A Survey-based Shadow Rate and Unconventional Monetary Policy Effects

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The Shadow Rate

- After the short rate hit the ZLB, many studies started to estimate the shadow rate, to examine macroeconomic effects of UMP
  - The shadow rate can be negative when the short rate is at the ZLB
- Most common approach uses term structure models (TSM)
  - Ichiue and Ueno (2006, 2007, 2013, 2015), Krippner (2014), and Wu and Xia (2015), among others

A Problem of TSM Approach

- TSM approach assumes that the shadow rate is equal to the short rate when the short rate is positive
- But, this assumption may not be relevant to its use as a monetary policy indicator
- The Fed started to hike the policy rate while keeping its holdings of assets at sizable levels in 2015
- The MP stance may be more accommodative than suggested by the short rate, to the extent that UMP loosens monetary conditions

What We Do

- We propose a novel estimation method using survey forecasts of macroeconomic variables
  – Our shadow rate can deviate from the short rate when the short rate is positive
- We apply this method to U.S. data and examine macroeconomic effects of the Fed's UMP

Preview

- The shadow rate remained negative in 2015-17.
- The shadow spread is negatively correlated with the Fed's holdings of assets, particularly MBSs.
  - A 1%p increase in MBSs/GDP is associated with a more than 0.2%p decline in the shadow spread.
- The shadow spread has a weak relationship with term spreads.
- The peak effect of UMP on inflation is 0.5%p.

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3. METHOD AND DATA

An Illustrative Example

- A reduced-form VAR (1) with known parameters

$$\begin{bmatrix} z_t \\ s_t \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} z_{t-1} \\ s_{t-1} \end{bmatrix} + \begin{bmatrix} e_t^z \\ e_t^s \end{bmatrix}$$

- The optimal 1-period-ahead VAR forecast:

$$z_{t+1|t} = a_{11} \cdot z_t + a_{12} \cdot s_t$$

- The survey-based shadow rate:

$$s_t = \frac{z_{t+1|t} - a_{11} \cdot z_t}{a_{12}}$$

Data

- 1983Q1-2017Q4
- Actual data
  - GDP
  - GDP deflator
  - 3M TB rate (end of Q; -2008Q3)
- Macroeconomic survey forecasts
  - Blue Chip Economic Indicators (BCEI) report forecasts of Q/Q GDP growth and GDP deflator inflation
  - Quarterly data are constructed by assuming 1-month lag of information
  - Available until the end of next year (from 1Q- to 4-7Q-ahead)

State Space Model

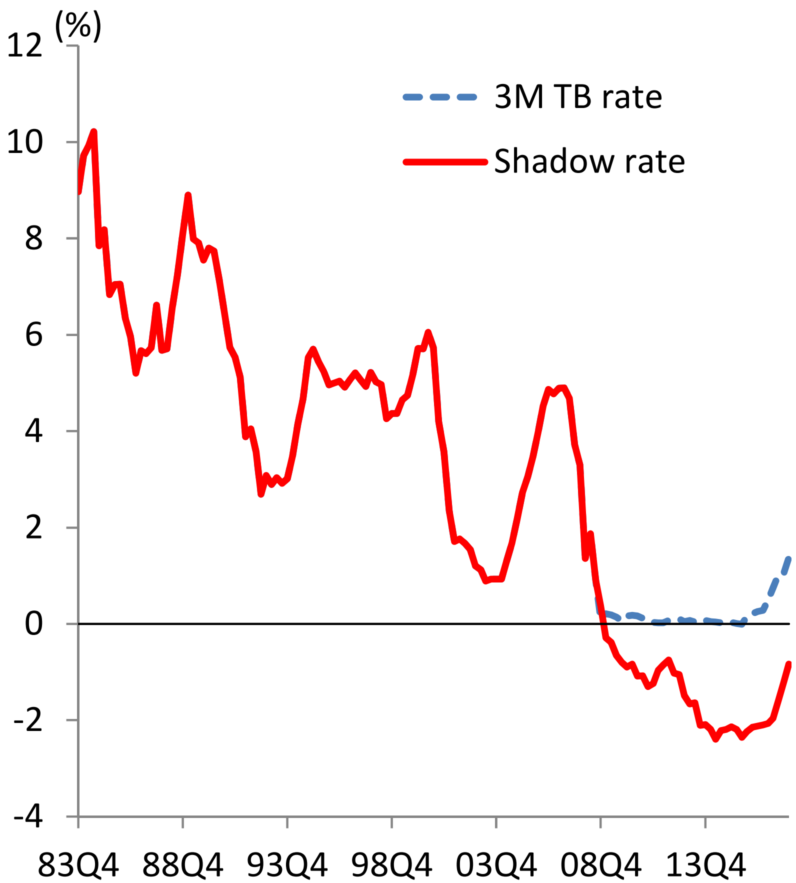
- State equation
  - VAR(4)
  - log GDP, log GDP deflator, and shadow rate
- Observation equation
  - TB rate = Shadow rate, until 2008Q3
  - BCEI forecast = VAR forecast + error
  - 15 observation equations (TB rate, 7 growth forecasts, and 7 inflation forecasts)
  - Observations errors are uncorrelated to each other

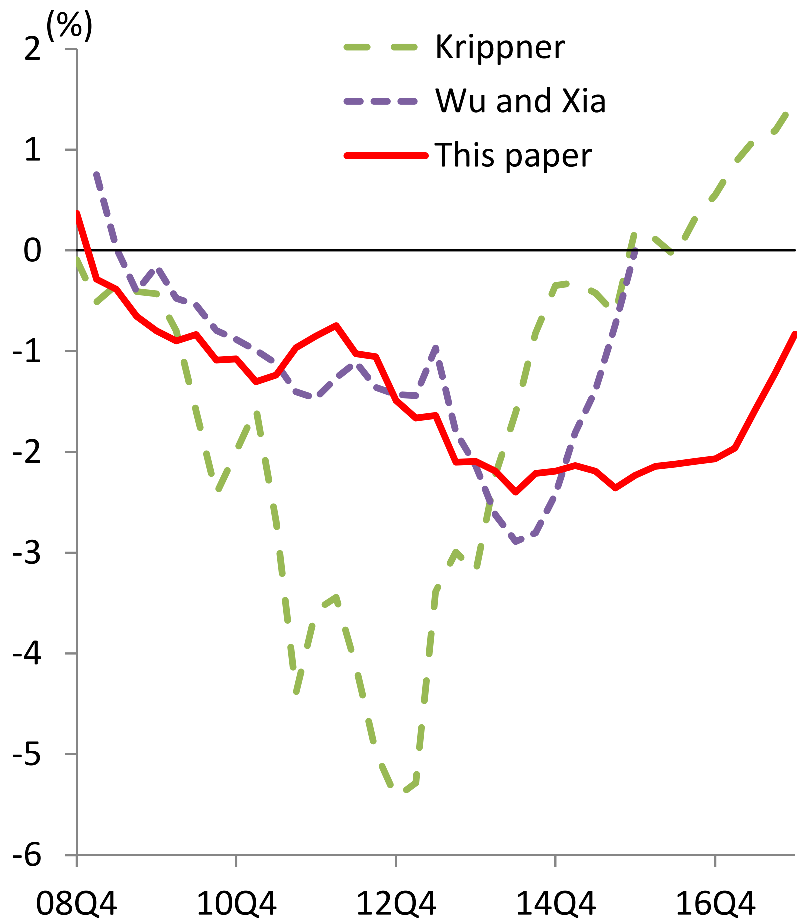
Estimation

- 2-step Estimation
  - First, we estimate the VAR, using data until 2008Q3
  - Second, given the VAR parameters, we estimate the shadow rate as well as the variances of observation errors, by applying the Kalman filter to the state space model

4. THE SHADOW RATE AND ITS PROPERTIES

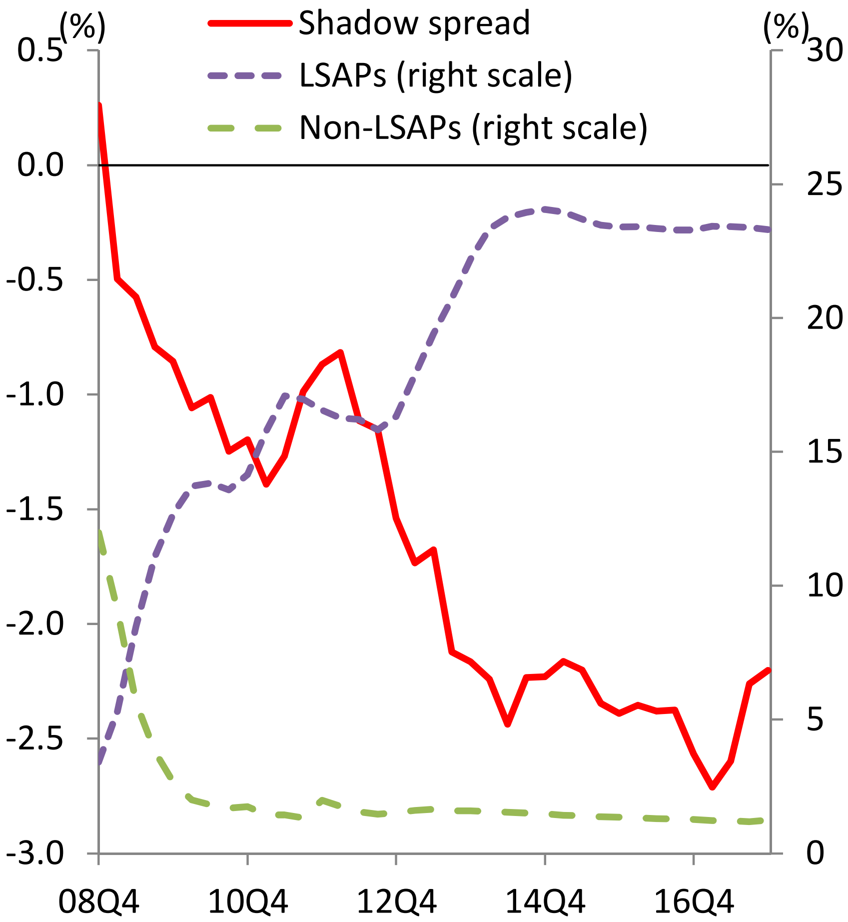
Estimated Shadow Rate

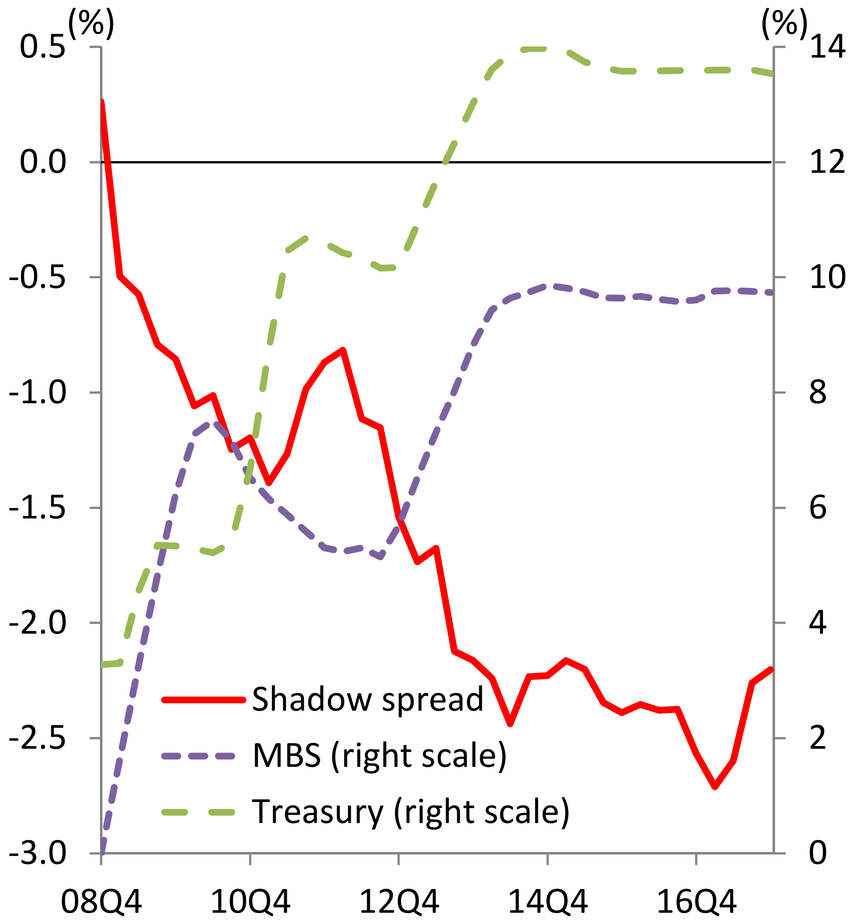




Note: Wu and Xia's in 2015Q4 is that in November, 2015.

Shadow Spread and Fed's Asset Holdings/GDP



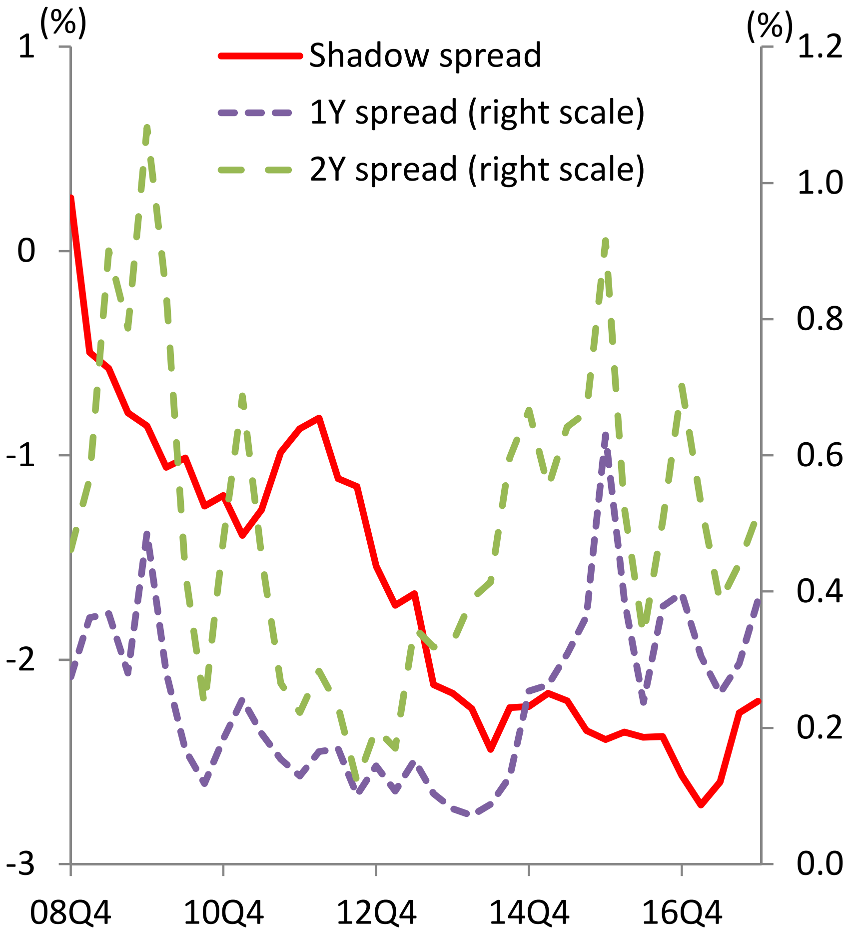


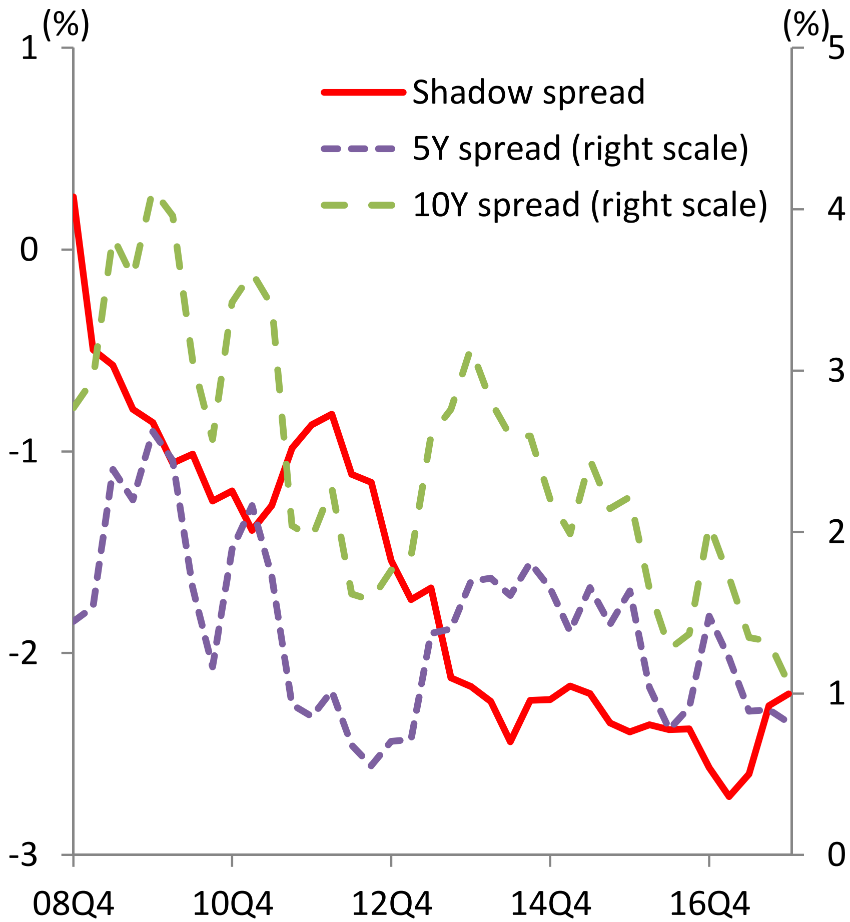
Regressions of the Shadow Rate on Asset Holdings/GDP

	(1)		(2)	
LSAPs	-0.145	**		
Non-LSAPs	-0.051			
Treasury			-0.088	**
MBS			-0.227	**
Other			-0.056	
Adjusted R-squared	0.884		0.913	
Durbin-Watson statistics	0.644		0.784	

Note: The observation period is 2008Q4-2017Q4. A constant is included and Newey and West's (1987) standard errors are used.

Shadow Spread and Treasury Spreads





Regressions of the Shadow Spread on a Term Spread

Maturity (years)	1	2	5	10
Treasury	-0.091 **	-0.086 **	-0.073 **	-0.068 **
	(0.021)	(0.023)	(0.026)	(0.025)
MBS	-0.214 **	-0.231 **	-0.252 **	-0.241 **
	(0.046)	(0.047)	(0.051)	(0.049)
Other	-0.045	-0.059	-0.069 *	-0.060
	(0.034)	(0.032)	(0.032)	(0.033)
Term spread	-0.335	0.047	0.118	0.094
	(0.235)	(0.121)	(0.079)	(0.051)
Adjusted R-squared	0.913	0.910	0.915	0.917
Durbin-Watson statistics	0.824	0.785	0.836	0.862

Note: The observation period is 2008Q4-2017Q4. A constant is included and Newey and West’s (1987) standard errors are used.

Are Longer-term Yields Useful?

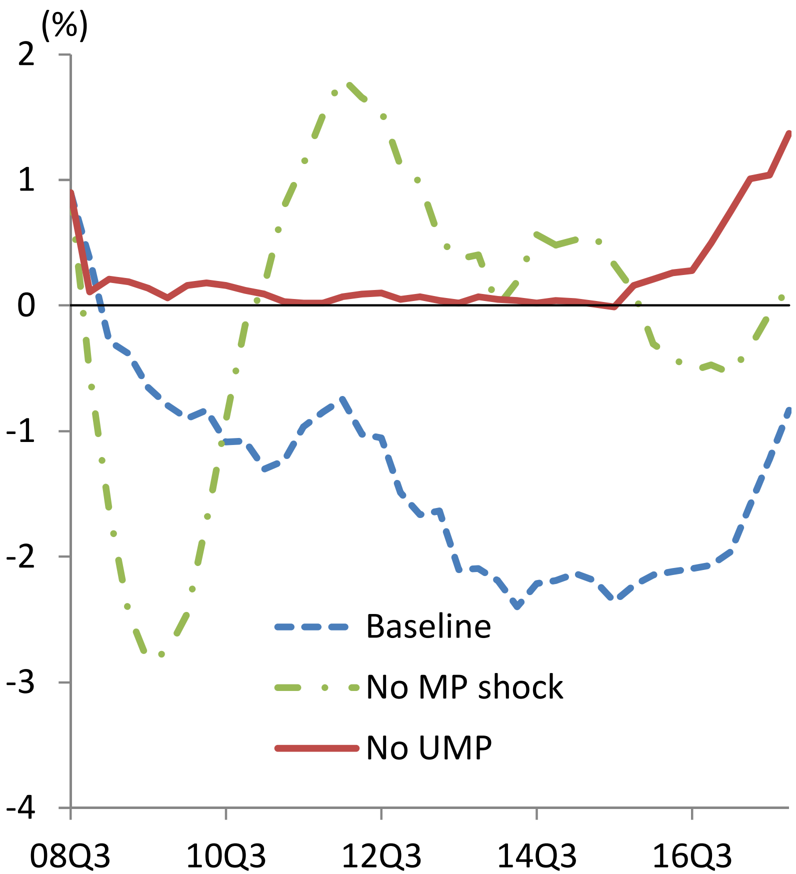
- Forward guidance puzzle
- May not capture asset purchases well
  - Confidence channel
  - More accommodative MP could have upward pressure on longer-term yields through improved expectations (Gertler and Karadi 2013)
- Macroeconomic effects of a lower long-term interest rate is smaller than those of a lower short rate (Chen et al. 2012, Kiley 2014, Stein 2012).
- At times of market stress, longer-term yields may be responsive to UMP, but macro variables may not to longer-term yields

5. EVALUATING UMP

How to evaluate UMP?

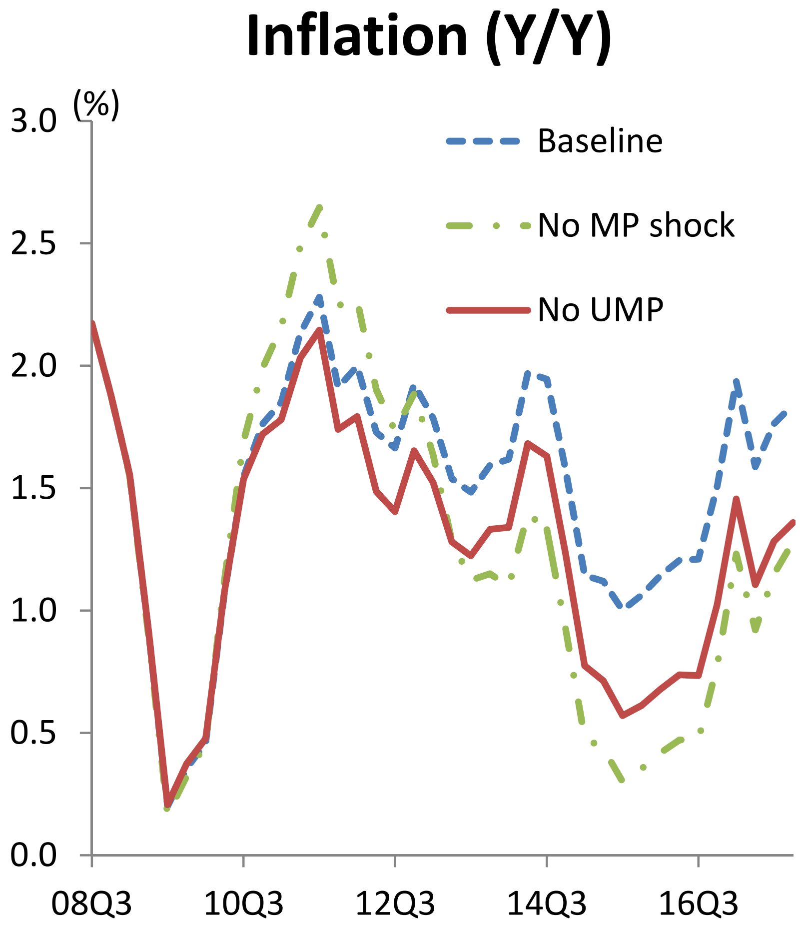
- We use the VAR that is used to estimate the shadow rate
  - Wu and Xia (2015) add the shadow rate estimated from yield data to a VAR
- MP shocks are identified by the standard recursive assumption
- Compare the baseline result with two counterfactual simulations

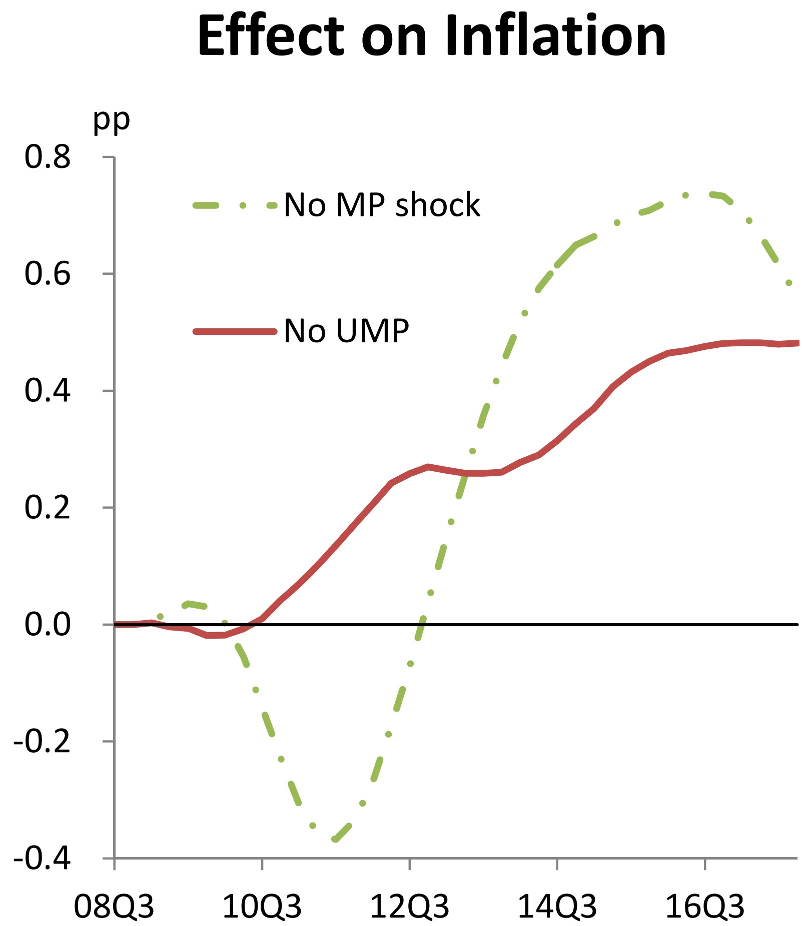
Counterfactual Shadow Rates



- Baseline
  - The estimated shadow rate
- No MP shock
  - Zero MP shocks from 2008Q4
- No UMP
  - Equal to TB3M by adding MP shocks

Simulation of Inflation





6. CONCLUSION

Conclusion

- A novel method to estimate the shadow rate
- On the Fed's UMP
  - The BS policy kept the shadow rate negative in 2015-17 despite the policy rate hikes
  - The policy stance was less accommodative than justified by the economic collapse in 2008-09
  - MBSs held have stronger effects than Treasuries, which is consistent with Krishnamurthy and Vissing-Jorgenson (2011)
  - The peak effect on inflation is 0.5%p, as in Engen et al. (2015)
  - Longer-term interest rates may not be proper to gauge macroeconomic effects of UMP

APPENDIX

Motivation

- Many studies used a short-term interest rate as the MP indicator
  - Empirical studies often used VARs to examine MP effects on output and inflation
- But the short rate no longer summarizes the state of MP because central banks started to rely on UMP after facing the ZLB
- This poses a challenge when examining the macroeconomic effects of MP

Three Existing Approaches

- Many papers estimate a shadow rate by applying nonlinear filtering techniques to Black's (1995) term structure model
  - Ichiue and Ueno (2006, 2007, 2013, 2015), Krippner (2014), and Wu and Xia (2015), among others
- Sugo and Kamada (2006) and Lombardi and Zhu (2014) summarize financial/monetary variables based on the correlations with the policy rate in the pre-ZLB period
- Kitamura (2010) applies the particle filter to a small DSGE

Problems of TSM Approach (2): Nonlinearity

- Nonlinearity is not only a matter of computational burden
- In shadow rate TSM, relative changes in the shadow rate to longer-term yields are generally larger as longer-term yields are closer to their ZLB.
- Wu and Xia (2015) use a VAR, which assumes a linear relationship between the shadow rate and macroeconomic variables.
- Putting these together, they implicitly assume that one unit of change in a macroeconomic variable is associated with a smaller change in longer-term yields as longer-term yields are lower.
- Ichiue and Ueno (2006) also implicitly assume a nonlinear relationship between longer-term yields and the inflation rate.

Other Problems of Existing Approaches

- Financial/monetary variables, including longer-term yields may not have adequate information of UMP.
  - UMP may work on the economy not only via financial/monetary variables (e.g., confidence of households/businesses)
  - UMP may have upward pressure on longer-term yields through improved growth/inflation expectations (Gertler and Karadi 2013)
  - At times of market stress, longer-term yields may be responsive to UMP, but macro variables may not to longer-term yields
- Correlations across monetary/financial variables may have changed.
  - In the pre-ZLB period, the central bank BS was very stable and had little correlation with the policy rate.

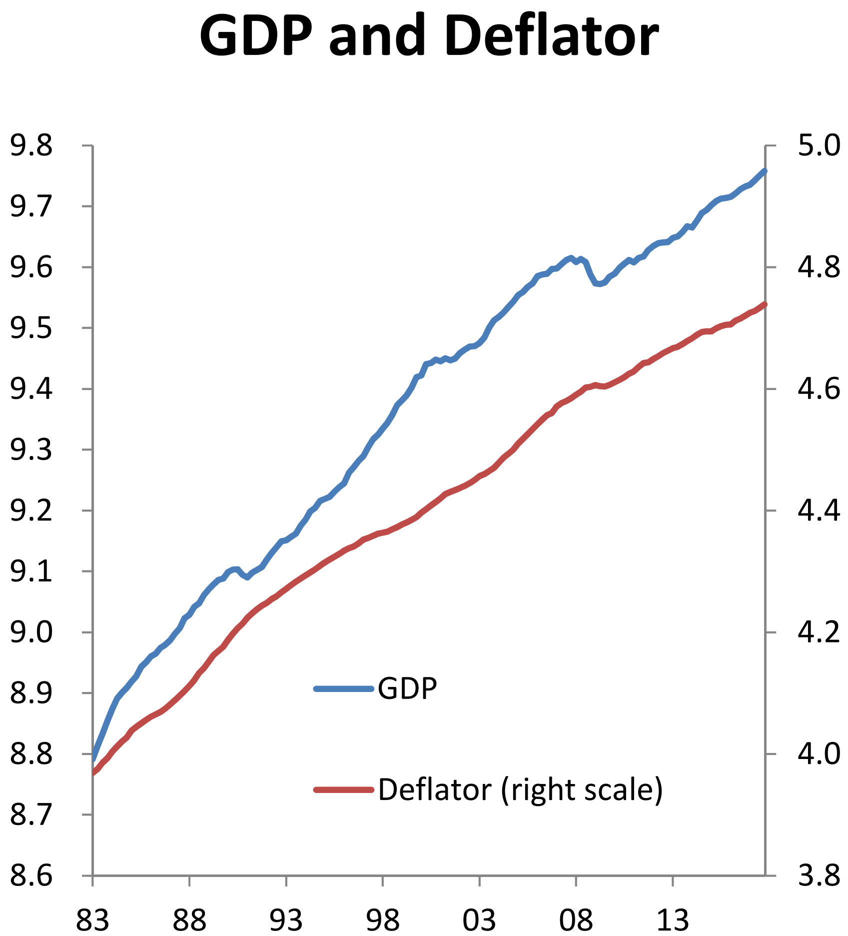
The UMP Literature

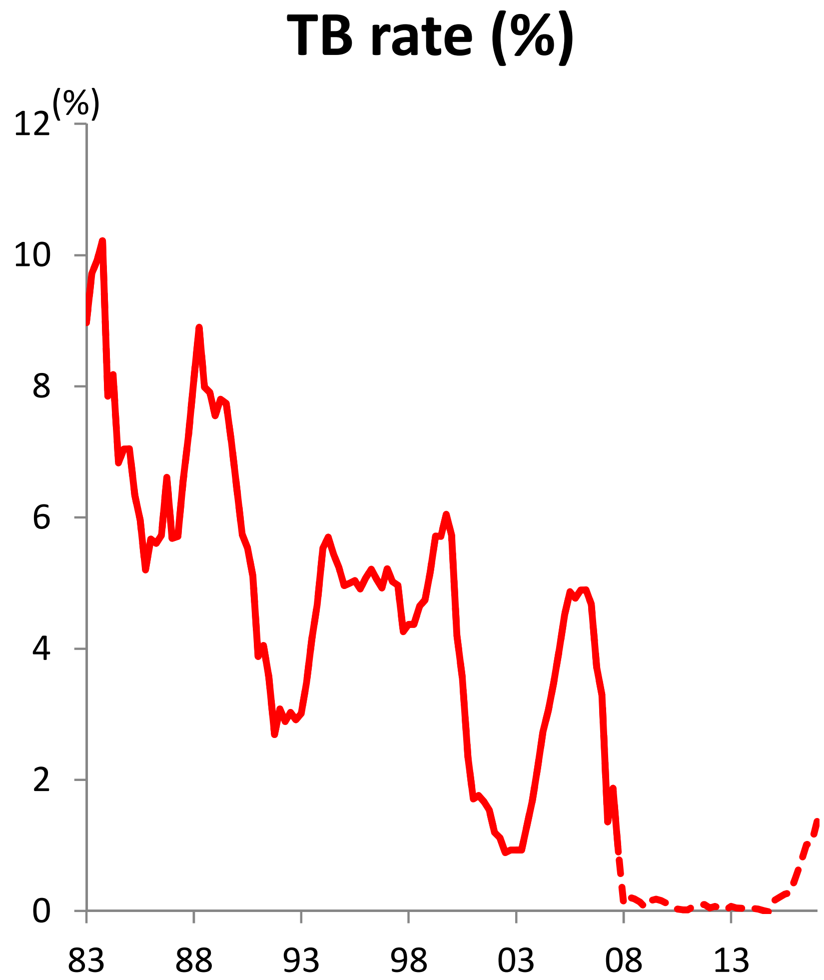
- Survey forecasts or other indicators of expectations
  - Engen et al. (2015) match forecasts from FRB/US with Blue Chip forecasts
  - Aoki and Ueno (2012) show that even if a DSGE is nonlinear due to the ZLB, it can be estimated without nonlinear solution techniques if expectations data are available
- Macroeconomic effects of the Fed's UMP
  - Existing studies, such as Baumeister and Benati (2013), Chung et al. (2012), and Fuhrer and Olivei (2011), generally focus on the effects via long-term yields
  - Chen et al. (2012), Engen et al. (2015), Kiley (2014), and Wu and Xia (2016) discuss the reasons behind the large estimates of UMP effects reported by earlier studies

Shadow Rate in MP Literature

- Shadow rate estimation can be a useful addition to the literature, which largely relies on structured models and event studies
  - The shadow rate is estimated in a relatively model-free manner; Bernanke: “The problem with QE is it works in practice, but it doesn't work in theory”
  - Hanson et al. (2017) argue that the slow-moving capital could result in overestimation of monetary policy shocks
  - Debortoli et al.’s (2018) result is consistent with the hypothesis of perfect substitutability between conventional and unconventional MPs.

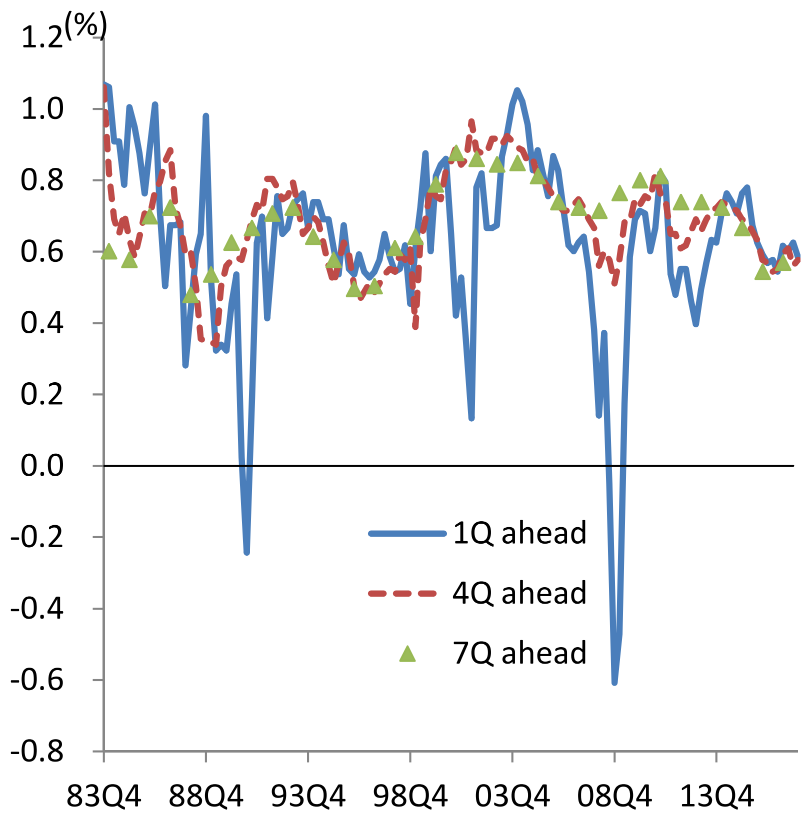
Actual Data


GDP and Deflator
9.8
9.7
9.6
9.5
9.4
9.3
9.2
9.1
9.0
8.9
8.8
8.7
8.6
5.0
4.8
4.6
4.4
4.2
4.0
3.8
83
88
93
98
03
08
13
GDP
Deflator (right scale)

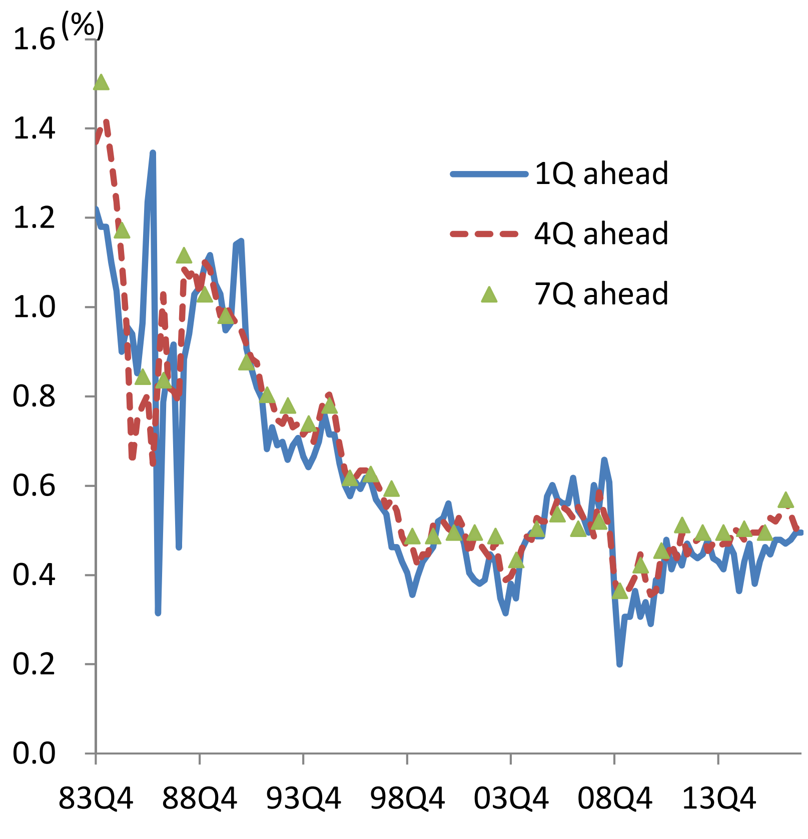

TB rate (%)
(%)
12
10
8
6
4
2
0
83
88
93
98
03
08
13

Selected Survey Forecasts (Q/Q Log Difference)

GDP



Deflator



Why not Add Financial/Monetary Variables to the VAR?

- Some studies add a financial/monetary variable other than the short rate
  - Term spread (Baumeister and Benati 2013)
  - Credit spread (Gertler and Karadi 2015)
  - Cumulative size of asset purchase announcements to GDP (Weale and Wieladek 2016)
- But it would make the estimation depend on the pre-ZLB correlation
- Our method can capture UMP effects through such variables
  - For example, when a lower credit spread leads to better expectations of economic conditions, the shadow rate is likely to be estimated lower

State Equation

$$\boldsymbol{\xi}_{t+1} = \mathbf{d} + \mathbf{F}\boldsymbol{\xi}_t + \boldsymbol{\nu}_{t+1}$$

where

$$\boldsymbol{\xi}_t = \begin{bmatrix} \mathbf{x}_t \\ \mathbf{x}_{t-1} \\ \mathbf{x}_{t-2} \\ \mathbf{x}_{t-3} \end{bmatrix}, \ \mathbf{d} = \begin{bmatrix} \mathbf{c} \\ \mathbf{0} \\ \mathbf{0} \\ \mathbf{0} \end{bmatrix}, \ \mathbf{F} = \begin{bmatrix} \mathbf{A}_1 & \mathbf{A}_2 & \mathbf{A}_3 & \mathbf{A}_4 \\ \mathbf{I} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{I} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{I} & \mathbf{0} \end{bmatrix}, \text{ and } \boldsymbol{\nu}_t \sim N\left(\begin{bmatrix} \mathbf{0} \\ \mathbf{0} \\ \mathbf{0} \\ \mathbf{0} \end{bmatrix}, \begin{bmatrix} \boldsymbol{\Omega} & \mathbf{O} & \mathbf{O} & \mathbf{O} \\ \mathbf{O} & \mathbf{O} & \mathbf{O} & \mathbf{O} \\ \mathbf{O} & \mathbf{O} & \mathbf{O} & \mathbf{O} \\ \mathbf{O} & \mathbf{O} & \mathbf{O} & \mathbf{O} \end{bmatrix} \right).$$

Observation Equation

$$\mathbf{o}_t = \boldsymbol{a} + \mathbf{H}'\boldsymbol{\xi}_t + \mathbf{w}_t$$

where

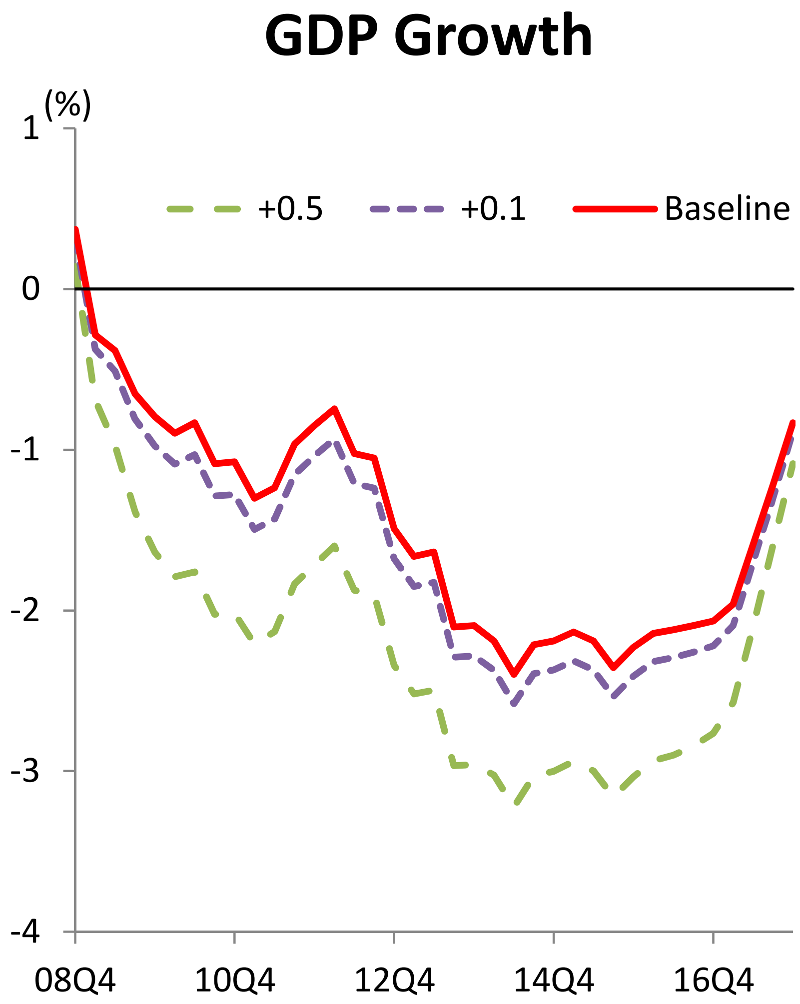
$$\mathbf{o}_t = \begin{bmatrix} i_t^o \\ \Delta y_{t+1|t}^o \\ \vdots \\ \Delta y_{t+7|t}^o \\ \Delta p_{t+1|t}^o \\ \vdots \\ \Delta p_{t+7|t}^o \end{bmatrix}, \ \mathbf{a} = \begin{bmatrix} 0 \\ (\mathbf{e}_1 - \mathbf{e}_4)'\mathbf{d} \\ \vdots \\ (\mathbf{e}_1 - \mathbf{e}_4)'\left(\mathbf{I} + \cdots + \mathbf{F}^6\right)\mathbf{d} \\ (\mathbf{e}_2 - \mathbf{e}_5)'\mathbf{d} \\ \vdots \\ (\mathbf{e}_2 - \mathbf{e}_5)'\left(\mathbf{I} + \cdots + \mathbf{F}^6\right)\mathbf{d} \end{bmatrix}, \ \mathbf{H}' = \begin{bmatrix} \mathbf{e}_3{}' \\ (\mathbf{e}_1 - \mathbf{e}_4)'\mathbf{F} \\ \vdots \\ (\mathbf{e}_1 - \mathbf{e}_4)'\mathbf{F}^7 \\ (\mathbf{e}_2 - \mathbf{e}_5)'\mathbf{F} \\ \vdots \\ (\mathbf{e}_2 - \mathbf{e}_5)'\mathbf{F}^7 \end{bmatrix}, \ \text{and} \ \mathbf{w}_t = \begin{bmatrix} 0 \\ \mathbf{w}_{y,1,t} \\ \vdots \\ \mathbf{w}_{y,7,t} \\ \mathbf{w}_{p,1,t} \\ \vdots \\ \mathbf{w}_{p,7,t} \end{bmatrix}.$$

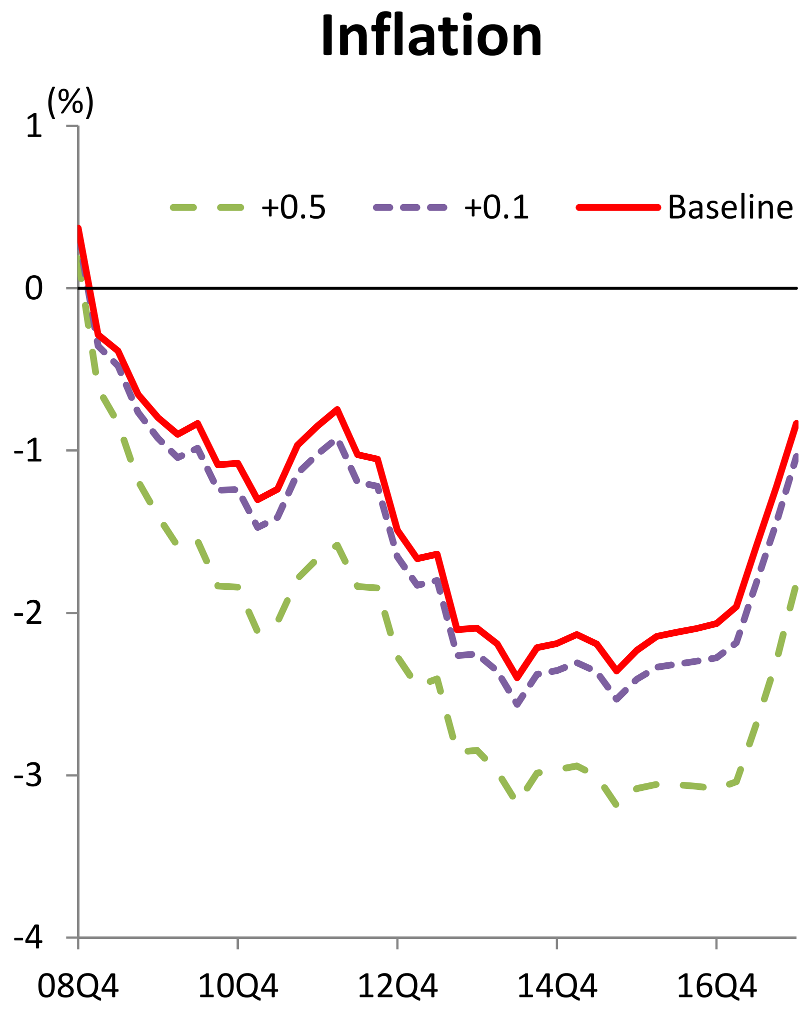
The error term $\mathbf{w}_t$ is uncorrelated with that of the state equation $\boldsymbol{\nu}_t$.
We assume that $\mathbf{w}_t \sim$i.i.d $N(\mathbf{0}, \mathbf{R})$ with a diagonal matrix $\mathbf{R}$.

Wu and Xia (2015) vs Krippner (2014)

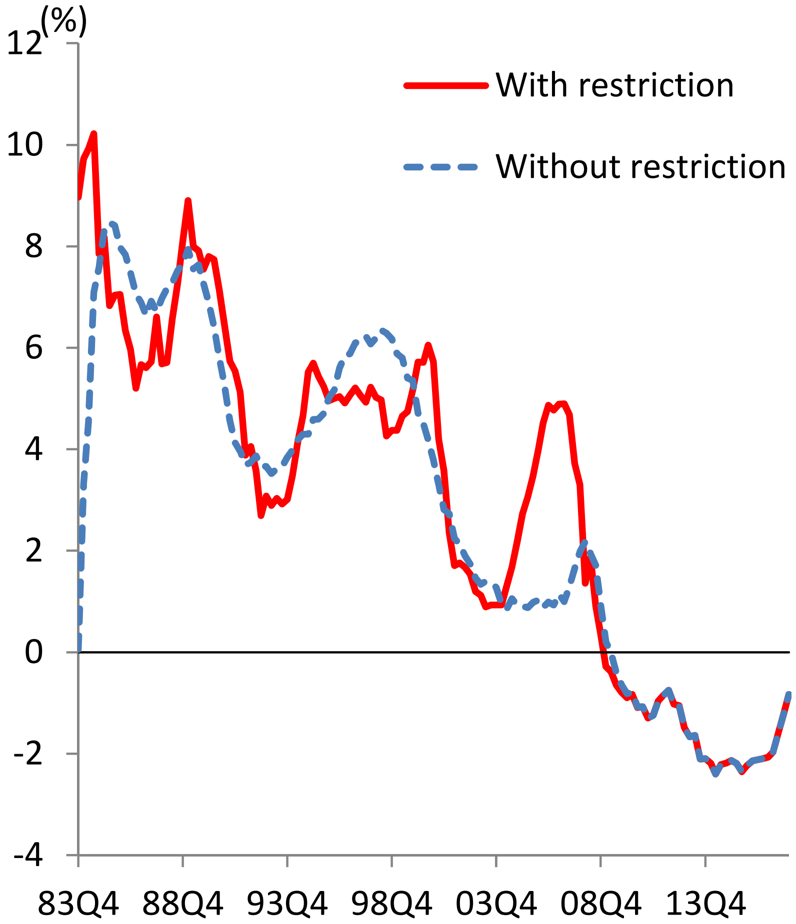
- Wu and Xia (2015) use 3 factors while Krippner (2014) uses 2 factors.
- Christensen and Rudebusch (2015) document that shadow rate estimation is sensitive to the number of latent factors
- The shadow rate estimated from TSM is just a linear combination of latent factors, which can best explain movements in the yield curve, with one property that the shadow rate is equal to the short rate when the short rate is positive

Sensitivity to Survey Data





The Shadow Rate in the Pre-ZLB



- Given the estimated parameters, the shadow rate is calculated from the Kalman filter without restricting it to equal the TB3M rate

Impact of Global Saving Glut

- Bertaut et al. (2012) show that the roughly $1 trillion acquisitions of U.S. bonds by the global saving glut countries during the 2003–2007 period lowered the U.S. 10Y yield by 1.1%P
- According to Chung et al. (2012), regressing quarterly changes in the 10Y yield on those in the federal funds rate for the period 1987–2007 yields a coefficient of about 0.25
- Combining these results, the impact of the global saving glut corresponded to a 4-5%P reduction in the short rate

Regressions of the Shadow Rate on Assets Holdings/GDP

	(1)	(2)	(3)	(4)	(5)	(6)
LSAPs	-0.145 **		-0.086 **		-0.066 *	
	(0.016)		(0.019)		(0.026)	
Non-LSAPs	-0.051		-0.013		0.110	
	(0.032)		(0.033)		(0.070)	
Treasury		-0.088 **		-0.032		-0.007
		(0.022)		(0.025)		(0.035)
MBS		-0.227 **		-0.177 **		-0.145 **
		(0.049)		(0.038)		(0.035)
Other		-0.056		-0.032		0.031
		(0.035)		(0.028)		(0.051)
Gov. surplus					-0.097	-0.049
					(0.067)	(0.043)
Foreign offical inv.					0.111	0.022
					(0.055)	(0.043)
Trend			-0.027 **	-0.026 **	-0.005	-0.022
Adjusted R-squared	0.884	0.913	0.913	0.940	0.928	0.939
Durbin-Watson statistics	0.644	0.784	0.812	1.090	1.453	1.362

Note: The observation period is 2008Q4-2017Q4 for (1)-(4) and 2008Q4-2016Q4 for (5)-(6). A constant is included and Newey and West's (1987) standard errors are used.

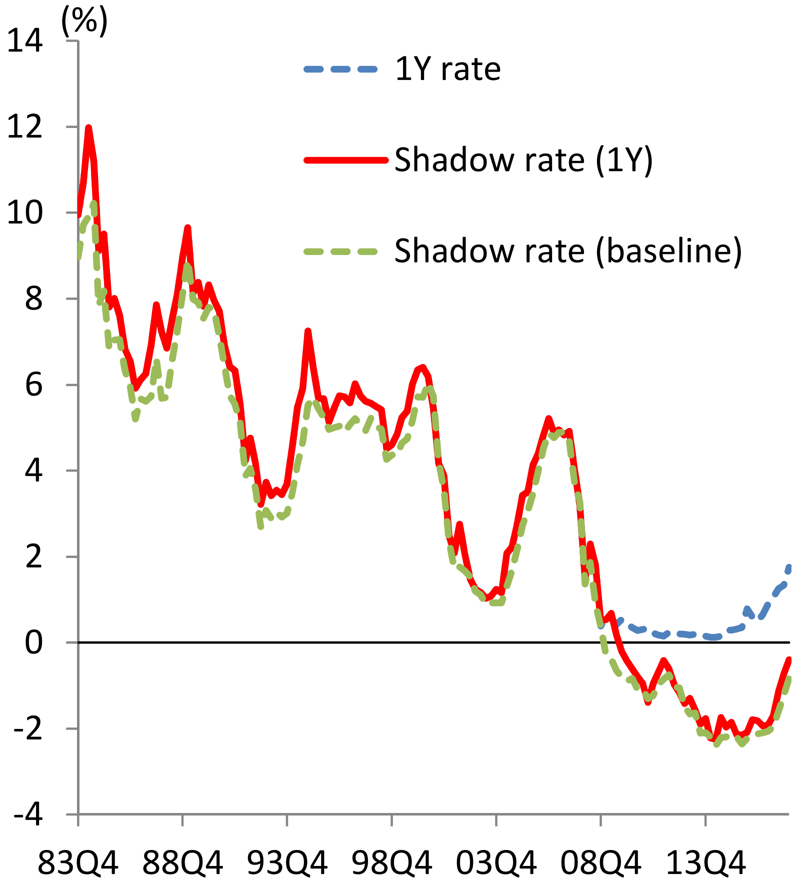
Comparison with Gagnon et al. (2011)

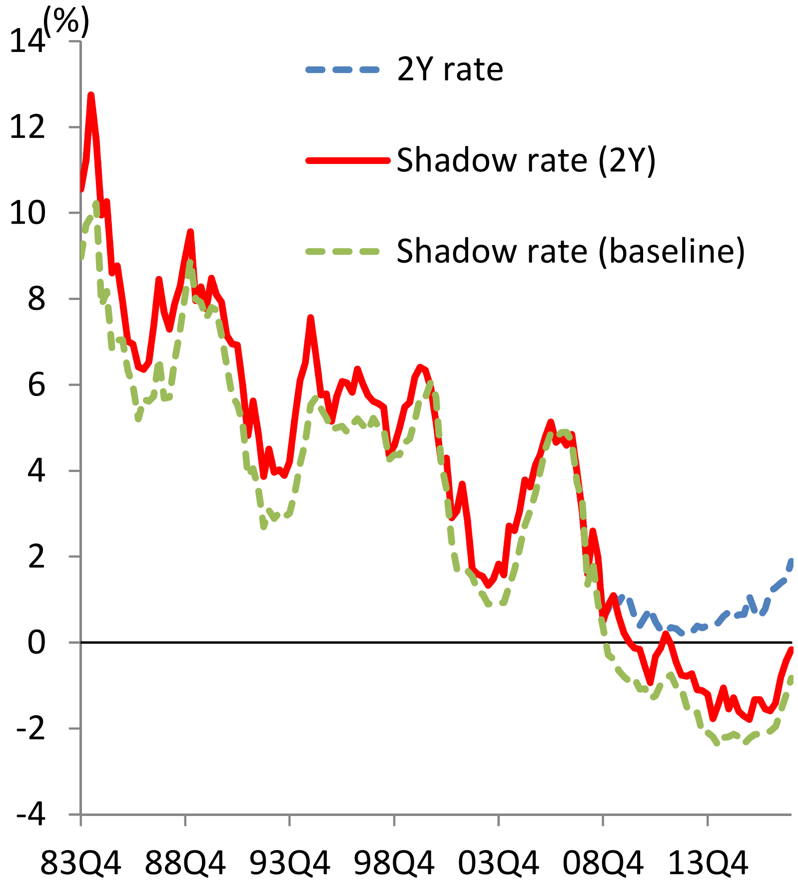
- Gagnon et al.'s (2011) time-series analysis suggests that a 1% of GDP increase in the Fed's longer-term debt holdings decreases the 10-year government bond yield by 0.069%P.
- According to Chung et al.'s (2012) result based on past correlation between the short- and long-term yields, Gagnon et al.'s (2011) estimate corresponds to a 0.25-0.30%P decline in the short rate.
- The fact that this back-of-envelope calculation result is larger than our estimate of 0.15%P suggests that the macroeconomic effect of a lower long-term yield is smaller than that of a lower short rate, as argued by Chen et al. (2012), Kiley (2014) and Stein (2012).

Literature Using Longer-term Yields as a MP Indicator

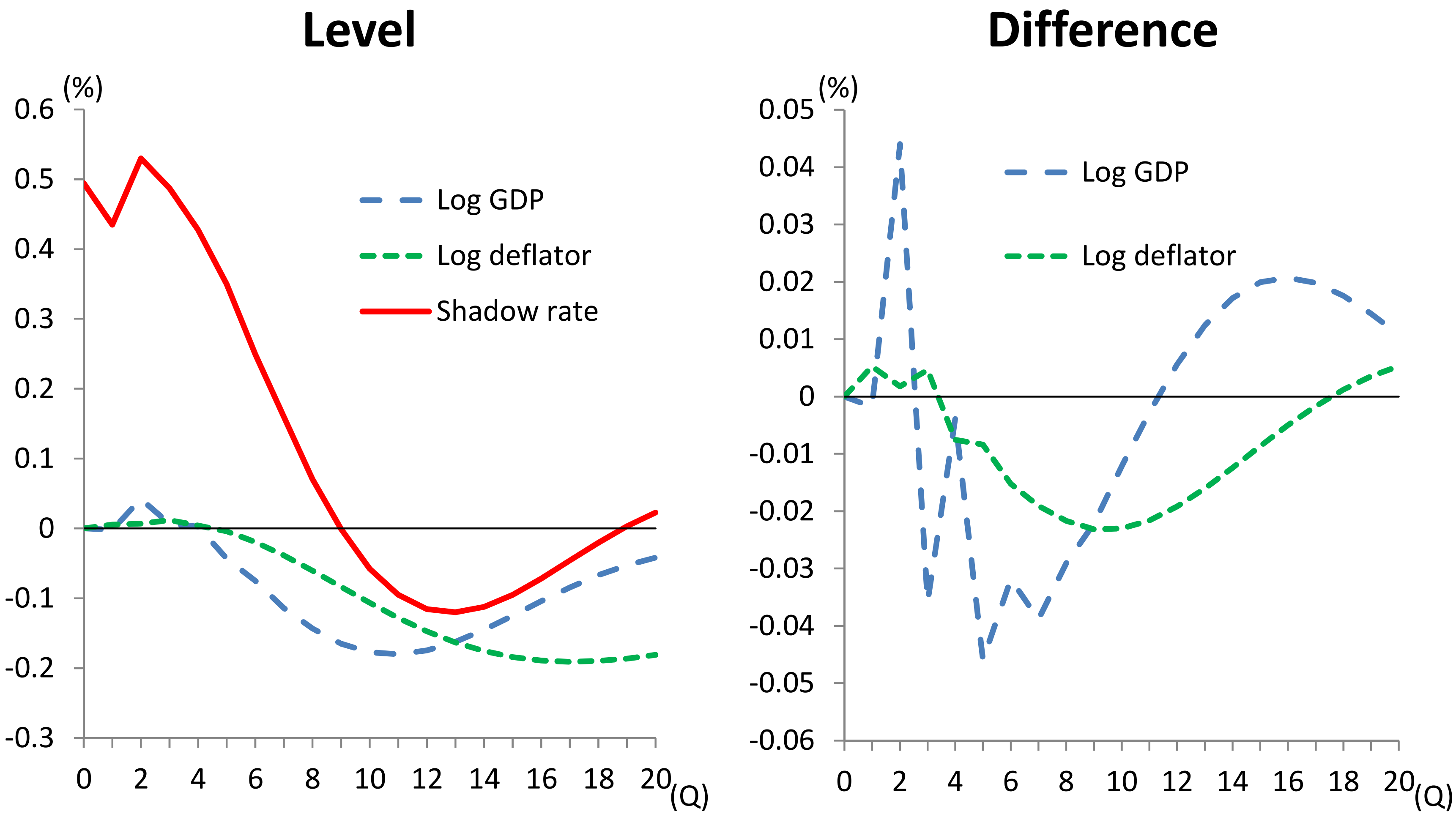
- Gürkaynak et al. (2005) find that the Fed's MP announcements affect asset prices primarily via their effects on financial market expectations of future MP, using futures rates with one year or less to expiration
- Williams and Swanson (2012) find that 1Y and 2Y Treasury yields were unconstrained through 2010
- Gertler and Karadi (2015) use the 1Y rate in their VAR with the data until June 2012
- Hansen and Stein (2012) use the 2Y yield for their event study with the data until February 2012

Shadow Rate Estimated when Using a Longer-term Yield, Instead of TB3M





IRFs Based on Recursive Identification



Simulation of GDP Growth