Endogenous Volatility at the Zero Lower Bound: Implications for Stabilization Policy

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Increased uncertainty played role in generating Great Recession

Stock & Watson (2012), Leduc & Liu (2014)

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Kocherlakota (2010)

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Why does uncertainty matter for recent macroeconomic outcomes?

How to conduct monetary policy under uncertainty?

Zero lower bound crucial in transmitting effects of uncertainty

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Simple model of nominal price rigidity

- Demand-determined output
- Monetary policy plays key stabilizing role

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Unconstrained central bank can fully stabilize

- $\Rightarrow$ Uncertainty about future has no effect

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- Asymmetry lowers mean outcome
- Endogenously generates volatility

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Induces precautionary saving by households

- Further decline in demand $\Rightarrow$ Constraint binds for longer
- Destabilizing feedback loop

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Higher uncertainty strengthens feedback

- Small uncertainty shocks imply large contractions

Roadmap

1. Illustrate mechanism under Taylor (1993)-type rule

   Feedback loop may cause equilibrium non-existence

2. Simple history-dependent rule ensures equilibrium exists

   Reduces some fluctuations

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1. Illustrate mechanism under Taylor (1993)-type rule

   Feedback loop may cause equilibrium non-existence

2. Simple history-dependent rule ensures equilibrium exists

   Reduces some fluctuations

3. Optimal policy can attenuate endogenous volatility

   Stabilize distribution of possible outcomes

   Commit to responding if bad shocks are realized

Model Summary

Standard New-Keynesian sticky price model without capital

Shares features with models of Ireland (2003, 2010)

Household consumes, works, & receives firm dividends

Firms employ labor & produce

Quadratic cost of adjusting nominal price

Stochastic Processes

Fluctuations in household discount factor (demand shocks)

$$a_t = (1 - \rho_a)a + \rho_a a_{t-1} + \sigma^a_{t-1}\varepsilon^a_t$$

$$\sigma^a_t = (1 - \rho_{\sigma^a})\sigma^a + \rho_{\sigma^a}\sigma^a_{t-1} + \sigma^{\sigma^a}\varepsilon^{\sigma^a}_t$$

Increase in uncertainty captured by increase in σ^a_t

Harder to forecast a_t under higher uncertainty

Calibrate & solve nonlinear model using policy function iteration

Examine uncertainty shock under two scenarios:

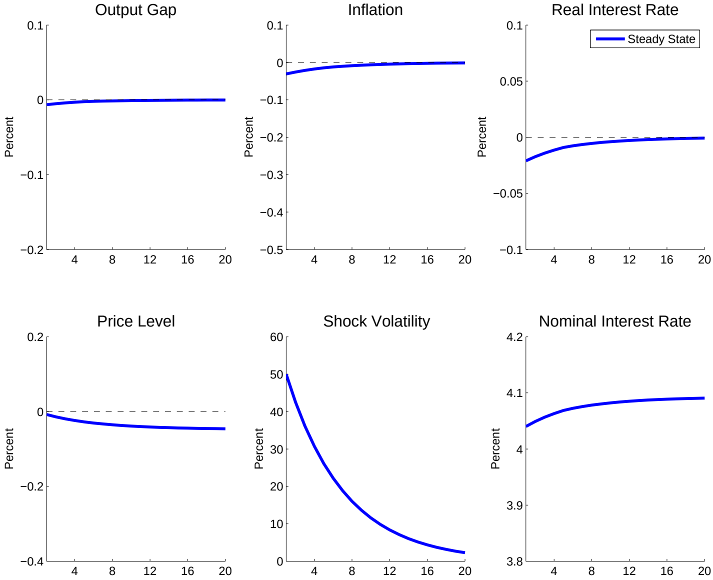
1. Steady state
2. Zero lower bound

Initially assume monetary policy follows Taylor (1993)-type rule

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

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

Impulse Responses to Demand Uncertainty Shock



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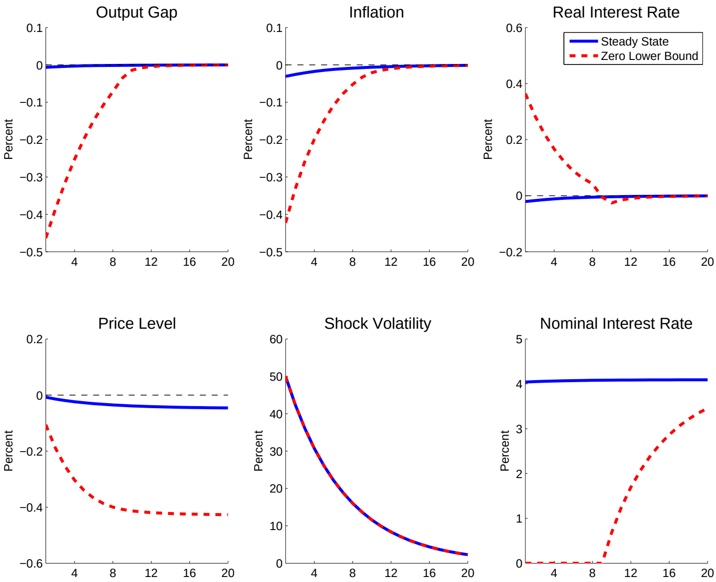
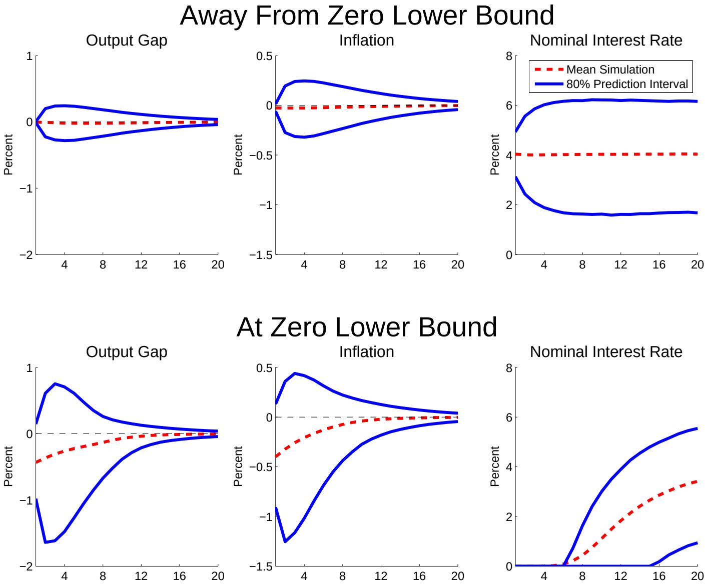


Expected Distributions of Possible Outcomes After Shock



Interactions Between Uncertainty & Zero Lower Bound

Two distinct mechanisms

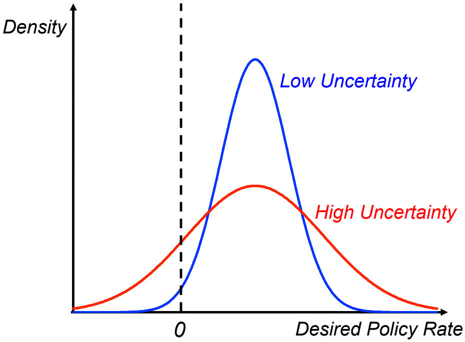
1. Precautionary saving & precautionary labor supply
2. Contractionary bias in nominal interest rate distribution

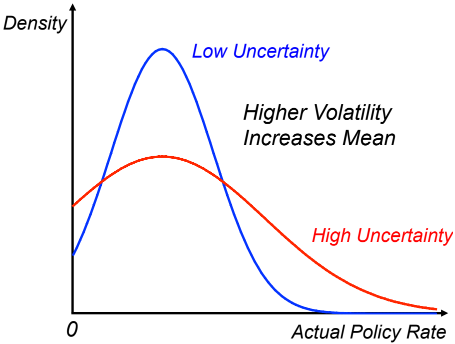
Contractionary bias emerges under standard Taylor-type rule

Misses inflation target on average due to zero lower bound

Contractionary Bias & Distribution of Policy Rates

$$r_t^d = r + \phi_\pi \left(\pi_t - \pi\right) \qquad\qquad r_t = \max\left(0, r_t^d\right)$$

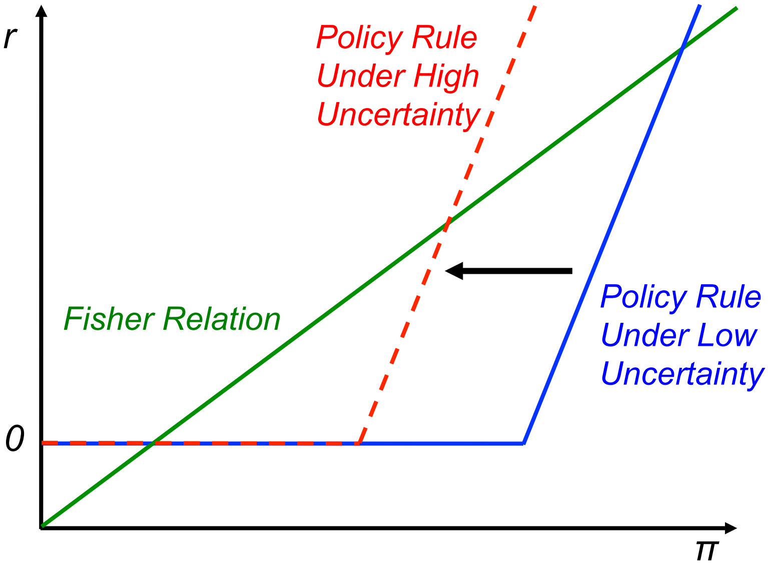




More volatile inflation $\Rightarrow$ Higher volatility in desired rates

$\Rightarrow$ Raises expected mean of **actual** rates

General-Equilibrium Effects of Contractionary Bias



Removing the Contractionary Bias

Simple history-dependent rule eliminates bias

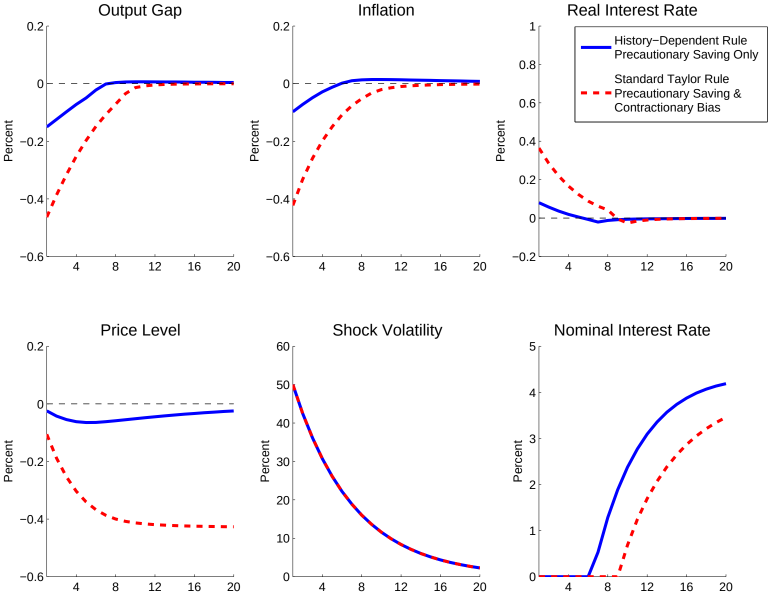
$$r_t^d = r + \phi_\pi\Big(\pi_t - \pi\Big) + \phi_x x_t + \phi_{pl}\Big(p_t - p^*\Big)$$

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

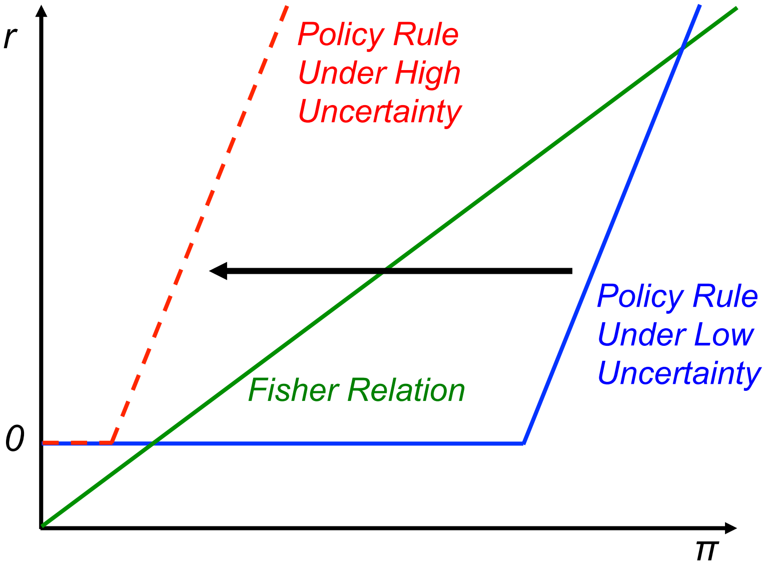
Higher-than-desired rates offset with lower rates in future

Removes bias by achieving inflation target on average

Decomposing the Impulse Responses



Contractionary Bias Can Cause Equilibrium Non-Existence



Should We Remove the Contractionary Bias?

Non-existence occurs for calibration needed to match data

Use history-dependent rule in calibration

- Minimum deviation that removes bias

Assumes central bank prevents disequilibrium in actual economy

- Continues to respond to economy at zero lower bound

Are uncertainty shocks a key driver of output and inflation?

Choose steady state & uncertainty shock volatility to match:

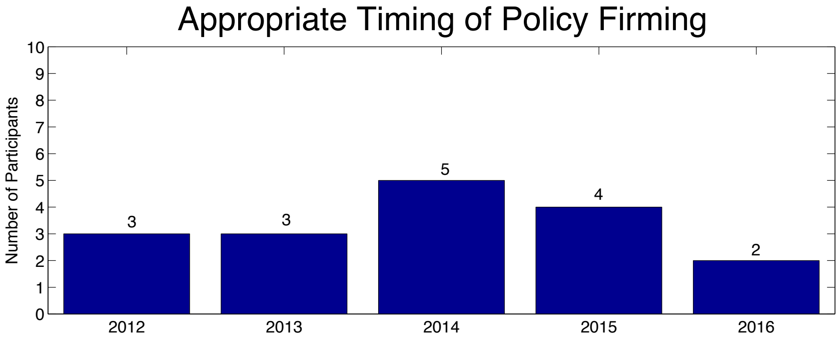
1. Unconditional volatility: x_t, π_t, r_t
2. Stochastic volatility: x_t, π_t, r_t
3. Number quarters at zero lower bound

Compare with 1984 - 2013 data

Assess fit via bootstrapped small-sample confidence intervals

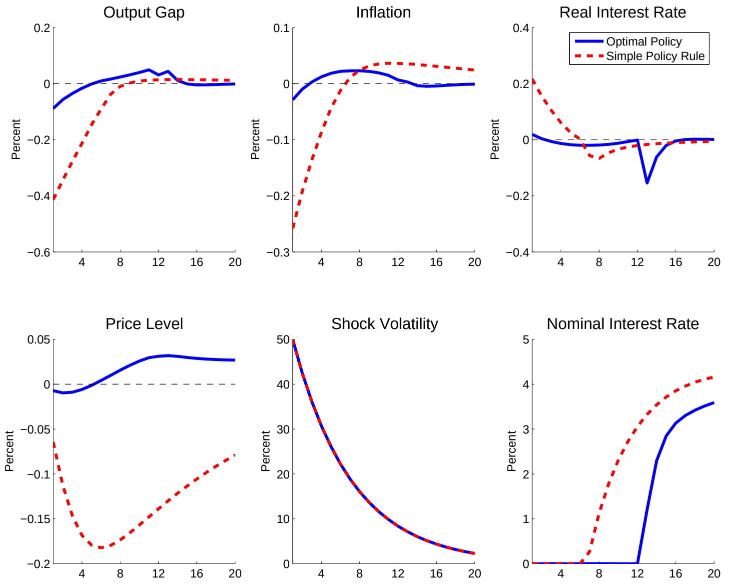
	Data	Baseline Model	
Moment	1984 - 2013	Mean	Confidence Interval
Unconditional Volatility			
x	**2.52**	**1.70**	**(0.89, 3.00)**
π	0.98	1.03	(0.62, 1.58)
r	2.91	2.42	(1.70, 3.28)
Stochastic Volatility			
x	**0.77**	**0.73**	**(0.28, 1.57)**
π	0.49	0.40	(0.19, 0.77)
r	0.74	0.72	(0.41, 1.16)
Quarters at Zero Lower Bound	**20**	**13**	**(2, 29)**

Survey of FOMC Participaints from January 2012

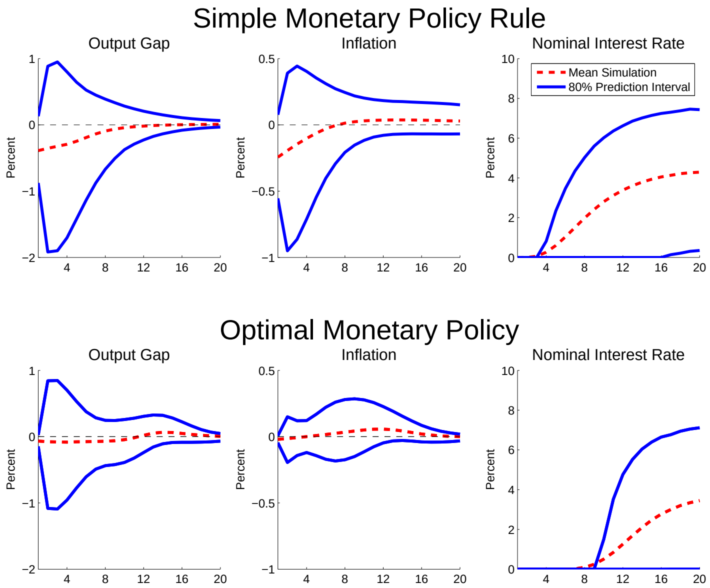


	Data	**Constant Shock Volatility**	
Moment	1984 - 2013	Mean	Confidence Interval
Unconditional Volatility			
x	**2.52**	**0.93**	**(0.72, 1.21)**
π	0.98	0.62	(0.49, 0.77)
r	2.91	1.89	(1.53, 2.29)
Stochastic Volatility			
x	**0.77**	**0.23**	**(0.12, 0.38)**
π	0.49	0.14	(0.09, 0.22)
r	0.74	0.40	(0.25, 0.58)
Quarters at Zero Lower Bound	**20**	**5**	**(0, 13)**

Impulse Responses Under Optimal Monetary Policy



Possible Outcomes Under Optimal Monetary Policy



	Simple Rule	Optimal Policy	
Moment	Mean	Mean	Confidence Interval
Unconditional Volatility			
x	**1.70**	**0.51**	**(0.03, 1.39)**
π	1.03	0.14	(0.01, 0.42)
r	2.42	2.65	(1.87, 3.60)
Stochastic Volatility			
x	**0.73**	**0.39**	**(0.03, 1.00)**
π	0.40	0.10	(0.01, 0.29)
r	0.72	0.78	(0.46, 1.24)
Quarters at Zero Lower Bound	**13**	**19**	**(2, 44)**

Conclusions

Zero lower bound crucial in transmitting effects of uncertainty

Form of monetary policy reaction function is crucial

Policy must commit to responding if bad shocks are realized

Additional Details

Representative Household

Household maximizes lifetime utility from consumption and leisure

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

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

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

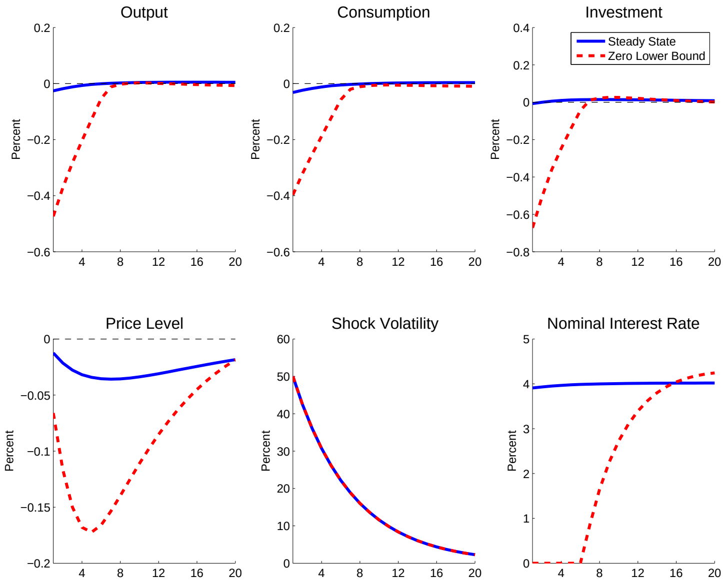
Model Summary

Model summarized by consumption Euler equation and NK Philips Curve

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

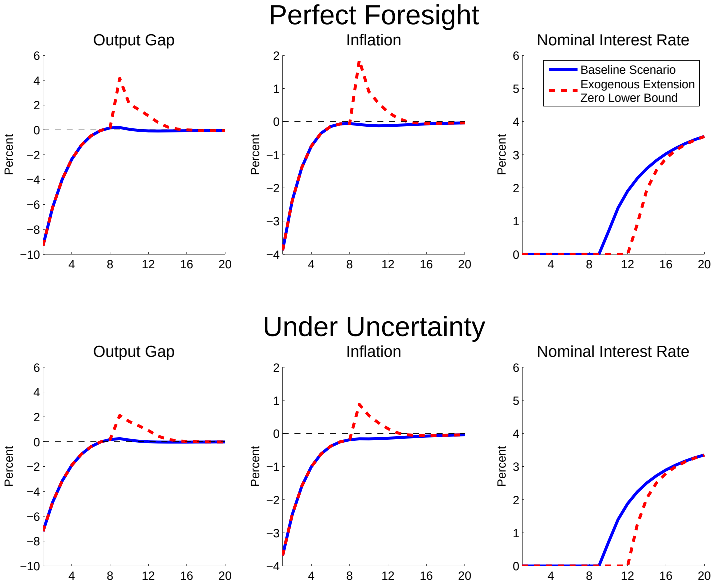
$$\phi_P \left(\frac{\Pi_t}{\Pi} - 1 \right) \left(\frac{\Pi_t}{\Pi} \right) = (1-\theta) + \theta \Xi_t$$
$$+ \phi_P E_t \left\{ M_{t+1} \frac{Y_{t+1}}{Y_t} \left(\frac{\Pi_{t+1}}{\Pi} - 1 \right) \left(\frac{\Pi_{t+1}}{\Pi} \right) \right\}$$

Impulse Responses to Uncertainty Shock with Capital



	Data	No Zero Lower Bound	
Moment	1984 - 2013	Mean	Confidence Interval
Unconditional Volatility			
x	2.52	1.24	(0.80, 1.79)
π	0.98	0.83	(0.55, 1.17)
r	2.91		
Stochastic Volatility			
x	0.77	0.41	(0.22, 0.70)
π	0.49	0.28	(0.28, 0.48)
r	0.74		
Quarters at Zero Lower Bound	20		

Our Solution to the “Forward Guidance Puzzle”



Two Steady States & Numerical Convergence

Gavin, Keen, Richter, Throckmorton (2015)

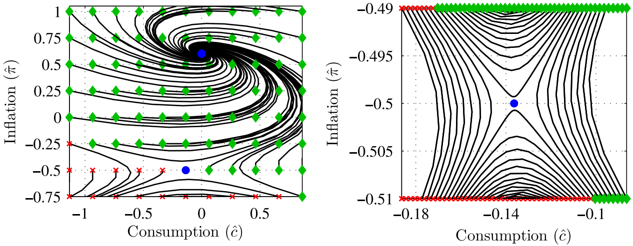


Fig. 16. Convergence paths to the steady-state equilibria (circles) in the deterministic version of Model 1. A diamond denotes an initial conjecture that converges to the positive inflation steady state, and a cross denotes an initial conjecture that asymptotically converges to a corner solution where there is no consumption.

Numerical Convergence Under Uncertainty

Gavin, Keen, Richter, Throckmorton (2015)

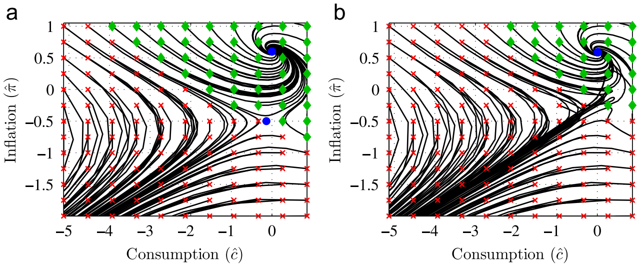


Fig. 18. Convergence paths to steady states (circles) for the perfect foresight and stochastic models when $\beta_{-1} = \overline{\beta}$. A diamond denotes an initial conjecture that converges to the positive inflation steady state, and a cross denotes an initial conjecture that asymptotically converges to a corner solution where there is no consumption. (a) Perfect foresight Model 1, (b) stochastic Model 1.