On the Empirical (Ir)Relevance of the Zero Lower Bound Constraint

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March 2019

Motivation

- Global financial crisis $\Rightarrow$ Binding ZLB $\Rightarrow$ Unconventional monetary policies (UMPs)
- How effective have UMPs been at getting around the ZLB constraint?

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- "The ZLB Irrelevance Hypothesis": the economy's performance has not been affected by the ZLB constraint

$\Rightarrow$ no increase in volatility
$\Rightarrow$ no change in the response of macro variables to shocks

This is indeed what we find

Related Literature

- Papers estimating the effects of QE and forward guidance:

  Krishnamurthy and Vissing-Jorgensen (2011), Hamilton and Wu (2012), D'Amico and King (2013, 2017), Andrade et al. (2016), Swanson (2017), Greenlaw et al. (2018), etc., etc..

- Papers assessing "irrelevance":

  Swanson and Williams (2014): response of yields to news
  Wu and Xia (2016), Wu and Zhang (2017): shadow rate approach
  Christiano et al. (2014), Gust et al. (2017): counterfactuals using a DSGE model

  ...

Our Approach

- Changes in macro volatility during the binding ZLB period
- Changes in response to shocks: TVC-SVAR analysis
- Comparison to predictions of a baseline macro model

Table 1
Relative Volatility

	ZLB		*Pre-84*
GDP	0.92	0.89	2.19
Hours	1.32	0.74	1.60
GDP Deflator	1.02	0.88	3.11
Core CPI	0.52	0.54	3.03
Core PCE	0.52	0.50	2.52
Great Recession?	yes	no	no

Standard deviations are computed relative to the NO-ZLB period given by 1984Q1-2008Q4 and 2016Q1-2018Q2. The ZLB period is 2009Q1-2015Q4. When the Great Recession is excluded the pre-ZLB sample period ends in 2007Q4 and the ZLB period starts in 2009Q3. The pre-84 period starts in 1960Q1 and ends in 1983Q4.

Table 2
Volatility Regressions

	CONST	*ZLB*	*GR*
GDP	0.41*	0.01	
	(0.04)	(0.05)	
	0.37*	−0.01	0.94*
	(0.03)	(0.05)	(0.19)
Hours	0.47*	0.05	
	(0.05)	(0.16)	
	0.42*	−0.00	1.39*
	(0.04)	(0.09)	(0.42)
GDP Deflator	0.70*	0.03	
	(0.07)	(0.12)	
	0.69*	0.02	0.37
	(0.07)	(0.11)	(0.26)
Core CPI	0.91*	−0.47*	
	(0.10)	(0.13)	
	0.91*	−0.47*	−0.05
	(0.10)	(0.13)	(0.13)
Core PCE	0.83*	−0.41*	
	(0.08)	(0.10)	
	0.83*	−0.42*	0.13
	(0.09)	(0.10)	(0.23)

The Table reports the estimated coefficients from an OLS regression of the absolute value of the deviation of each variable's growth rate from its mean, on a constant and a dummy for the ZLB period (2009Q1-2015Q4), with and without a control dummy for the Great Recession period (2008Q1-2009Q2). The sample period is 1984Q1-2018Q2. Standard errors obtained using the Newey-West estimator (4 lags).

Figure 1. Macroeconomic Volatility and the ZLB

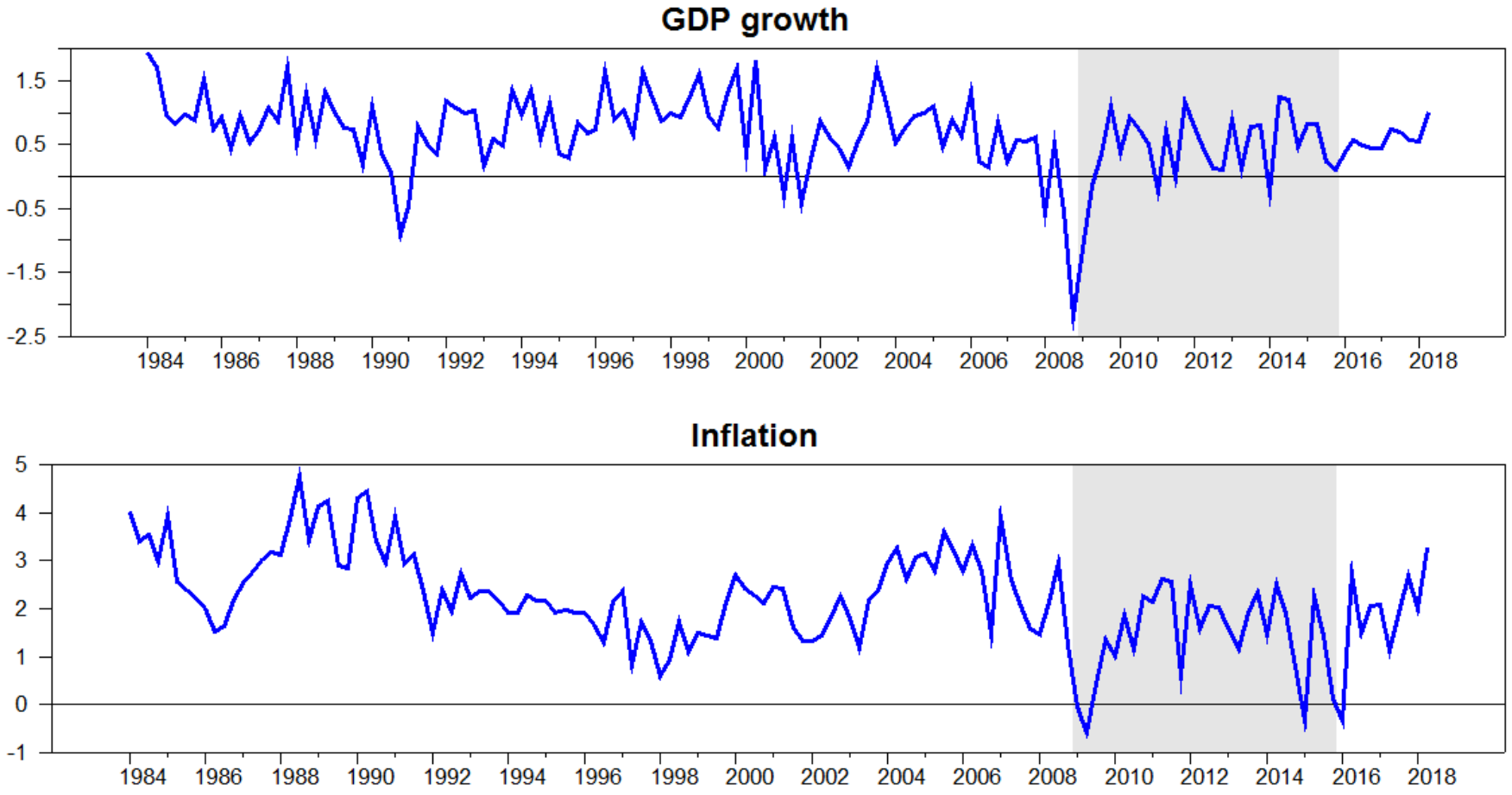
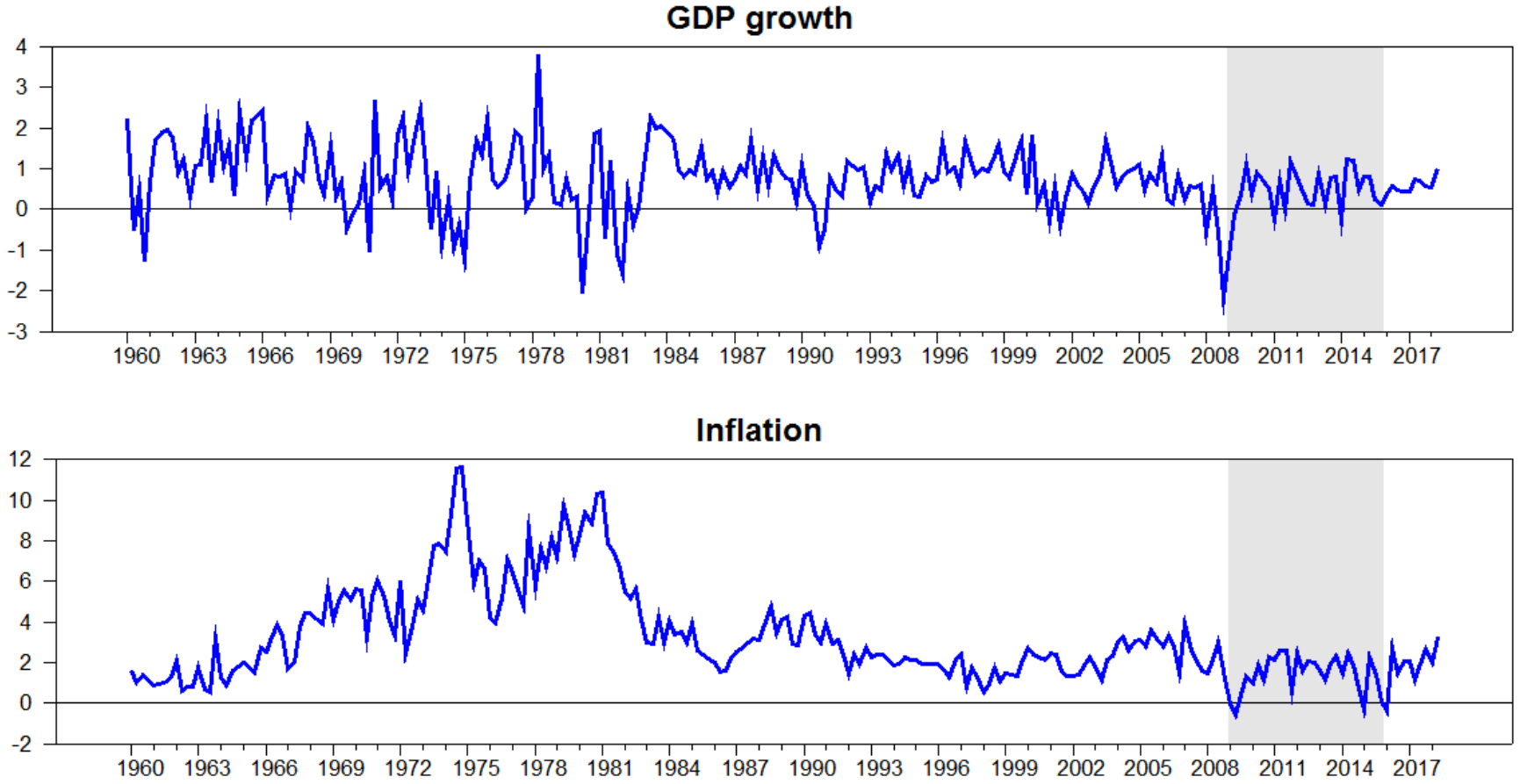


Figure 1X. Macroeconomic Volatility and the ZLB

Extended Sample Period



A Baseline Nonlinear NK Model: Equilibrium Conditions

- Private sector block:

$$\widehat{\pi}_t = \beta \mathbb{E}_t\{\widehat{\pi}_{t+1}\} + \kappa \widehat{y}_t$$

$$\widehat{y}_t = \mathbb{E}_t\{\widehat{y}_{t+1}\} - (i_t - \mathbb{E}_t\{\pi_{t+1}\} - z_t)$$

where

$$z_t = \rho_t + \eta_t$$

$$\eta_t = \rho_\eta \eta_{t-1} + \varepsilon_t^\eta$$

$$\rho_t \in \{\rho, \rho_L\} \sim \textit{Markov}$$

- Baseline interest rate rule

$$i_t = \max\left[0,\ \phi_i i_{t-1} + (1-\phi_i)(\rho + \pi + \phi_\pi \widehat{\pi}_t + \phi_y \Delta \widehat{y}_t)\right]$$

- Long-term rate:

$$i_t^L = (1 - \beta\gamma) i_t + \beta\gamma E_t\{i_{t+1}^L\}$$

A Baseline Nonlinear NK Model: Calibration

- Preferences: $\varphi = 1$, $\epsilon = 6$
- Technology: $\alpha = 0.25$
- Calvo parameter $\theta = 3/4$
- Policy rule: $\phi_\pi = 1.5$, $\phi_y = 0.5$, $\phi_i = 0.7$, $\pi = 0.005$
- Long-term bond: $\gamma = 0.975$ ($\Rightarrow$ 40 quarters)
- Exogenous processes:

$\rho_\eta = 0.8$, $\sigma_\eta = 0.001 \Rightarrow \sigma(\Delta y_t) = 0.007$ ($\simeq$ GM period)
$\rho = 0.005$, $\rho_L = -0.01$
$q_{NN} = 0.994$ and $q_{LL} = 0.66$
$\Rightarrow$ incidence every 140 quarters, average duration of 3 quarters, and -4.0 percent impact on output

A Baseline Nonlinear NK Model: Montecarlo Simulations

- Relative standard deviations
- Volatility regressions

Figure 2. The Impact of a Binding ZLB on the Dynamic Effects of a Demand Shock

Baseline Interest Rate Rule

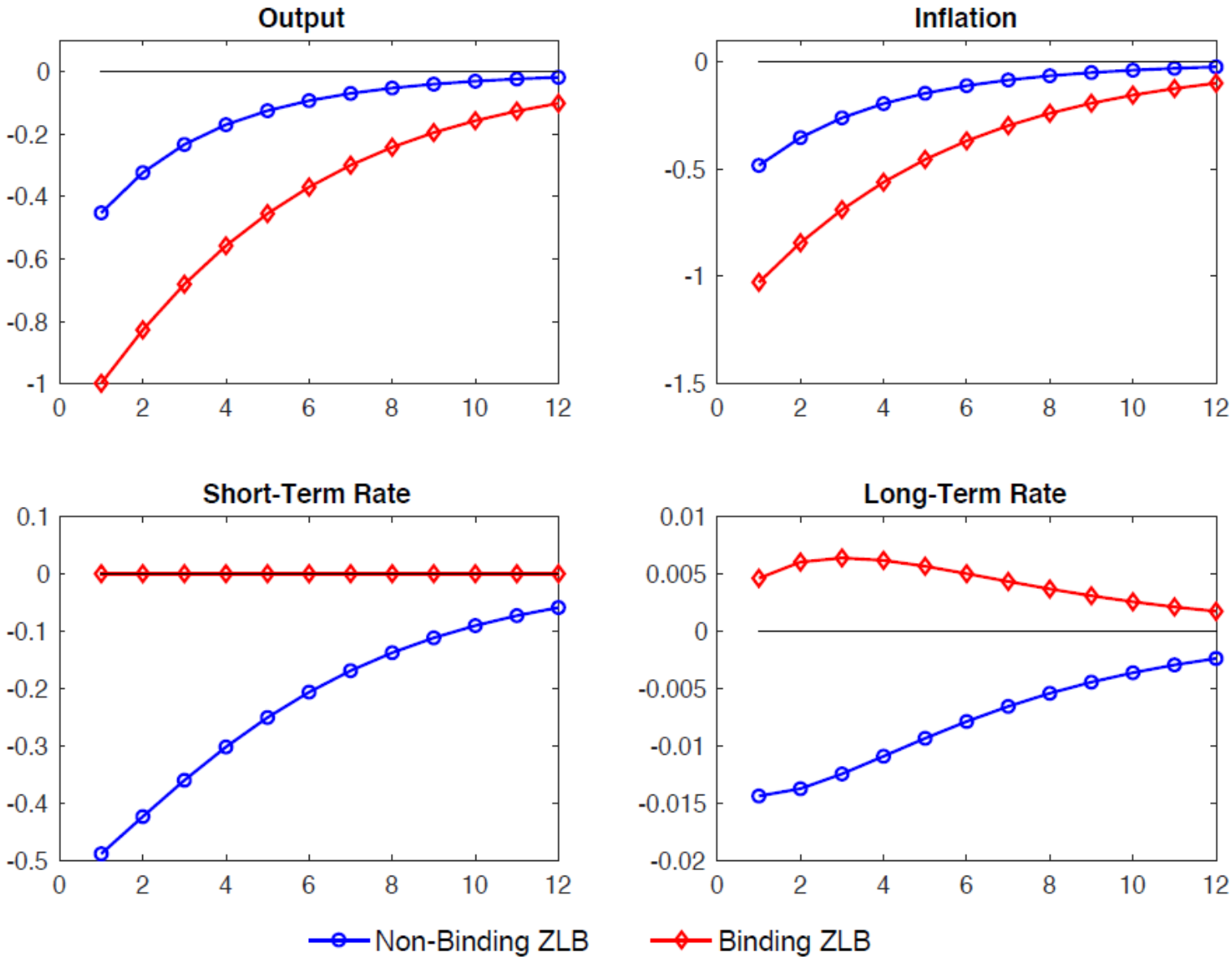


Table 3
Relative Volatility: Simulations
Baseline Interest Rate Rule

Output	1.49 [0.86,2.37]	2.29 [1.69,2.95]
Inflation	1.94 [0.91,3.38]	2.39 [1.02,3.86]
Markov transitions?	yes	no

For each variable the Table reports the mean of the standard deviation in the ZLB period relative to the no-ZLB period over 1000 model simulations under the baseline interest rate rule. The no-ZLB period is given by the first 100 observations and the last 8 observations in the simulation. The ZLB period corresponds to the intermediate 28 observations. 95% confidence intervals reported in brackets.

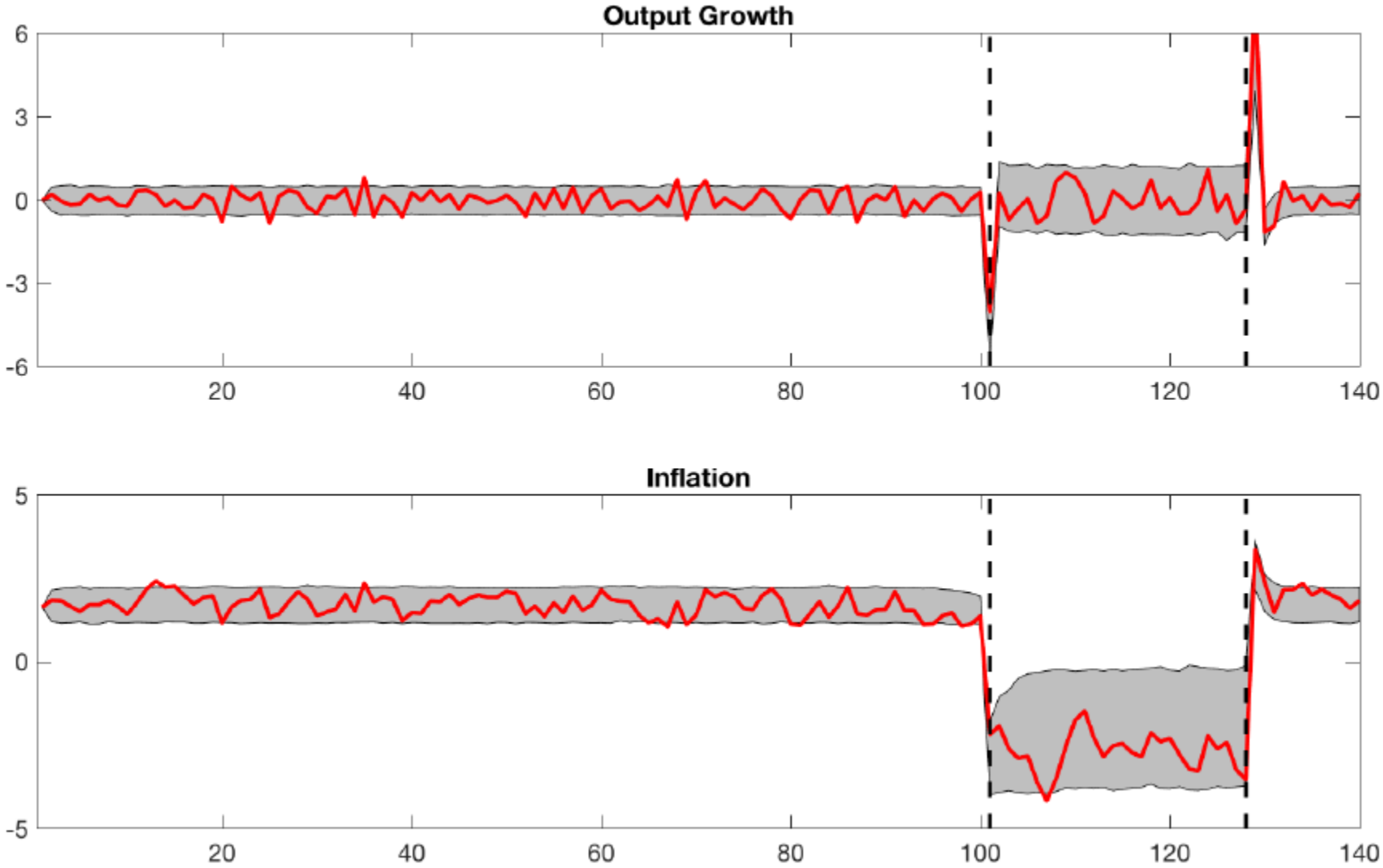
Table 4
Volatility Regressions: Simulations
Baseline Interest Rate Rule

	$CONST$	ZLB	MT	$\%REJ$
Output	0.32^* [0.27,0.36]	0.35^* (0.16,0.56)		0.86
	0.26^* [0.23,0.3]	0.34^* [0.19,0.50]	4.15^* [3.34,4.92]	0.98
Inflation	0.27^* [0.23,0.32]	0.47^* [0.21,0.79]		0.98
	0.26^* [0.22,0.30]	0.47^* [0.22,0.79]	0.61^* [0.02,1.31]	0.98

For each variable the Table reports the mean, over 1000 model simulations under the baseline interest rate rule, of the estimated coefficients from an OLS regression of the absolute value of the demeaned growth rate of each variable on a constant, a dummy indicating the ZLB period and, when it applies, a dummy for the two periods when a Markov transition occurs (MT). 95% confidence bands reported in brackets. $\%REJ$ is the fraction of simulations for which the estimated coefficient on the ZLB dummy is positive and statistically significant using the Newey-West estimate of the standard error (4 lags).

Figure 3. Macroeconomic Volatility and the ZLB: Model Simulations

Baseline Interest Rate Rule



Empirical Model

- Primiceri (2005)
- Reduced form TVC-VAR specification

$$\mathbf{x}_t = \mathbf{A}_{0,t} + \mathbf{A}_{1,t}\mathbf{x}_{t-1} + \mathbf{A}_{2,t}\mathbf{x}_{t-2} + ... + \mathbf{A}_{p,t}\mathbf{x}_{t-p} + \mathbf{u}_t$$

where $\mathbb{E}\{\mathbf{u}_t\mathbf{u}_t'\} = \Sigma_t$ and

$$\mathbf{u}_t \equiv \mathbf{Q}_t\boldsymbol{\varepsilon}_t$$

with $\mathbb{E}\{\boldsymbol{\varepsilon}_t\boldsymbol{\varepsilon}_t'\} = I$ and $\mathbb{E}\{\boldsymbol{\varepsilon}_t\boldsymbol{\varepsilon}_{t-k}'\} = 0$ for $k \neq 0$

$$\Rightarrow \mathbf{Q}_t\mathbf{Q}_t' = \boldsymbol{\Sigma}_t$$

Empirical Model

- Evolution of coefficients:

$$\boldsymbol{\theta}_t = \boldsymbol{\theta}_{t-1} + \boldsymbol{\omega}_t$$

where $\theta_t = vec(\mathbf{A}_t')$ with $\mathbf{A}_t = [\mathbf{A}_{0,t}, \mathbf{A}_{1,t}..., \mathbf{A}_{p,t}]$.

Letting $\boldsymbol{\Sigma}_t = \mathbf{F}_t \mathbf{D}_t \mathbf{F}_t'$ with $\mathbf{F}_t$ lower triangular and $\mathbf{D}_t$ diagonal,

$$\log \sigma_t = \log \sigma_{t-1} + \boldsymbol{\zeta}_t.$$

$$\boldsymbol{\phi}_{i,t} = \boldsymbol{\phi}_{i,t-1} + \boldsymbol{\nu}_{i,t}$$

where $\boldsymbol{\phi}_{i,t}$ is the ith row of $\mathbf{F}_t^{-1}$ and σ_t contains the diagonal elements of $\mathbf{D}_t^{1/2}$

Empirical Model

- Reduced form (local) TVC-MA representation:

$$\mathbf{x}_t = \boldsymbol{\mu}_t + \mathbf{B}_t(L)\mathbf{u}_t$$

- Structural (local) TVC-MA representation:

$$\mathbf{x}_t = \boldsymbol{\mu}_t + \mathbf{C}_t(L)\boldsymbol{\varepsilon}_t$$

where $\mathbf{C}_t(L) \equiv \mathbf{B}_t(L)\mathbf{Q}_t$

Empirical Model

- Specification

$$\mathbf{x}_t = [\Delta(y_t - n_t),\ n_t,\ \pi_t,\ i_t^L]'$$

- Identification: combination of long-run and sign restrictions on comovements at a one-year horizon

(i) Technology shocks: source of the unit root in labor productivity
(ii) Demand shocks: positive comovement among y_t, π_t and i_t^L
(iii) Monetary policy shocks: positive comovement between y_t and π_t, negative with i_t^L
(iv) Transitory supply shocks: negative comovement between y_t and π_t

Data

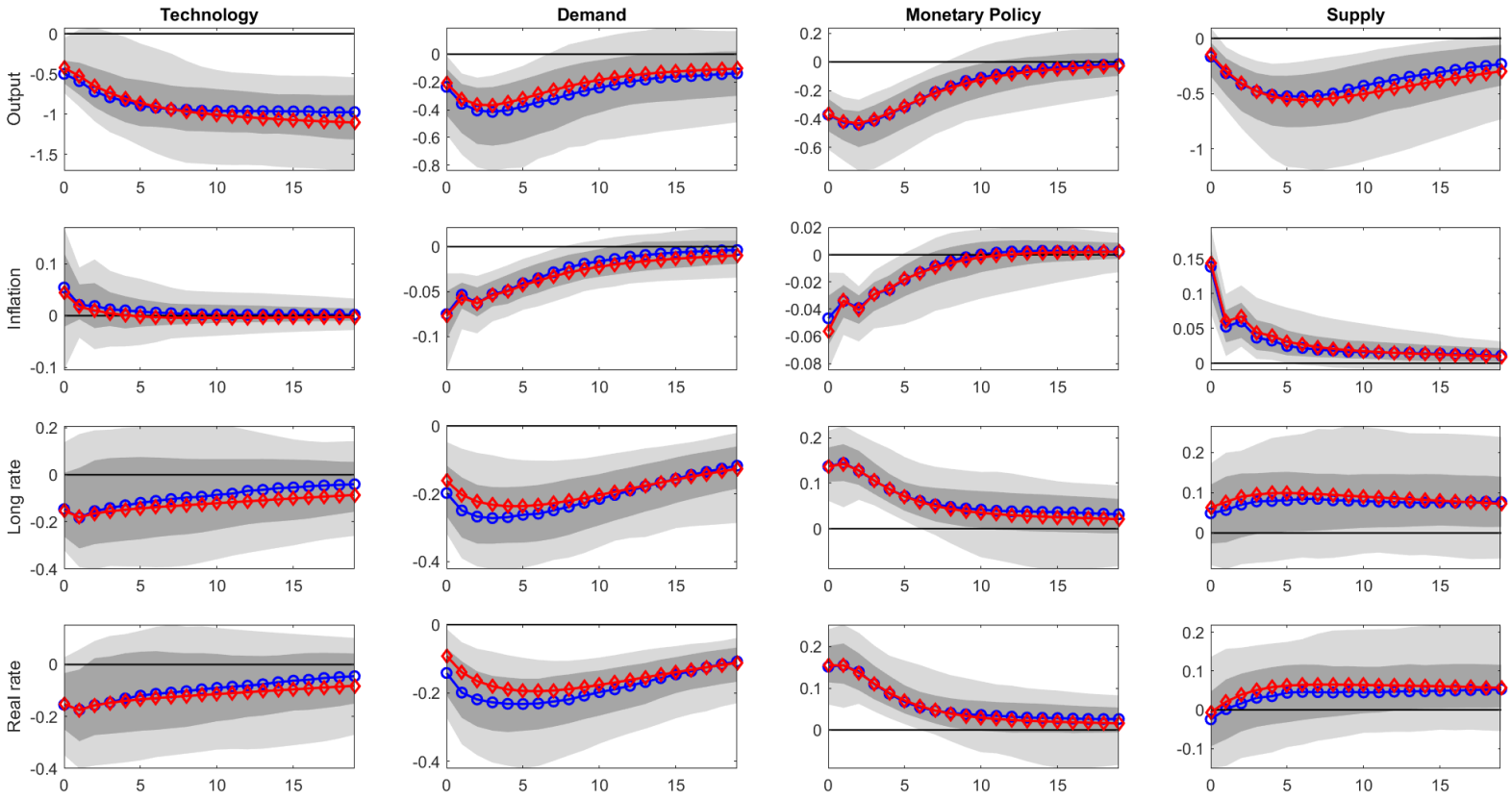
- Sample period: 1953Q1-2015Q4
- y_t: (log) output nonfarm business sector, normalized by population.
- n_t: (log) hours of all persons (nonfarm), normalized by population
- π_t : GDP deflator inflation
- i_t^L : 10-year Treasury bond yield

Evidence: Average Impulse Responses

- Pre-ZLB (2002Q1-2008Q4) vs. ZLB (2009Q1-2015Q4)

Figure 4a. Dynamic Responses: The Impact of the Binding ZLB

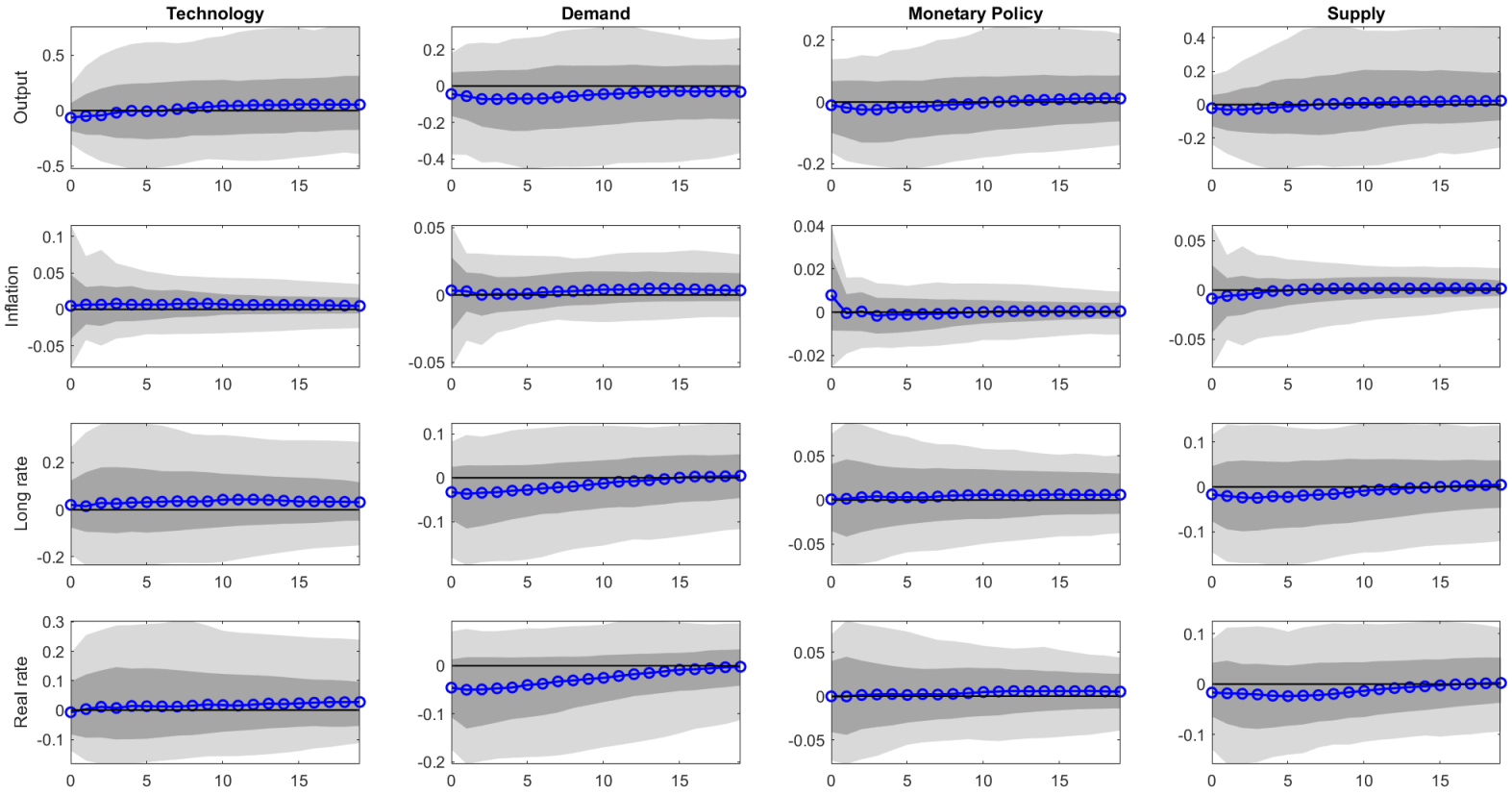
Short sample



blue: 2002Q1-2008Q4 red: 2009Q1-2015Q4

Figure 4B. Dynamic Response Differentials: The Effect of the Binding ZLB

Short sample

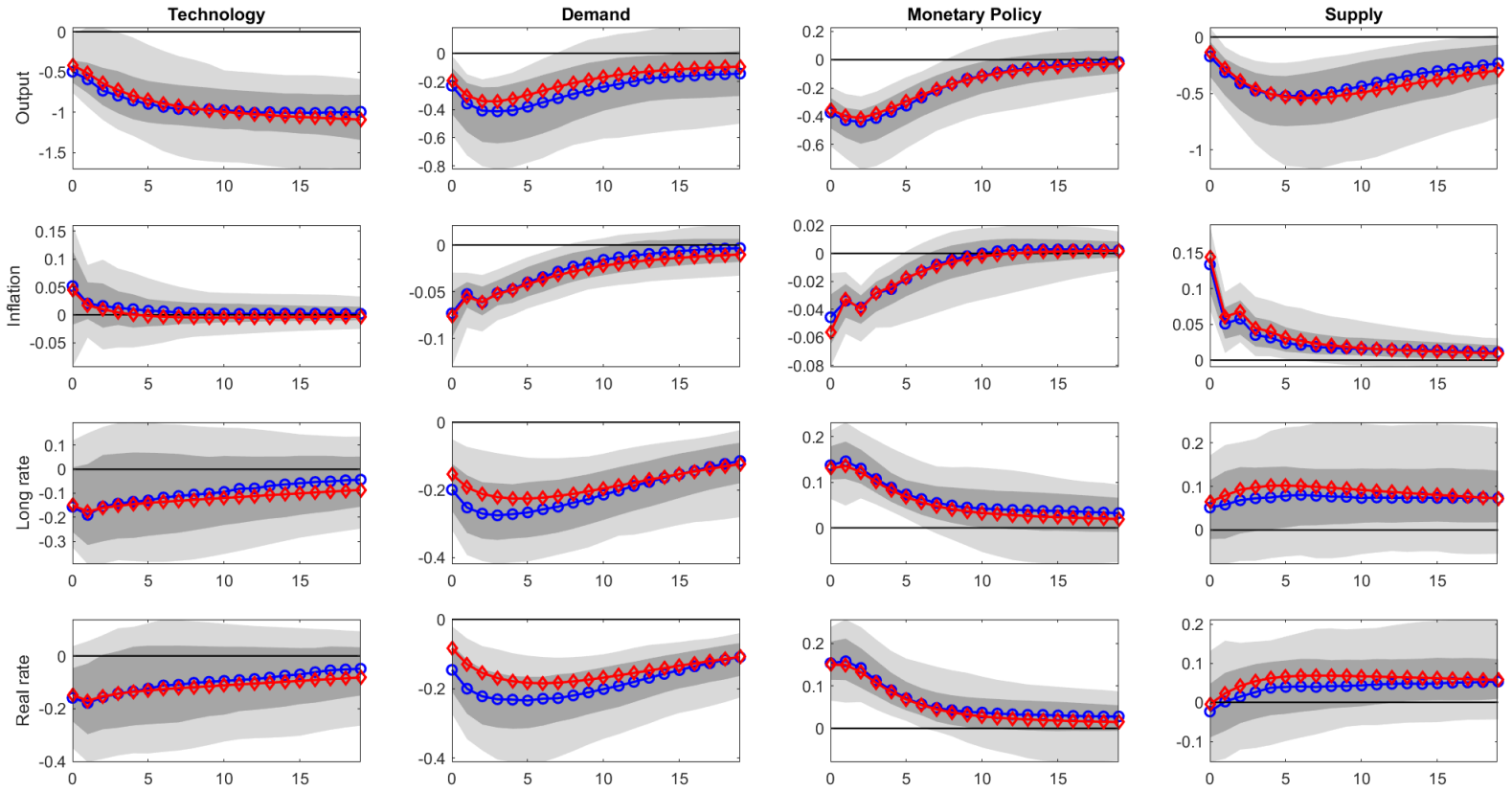


Evidence: Average Impulse Responses

- Pre-ZLB (2002Q1-2008Q4) vs. ZLB (2009Q1-2015Q4)
- Excluding Great Recession

Figure 4C. Dynamic Responses: The Effect of the Binding ZLB

Short sample excluding Great Recession



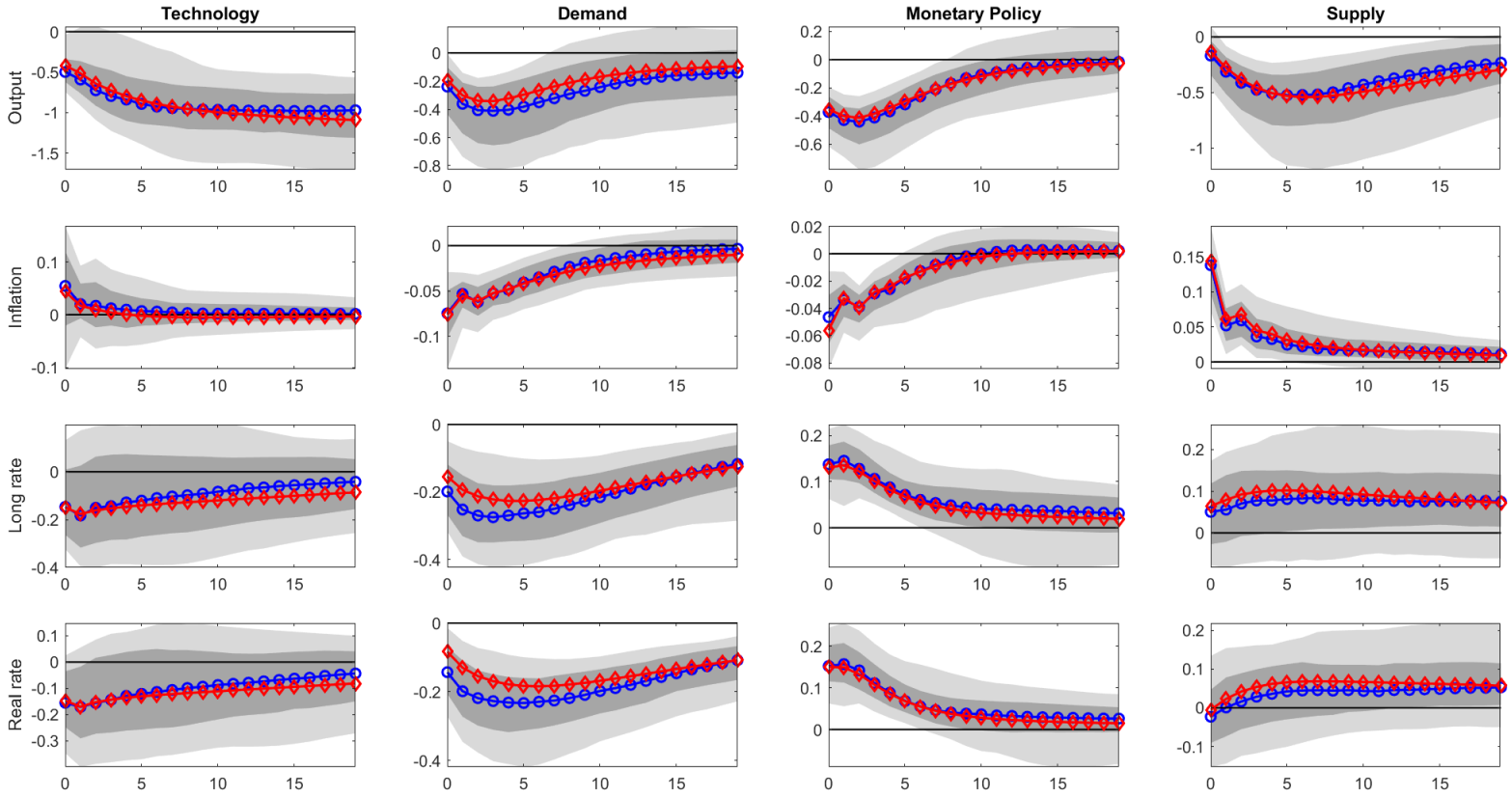
blue: 2002Q1-2007Q4 red: 2010Q1-2015Q4

Evidence: Average Impulse Responses

- Pre-ZLB (2002Q1-2008Q4) vs. ZLB (2009Q1-2015Q4)
- Excluding Great Recession
- Longer pre-ZLB sample (1984Q1-2008Q4)

Figure 4D. Dynamic Responses: The Effect of the Binding ZLB

Extended pre-ZLB sample



blue: 1984Q1-2008Q4 red: 2009Q1-2015Q4

An Estimated Long-Term Interest Rate Rule

- Specification

$$i_t^L = \phi_0 + \phi_i i_{t-1}^L + (1-\phi_i)[\phi_\pi \pi_t + \phi_y \Delta y_t] + \varepsilon_t^m$$

- Multiplicative dummies for binding ZLB period
- Instruments: estimated non-monetary shock component from TVC-SVAR
- Did the binding ZLB constraint affect the response of the long-term rate to output and inflation developments?

Table 5
Estimated Long-Term Interest Rate Rule

π_t	2.42^*	2.82^*	2.26^*	2.61^*
	(0.61)	(0.82)	(0.23)	(0.32)
$\pi_t * ZLB_t$	-0.08	-0.01	-0.17^*	-0.45
	(0.08)	(0.06)	(0.06)	(0.50)
Δy_t			3.52^*	4.43^*
			(0.42)	(0.58)
$\Delta y_t * ZLB_t$			-0.16	-0.60
			(0.08)	(0.89)
ϕ_0 and ϕ_i dummies?	Yes	No	Yes	No

The Table reports the OLS estimates of the long term rate rule described in the text, with multiplicative dummies for the binding ZLB period, and using the non-monetary component of the long-term interest rate, output growth and inflation obtained from the estimated TVC-SVAR model.

Reconciling Theory and Evidence

- A shadow rate rule

$$i_t = \max[0, i_t^s]$$

$$i_t^s = \phi_i i_{t-1}^s + (1-\phi_i)(\rho + \pi + \phi_\pi \widehat{\pi}_t + \phi_y \Delta \widehat{y}_t)$$

- Simulations:

  - relative standard deviations
  - volatility regressions

Figure 5. The Impact of a Binding ZLB on the Dynamic Effects of a Demand Shock

Shadow Rate Rule

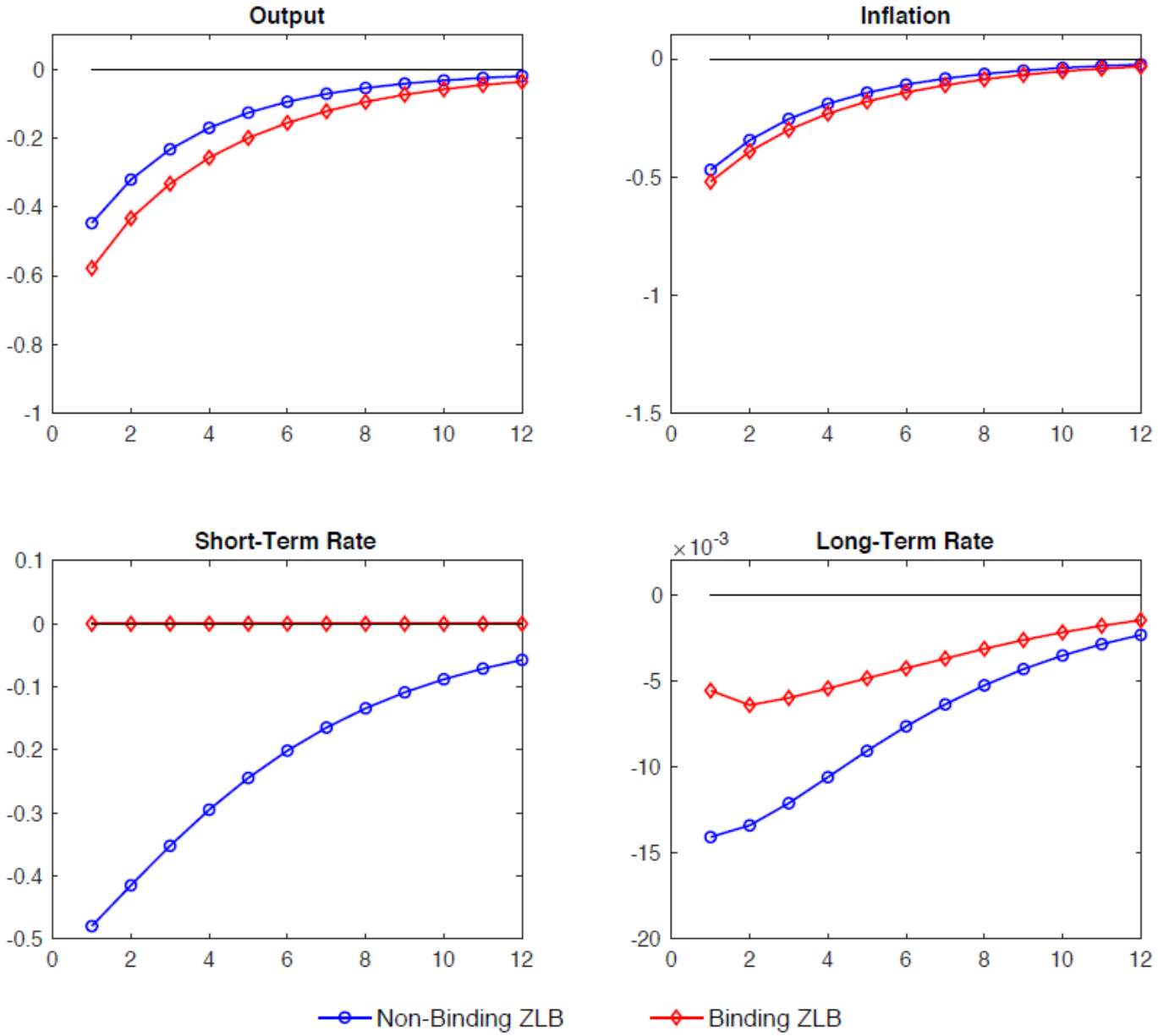


Table 6
Relative Volatility: Simulations
Shadow Rate Rule

Output	1.01 [0.65,1.9]	1.50* [1.03,1.94]
Inflation	0.82 [0.50,1.38]	1.0 [0.59,1.41]
Markov transitions?	yes	no

For each variable the Table reports the mean of the standard deviation in the ZLB period relative to the pre-ZLB period over 1000 model simulations under the baseline interest rate rule. The no-ZLB period is given by the first 100 observations and the last 8 observations in the simulation. The ZLB period corresponds to the intermediate 28 observations.. 95% confidence intervals reported in brackets.

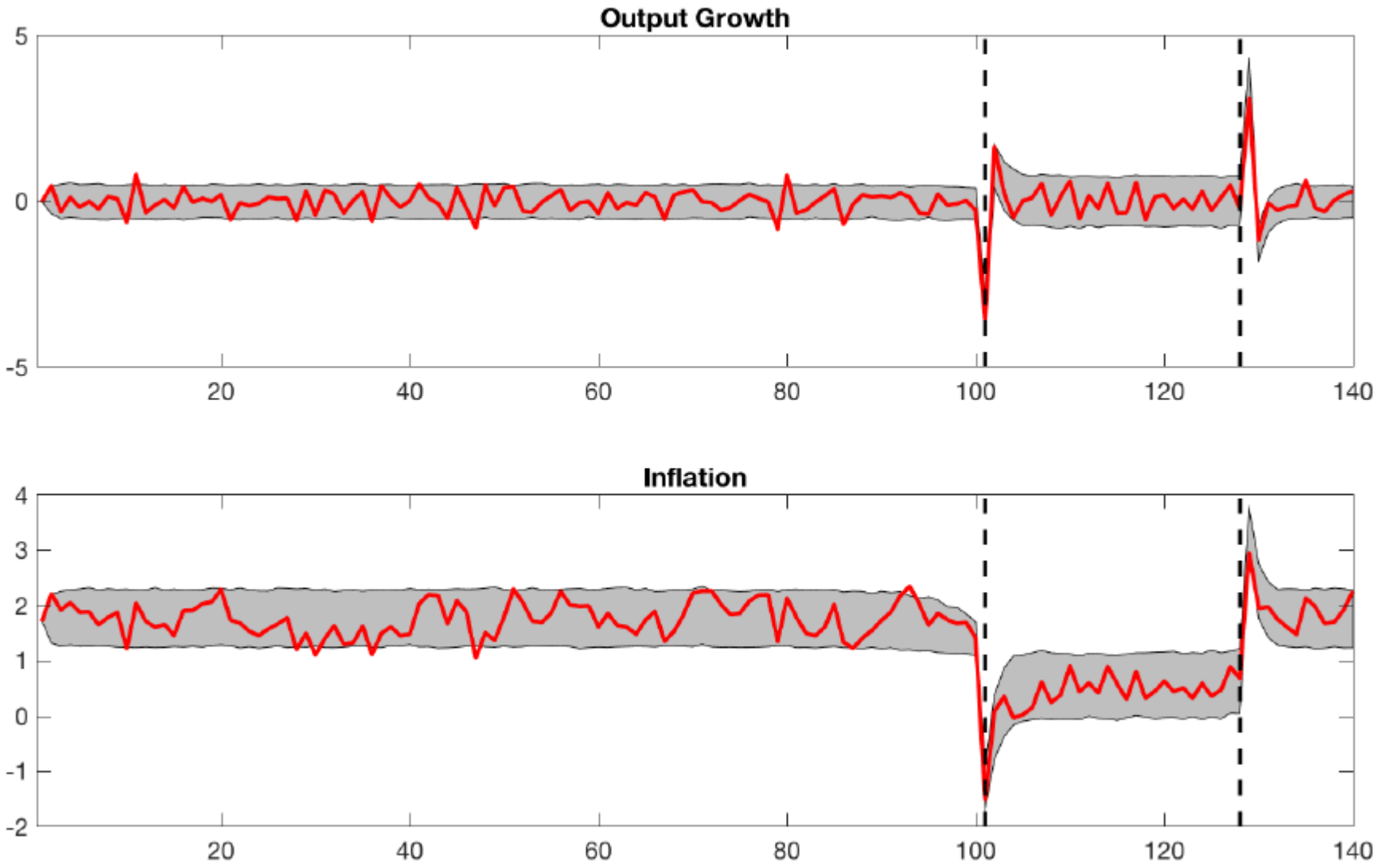
Table 7
Volatility Regressions: Simulations
Shadow Rate Rule

	$CONST$	ZLB	MT	$\%REJ$
Output	0.31* [0.28,0.35]	0.1 [−0.03,0.27]		0.15
	0.26* [0.23,0.3]	0.14* [0.02,0.26]	3.11* [2.66,3.6]	0.49
Inflation	0.28* [0.24,0.32]	0.03 [−0.06,0.14]		0.07
	0.26* [0.22,0.29]	0.05 [−0.04,0.14]	1.37* [1.07,1.69]	0.16

For each variable the Table reports the mean over 1000 simulations under the shadow rate rule of the estimated coefficients from an OLS regression of the absolute value of the demeaned growth rate of the variable on a constant, a dummy indicating the ZLB period and, when it applies, a dummy for the period of a Markov transition. 95% confidence bands reported in brackets. $\%REJ$ is the fraction of simulations for which the estimated coefficient on the ZLB dummy is positive and statistically significant using the Newey-West estimate of the standard error (4 lags).

Figure 6. Macroeconomic Volatility and the ZLB: Model Simulations

Shadow Rate Rule



Concluding Comments

- How binding has the ZLB been? How effective have UMPs at getting around the ZLB constraint?

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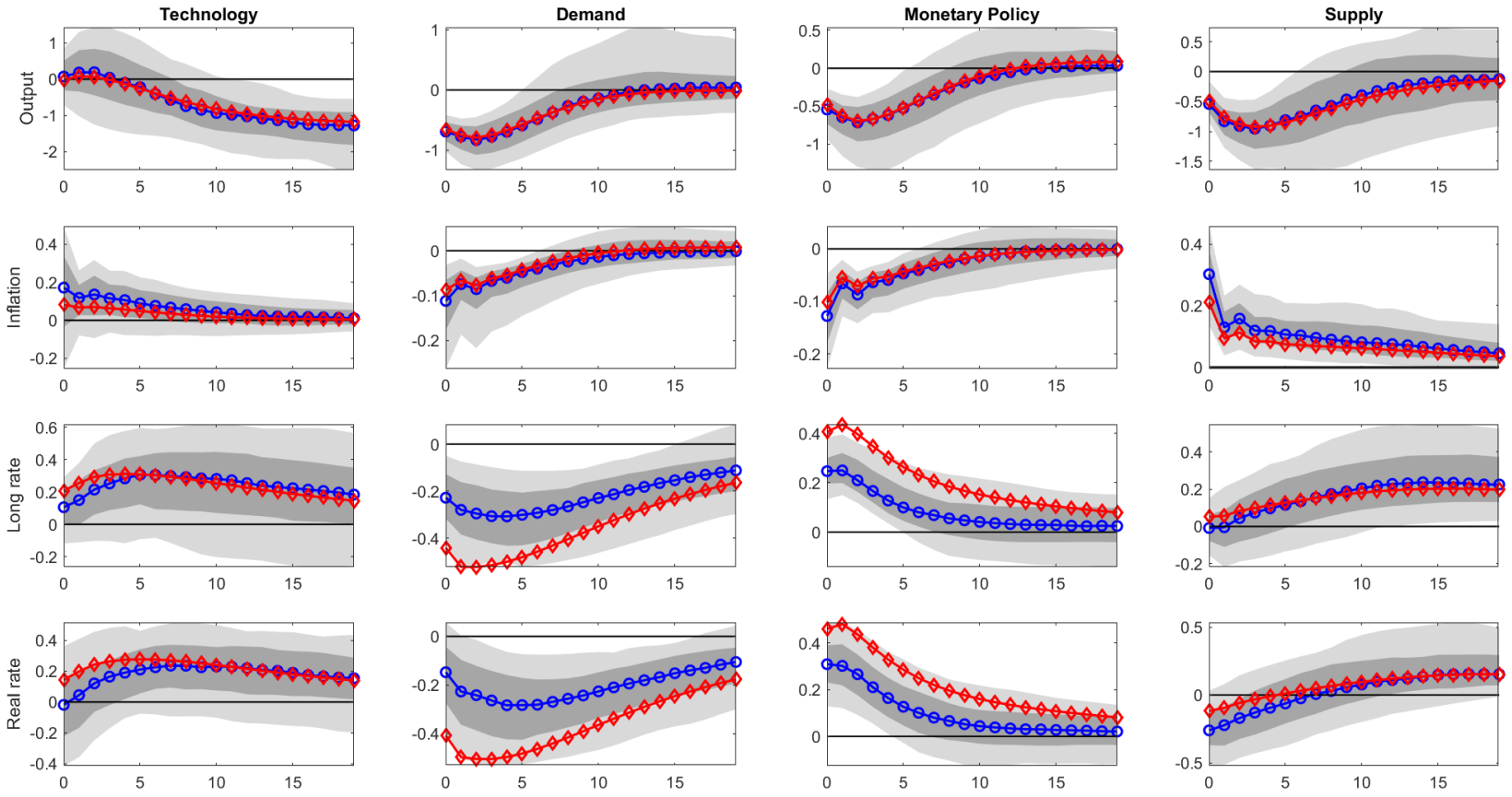
- How binding has the ZLB been? How effective have UMPs at getting around the ZLB constraint?
- No evidence of an increase in volatility
- Little evidence of change in the response of macro variables to shocks
- Little evidence of a change in the response of the long rate to macro developments
- Evidence at odds with the predictions of a baseline NK model with a truncated Taylor-type rule, but consistent with a shadow rate rule.
- Overall support for the "ZLB irrelevance hypothesis": the Federal Reserve may have succeeded in getting around the constraints imposed by the ZLB, possibly through UMPs.
- Alternative non-monetary explanations hard to reconcile with long-rate response (e.g. fiscal policy)

Figure 4f. Dynamic Responses: Pre-Volcker vs Post-Volcker



blue: 1973Q2-1979Q2 red: 1979Q3-1985Q3