho^{\mathbb{Q}} X_t + \Sigma \varepsilon^{\mathbb{Q}}_{t+1}, \quad \varepsilon^{\mathbb{Q}}_{t+1} \overset{\mathbb{Q}}{\sim} N(0, I).$$

Pricing kernel

Pricing equation

$$P_t^n = \mathbb{E}_t^{\mathbb{Q}}[\exp(-r_t - r_{t+1} - \ldots - r_{t+n-1})]$$

Yield

$$y_t^n = -\frac{1}{n}\log(P_t^n)$$

Forward rate

$$f_{n,n+1,t} = (n+1)y_{n+1,t} - ny_{nt}$$

SRTSM and GATSM

SRTSM

$$\begin{aligned} r_t &= max(\underline{r}, s_t) \\ s_t &= \delta_0 + \delta_1' X_t \end{aligned}$$

Forward rate

$$f^{SRTSM}_{n,n+1,t} = \underline{r} + \sigma^{\mathbb{Q}}_n g\left(\frac{a_n + b_n' X_t - \underline{r}}{\sigma^{\mathbb{Q}}_n}\right)$$

where $g(z) = z\Phi(z) + \phi(z)$

▸ a_n, b_n

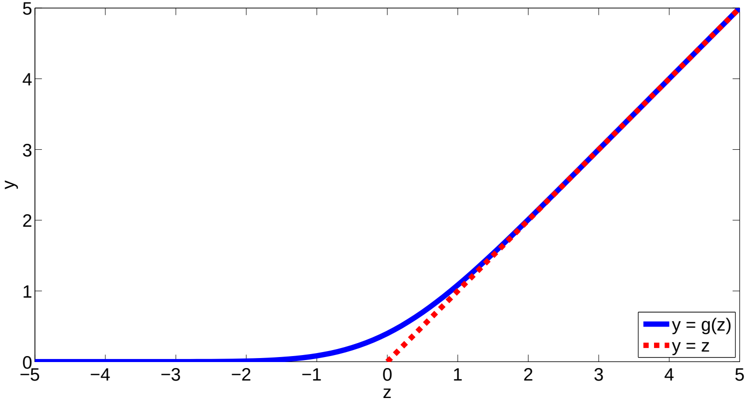
GATSM

$$r_t = \delta_0 + \delta_1' X_t$$

Forward rate

$$f^{GATSM}_{n,n+1,t} = a_n + b_n' X_t.$$

Property of $g(.)$



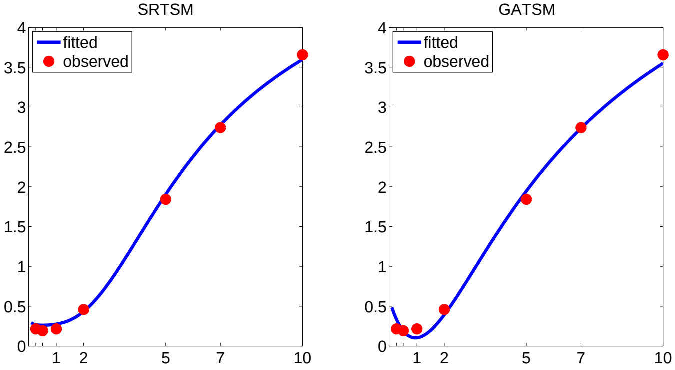
$$f^{SRTSM}_{n,n+1,t} \begin{cases} \approx \underline{r}, \text{ at the ZLB} \\ \approx a_n + b'_n X_t = f^{GATSM}_{n,n+1,t}, \text{ when interest rates are high} \end{cases}$$

Model fit

GSW Data: monthly 1990-2013; maturities: 3m, 6m, 1y, 2y, 5y, 7y, 10y
Estimation: Kalman filters ▸ details
Log likelihood values ▸ specification

- SRTSM: 850; GATSM: 750

Figure: Average forward curve in 2012



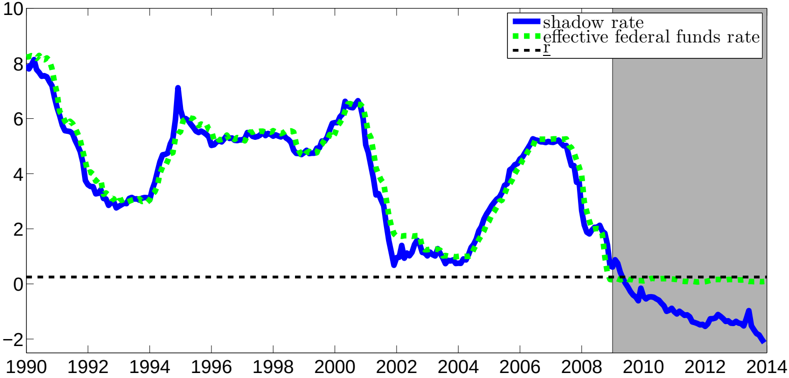
Approximation error

Average absolute approximation error between 1990M1 and 2013M1

	3M	6M	1Y	2Y	5Y	7Y	10Y
forward rate error	0.01	0.02	0.04	0.13	0.69	1.14	2.29
forward rate level	346	357	384	435	551	600	636
yield error	0.00	0.01	0.01	0.04	0.24	0.42	0.78

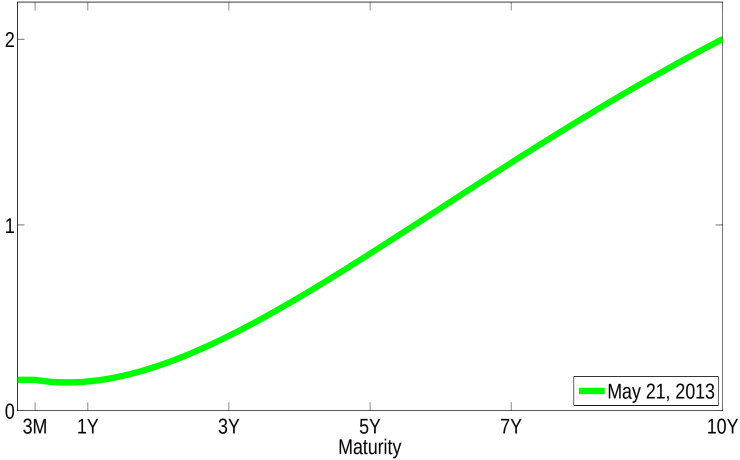
ZLB

Shadow rate

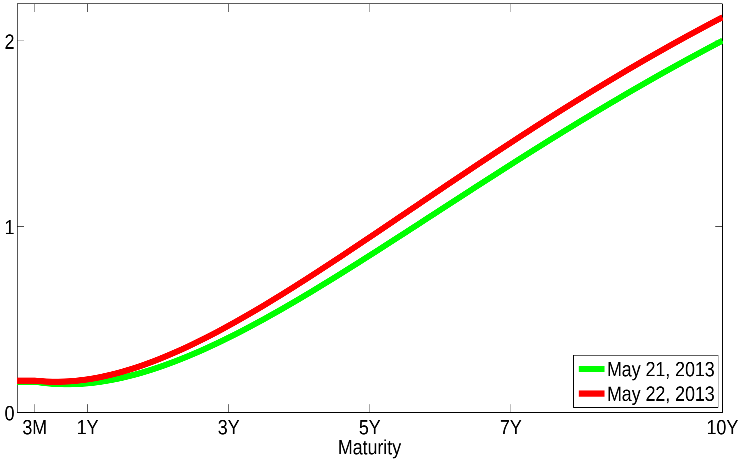


Summary for unconventional monetary policy?

Yield curve on May 21, 2013

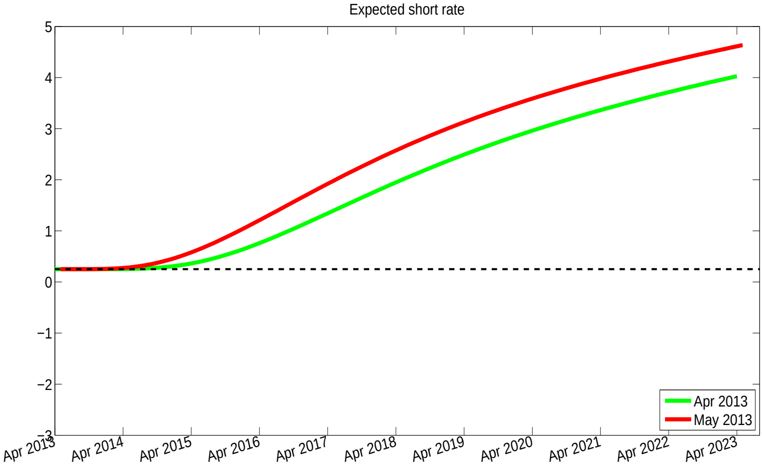


Hint of tapering (yield)



May 22: Bernanke tells Congress Fed may decrease the size of monthly large-scale asset purchases

Hint of tapering (forward rate)



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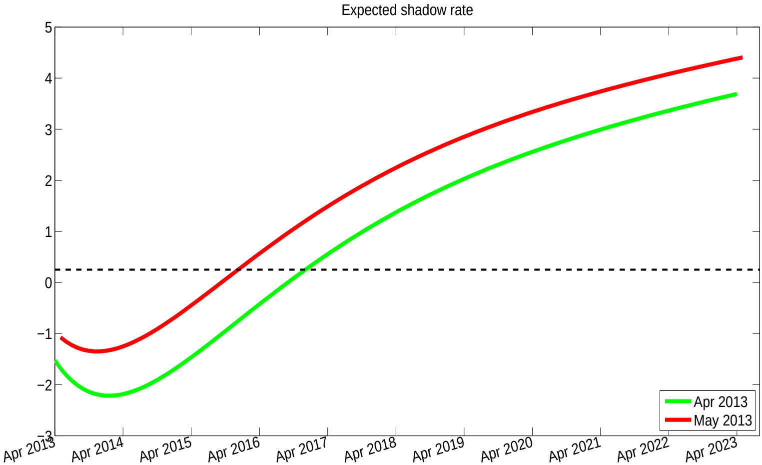
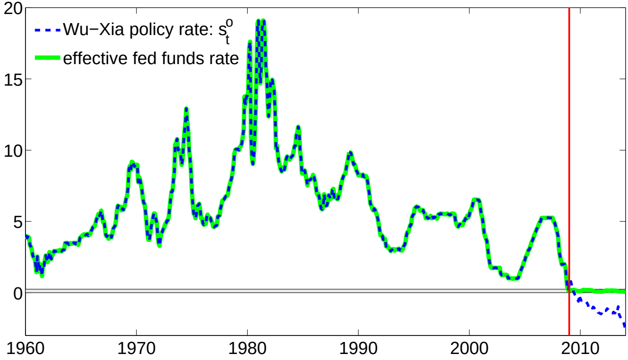
Shift in shadow rate might summarize the effect



Monetary policy



$$s_t^o = \begin{cases} \text{effective federal funds rate} & \text{before 2009} \\ \text{shadow rate} & \text{since 2009} \end{cases}$$

Can we use shadow rate as similar summary of Fed actions as fed funds rate provided historically?

Factor augmented vector autoregression

Replace the fed funds rate with s_t^o in Bernanke, Boivin, and Eliasz (2005)

$$Y_t^m = a_m + b_x x_t^m + b_s s_t^o + \eta_t^m, \quad \eta_t^m \sim N(0, \Omega)$$

- Y_t^m: 97 economic variables from 1960 to 2013
- x_t^m: 3 underlying macro factors

Factor dynamics:

$$\begin{bmatrix} x_t^m \\ s_t^o \end{bmatrix} = \begin{bmatrix} \mu^x \\ \mu^s \end{bmatrix} + \begin{bmatrix} \rho^{xx} & \rho^{xs} \\ \rho^{sx} & \rho^{ss} \end{bmatrix} \begin{bmatrix} X_{t-1}^m \\ S_{t-1}^o \end{bmatrix} + \Sigma^m \begin{bmatrix} \varepsilon_t^m \\ \varepsilon_t^{\mathrm{MP}} \end{bmatrix}, \quad \begin{bmatrix} \varepsilon_t^m \\ \varepsilon_t^{\mathrm{MP}} \end{bmatrix} \sim N(0, I)$$

- monthly VAR(13)
- Σ^m: Cholesky decomposition

Measures of monetary policy

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Hypothesis I

$$H_0 : \rho^{xs}(t < \text{Great Recession}) = \rho^{xs}(t > \text{Great Recession})$$

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Hypothesis II

$$H_0 : \rho^{sx}(t < \text{Great Recession}) = \rho^{sx}(t > \text{Great Recession})$$

- $p = 1$ for s_t^o
- $p = 1$ for EFFR

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Implication: researchers can use shadow rate to update earlier studies that had been based on the historical fed funds rate.

Robustness

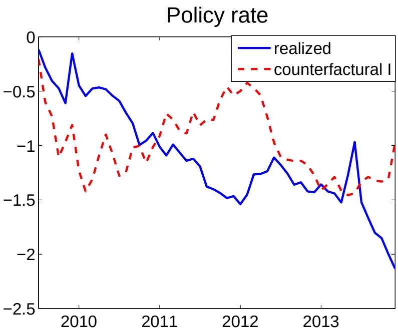
Historical decomposition

What if there had been no monetary policy shocks?

- realized: $\varepsilon_t^{\mathrm{MP}} = \hat{\varepsilon}_t^{\mathrm{MP}}$
- counterfactual: $\varepsilon_t^{\mathrm{MP}} = 0$ for ZLB

Unconventional monetary policy

- reduced the shadow rate by 0.4% between 2011 and 2013.



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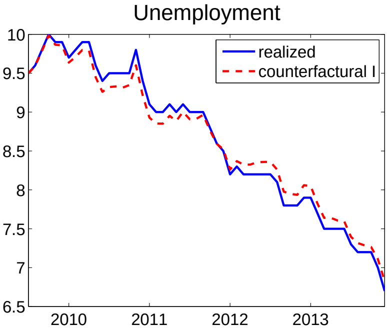
Unconventional monetary policy

- reduced unemployment by 0.13% in Dec 2013. More



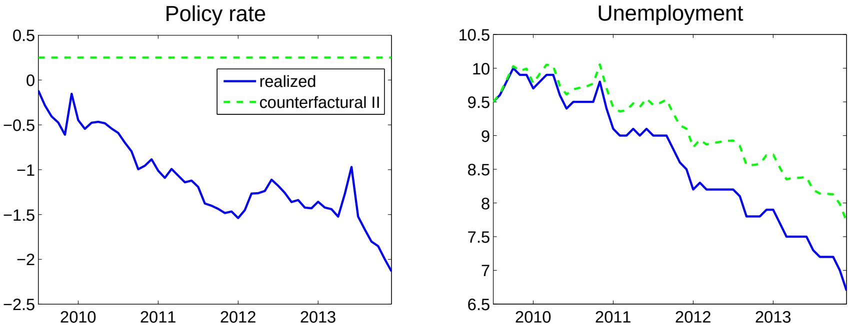
Counterfactual II

What if the shadow rate had been kept at $\underline{r}$?

- counterfactual: $\varepsilon_t^{\mathrm{MP}}$ is such that $s_t^o = \underline{r}$ at ZLB

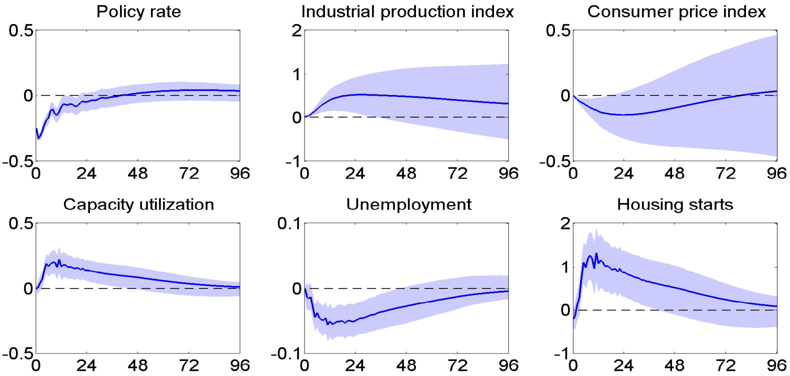
Unconventional monetary policy

- reduced unemployment by 1% in December 2013 ▸ More



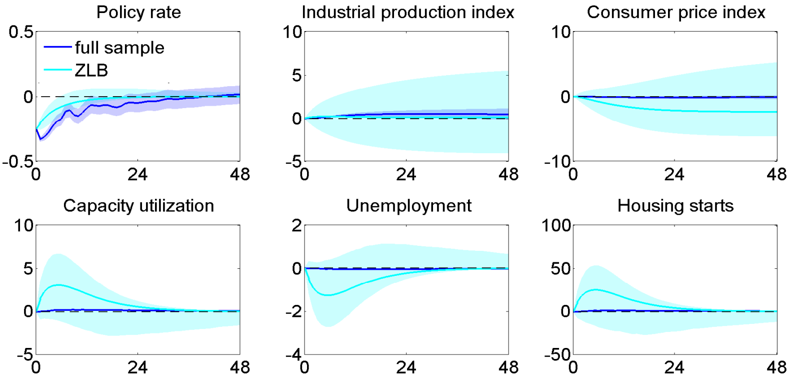
Impulse resposne: full sample

A -25bps monetary policy shock



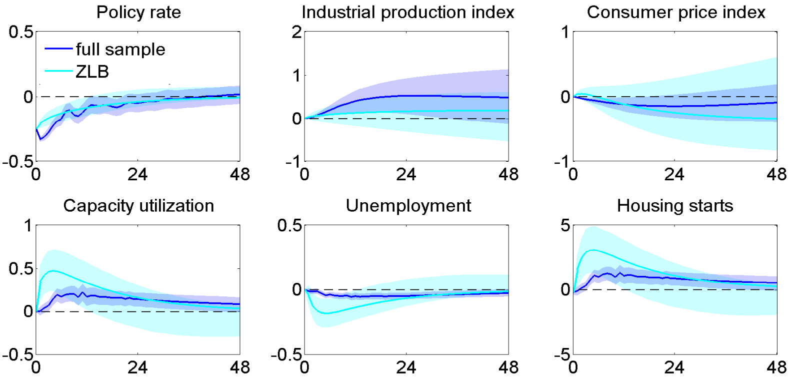
Full sample FAVAR(13) vs. ZLB FAVAR(1)

ZLB with effective federal funds rate



Full sample FAVAR(13) vs. ZLB FAVAR(1)

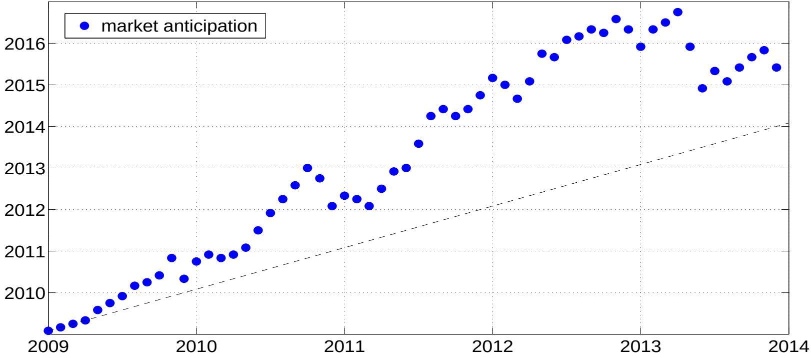
ZLB with shadow rate



Forward guidance

ZLB duration

$$\tau_t = \inf\{\tau_t \geq 0 | s_{t+\tau} \geq \underline{r}\}.$$



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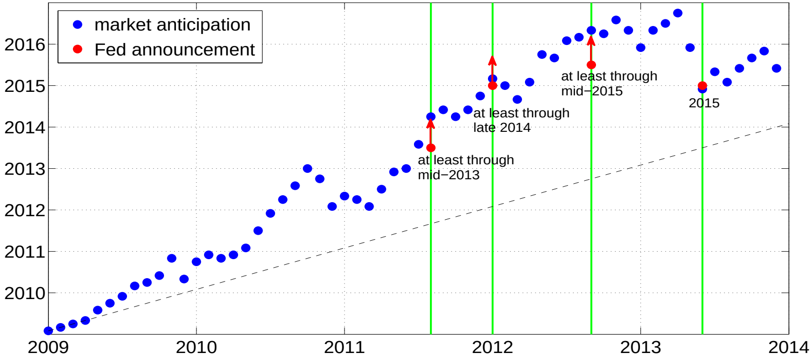


Impulse responses

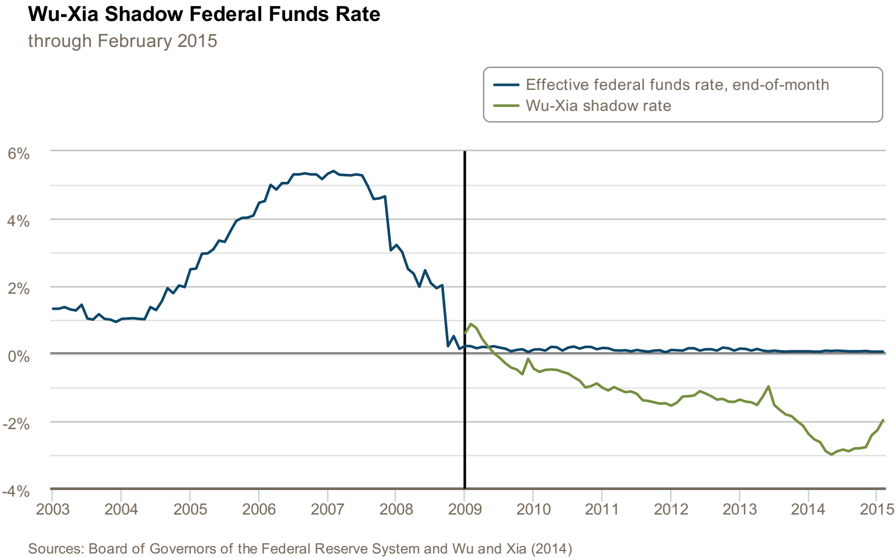
Conclusion

Method

- Develop an approximation for bond prices in the SRTSM

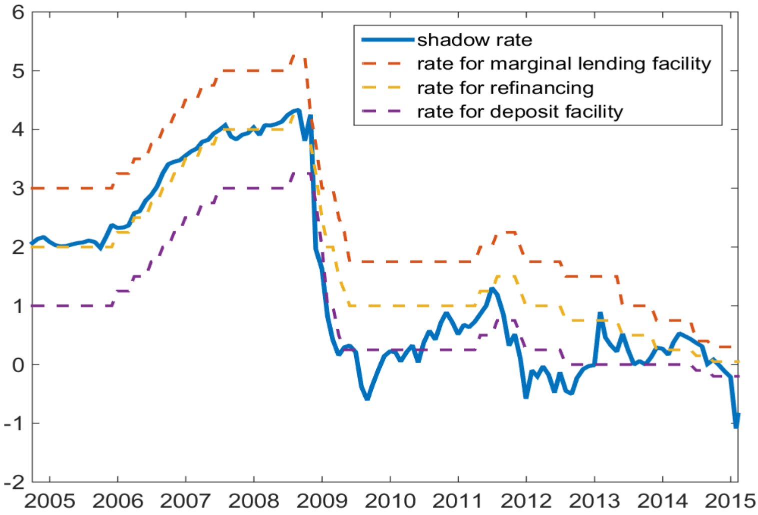
Economics

- The shadow rate exhibits similar dynamic correlations with economic variables after the Great Recession as the fed funds rate did earlier in data.
- Unconventional monetary policy lowered the unemployment rate by 0.13% in December 2013.



Source: `www.frbatlanta.org/cqer/researchcq/shadow_rate.cfm`

ECB shadow rate



Pricing kernel

Factor dynamics:

$$X_{t+1} = \mu + \rho X_t + \Sigma \varepsilon_{t+1}, \quad \varepsilon_{t+1} \sim N(0, I).$$

Pricing kernel

$$m_{t+1} = r_t + \frac{1}{2}\lambda_t' \lambda_t + \lambda_t' \varepsilon_{t+1}$$
$$\lambda_t = \lambda_0 + \lambda_1 X_t$$

where $\mu^{\mathbb{Q}} = \mu - \Sigma\lambda_0$, and $\rho^{\mathbb{Q}} = \rho - \Sigma\lambda_1$

Pricing equation

$$P_t^n = \mathbb{E}_t[\exp(-m_{t+1}) P_{t+1}^{n-1}]$$

Back

Bond recursions

$$a_n = \delta_0 + \delta_1' \left(\sum_{j=0}^{n-1} \left(\rho^{\mathbb{Q}}\right)^j \right) \mu^{\mathbb{Q}} - \frac{1}{2} \delta_1' \left(\sum_{j=0}^{n-1} \left(\rho^{\mathbb{Q}}\right)^j \right) \Sigma\Sigma' \left(\sum_{j=0}^{n-1} \left(\rho^{\mathbb{Q}}\right)^j \right)' \delta_1,$$

$$b_n' = \delta_1' \left(\rho^{\mathbb{Q}}\right)^n.$$

Back

Model specification

$\underline{r} = 0.25$, interest rate on reserves

three factors

Normalization: restrict $\mathbb{Q}$ parameters

Repeated eigenvalues

$$\rho^{\mathbb{Q}} = \begin{bmatrix} \rho_1^{\mathbb{Q}} & 0 & 0 \\ 0 & \rho_2^{\mathbb{Q}} & 1 \\ 0 & 0 & \rho_2^{\mathbb{Q}} \end{bmatrix}.$$

▸ Back

Kalman filters

State equation

$$X_{t+1} = \mu + \rho X_t + \Sigma \varepsilon_{t+1}, \varepsilon_{t+1} \sim N(0, I)$$

observation equation for SRTSM ⇒ extended Kalman filter

$$f^o_{n,n+1,t} = \underbrace{\underline{r} + \sigma^{\mathbb{Q}}_n g\left(\frac{a_n + b'_n X_t - \underline{r}}{\sigma^{\mathbb{Q}}_n}\right)}_{f^{SRTSM}_{n,n+1,t}} + \eta_{nt}, \eta_{nt} \sim N(0, \omega)$$

observation equation for GATSM ⇒ Kalman filter

$$f^o_{n,n+1,t} = \underbrace{a_n + b'_n X_t}_{f^{GATSM}_{n,n+1,t}} + \eta_{nt}, \eta_{nt} \sim N(0, \omega)$$

▸ Back

Approximation error for ZLB

Average absolute approximation error between 2009M1 and 2013M1

	3M	6M	1Y	2Y	5Y	7Y	10Y
forward rate error	0.00	0.01	0.06	0.43	2.50	3.51	5.41
forward rate level	23	26	46	111	326	418	481
yield error	0.00	0.00	0.01	0.10	0.91	1.50	2.37

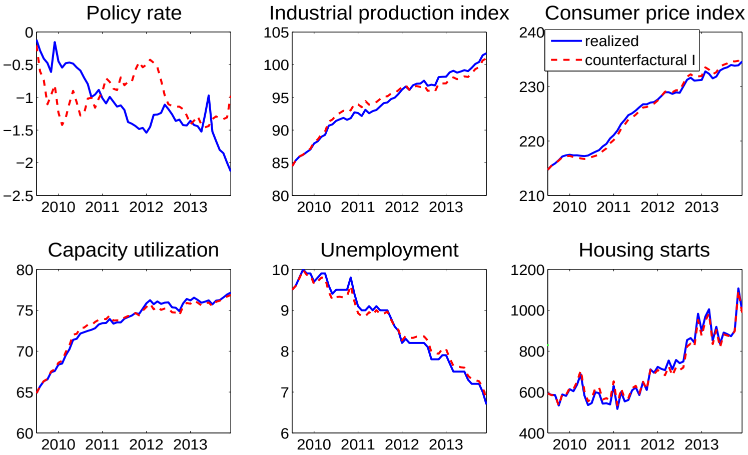
back

Robustness

		p-value for $\rho_1^{xs} = \rho_3^{xs}$	p-value for $\rho_1^{sx} = \rho_3^{sx}$
	Baseline	0.29	1.00
A1	estimate $\underline{r}$	0.18	1.00
A2	2-factor SRTSM	0.13	0.97
A3	Fama-Bliss	0.38	1.00
A4	5-factor FAVAR	0.70	1.00
A5	6-lag FAVAR	0.09	0.98
	7-lag FAVAR	0.19	0.97
	12-lag FAVAR	0.22	1.00

Back

Historical decomposition



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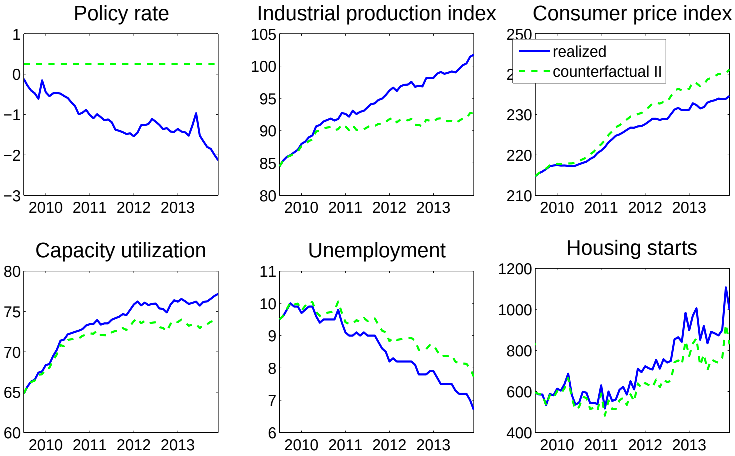
Counterfactual II



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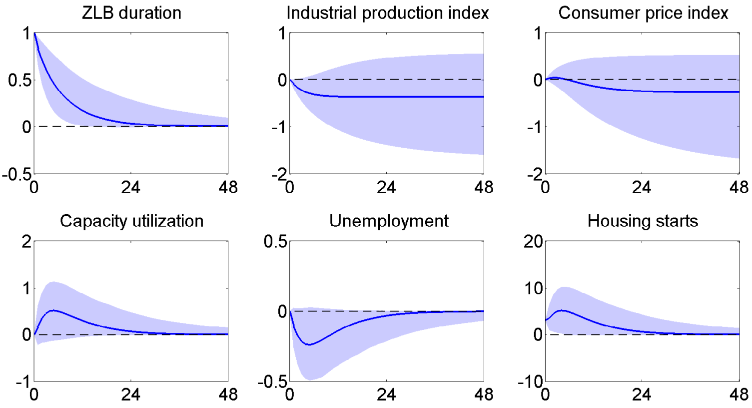
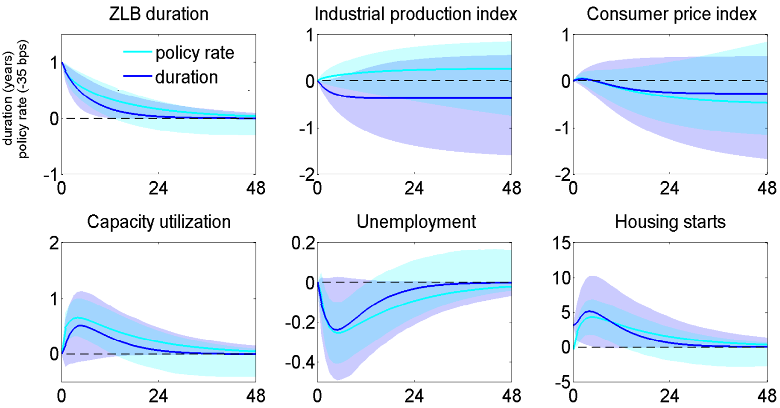
Impulse responses: forward guidance

A monetary policy shock to increase the ZLB by 1 year



Forward guidance vs. shadow rate



Unemployment rate decreases by 0.25% with

- a one year increase in the expected ZLB duration
- 35 basis-point decrease in the policy rate

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