State-Dependent Pricing and the Paradox of Flexibility

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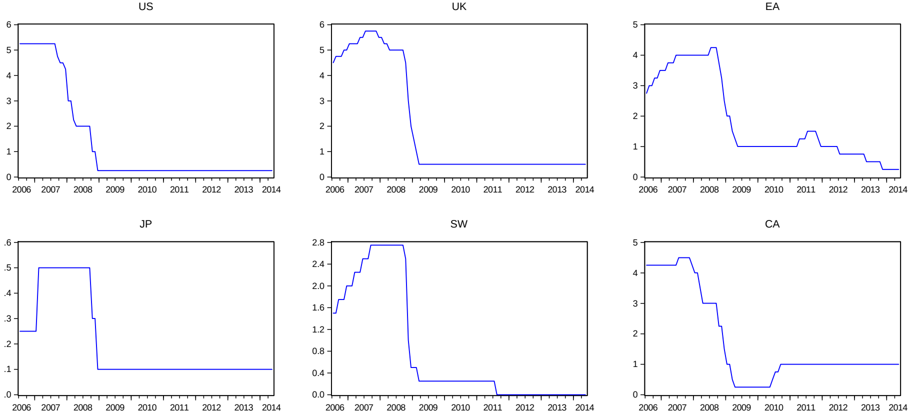
Policy rates in major economies have been constant for years



In theory leading to amplification of shocks

- Recent literature shows that ZLB leads to the amplification of shocks:
  - Eggertsson and Krugman (2012): "paradoxes of thrift, toil, and flexibility"
  - Woodford (2011), Christiano, Eichenbaum, Rebelo (2011): "fiscal multiplier is large at ZLB"
  - Erceg and Linde (2014), Del Negro et al. (2013), Kiley (2014) ...

- Mechanism:
  - If $i_t = i$, then $c_t = \gamma^{-1} \sum_{k=1}^{T} E_t \pi_{t+k} + c_{t+T} \approx \gamma^{-1} \left(E_t p_{t+T} - p_t \right)$
  - $G_t \uparrow \Rightarrow C_t \uparrow$ provided monetary policy implies that the price level at exit exceeds the current price level
  - Then $\frac{\partial Y_t}{\partial G_t} > 1$

The paradox of flexibility

- The "paradox of flexibility": with $i_t = i$ increasing price or wage flexibility leads to a larger response of cumulative inflation and larger amplification

- I.e. it leads to a deeper recession and deflation when hit by a deflationary shock (Eggertsson and Krugman)

- Also leads to a larger government spending multiplier (Christiano et. al., Erceg and Linde)

What role for the form of nominal price rigidities?

- These papers all assume Calvo price setting
    - Ohanian (2012): Results depend on price rigidity in Calvo model, but incentives to change prices rise during turbulent/crisis periods
- In general the details of price setting at the micro level may matter a great deal for the dynamics of aggregate variables
- E.g. in a fixed menu cost model *a la* Golosov-Lucas (2007) a strong selection effect makes the price level a lot more flexible than in a Calvo model with the same average frequency of adjustment

This paper

- Looks at the effects of a shock to government spending when the nominal interest rate is held constant for T periods
- Across three pricing models: Calvo, fixed menu cost, and encompassing model
- Encompassing model is "smoothly state-dependent" (Costain and Nakov, 2011): adjustment probability is a smoothly increasing function of the adjustment gain
- We look at different monetary policy rules with/without CIR

Main finding

- With constant interest rates SDP can produce even larger amplification than Calvo
- The surprising results at the ZLB are a feature of sticky prices, not just an artifact of Calvo.
- Firm idiosyncratic shocks also affect aggregate price flexibility and amplification (Vavra, 2012)

A very large literature

- ZLB/constant rate in (large) DSGE models
- Normative analyses
- Empirical studies about amplification at ZLB
- We do not pretend to say anything about what happened in reality; we only try to shed light on a theoretical mechanism

Outline of the talk

1. Introduction ✓
2. Model
3. Results
4. Conclusions

Model: added ingredients

- Model is a two-step deviation from textbook New Keynesian model:
  - Idiosyncratic shocks
  - State-dependent pricing
- We focus on dynamics under a constant interest rate for T periods (anticipated shocks to Taylor rule, Galí 2012)

Model: households

- The household's period utility is

$$\frac{C_t^{1-\gamma}}{1-\gamma} - \frac{\chi N_t^{1+\psi}}{1+\psi} + \log(M_t/P_t)$$

- Consumption is a CES aggregate of differentiated products

$$C_t = \left\{ \int_0^1 C_{it}^{\frac{\epsilon-1}{\epsilon}} di \right\}^{\frac{\epsilon}{\epsilon-1}}$$

- The household's nominal period budget constraint is

$$\int_0^1 P_{it} C_{it} di + M_t + R_t^{-1} B_t = W_t N_t + M_{t-1} + T_t + B_{t-1}$$

Model: household optimality conditions

- Households choose C_{it}, N_t, B_t, M_t to maximize expected utility, subject to the budget constraint

- Optimal consumption across the differentiated goods

$$C_{it} = (P_t/P_{it})^{\epsilon} C_t$$
$$P_t \equiv \left[\int_0^1 P_{it}{}^{1-\epsilon} di \right]^{\frac{1}{1-\epsilon}}$$

- Optimal labor supply, consumption, and money use

$$\chi C_t^{\gamma} N_t^{\psi} = W_t/P_t$$
$$1 = \beta R_t E_t \left[P_t C_{t+1}^{-\gamma} / \left(P_{t+1} C_t^{-\gamma} \right) \right]$$
$$M_t/P_t = C_t^{\gamma} R_t / (R_t - 1)$$

Model: monopolistic competitor firms

- Firm i produces output $Y_{it} = A_{it} N_{it}$
- Productivity is **idiosyncratic**, $\log A_{it} = \rho_A \log A_{it-1} + \varepsilon^a_{it}$, $\varepsilon^a_{it} \sim N(0, \sigma_a^2)$
- Firm i faces demand from households, and the government, $Y_{it} = C_{it} + G_{it}$
- The government's consumption basket is also a CES, $G_t = \left\{ \int_0^1 G_{it}^{\frac{\epsilon-1}{\epsilon}} di \right\}^{\frac{\epsilon}{\epsilon-1}}$

Model: monopolistic competitor firms

- Demand curve, $Y_{it} = (C_t + G_t) P_t^{\epsilon} P_{it}^{-\epsilon}$
- Period profits, $U_{it} = P_{it} Y_{it} - W_t N_{it}$
- Discount rate, $Q_{t,t+1} = \beta \frac{P_t C_t^{-\gamma}}{P_{t+1} C_{t+1}^{-\gamma}}$

Model: firm value function

- Value function $V(P, A, \Omega) =$

  $U(P, A, \Omega) + \beta E \left\{ Q_{t,t'} \left[V(P, A', \Omega') + EG(P, A', \Omega') \right] \middle| A, \Omega \right\}$ where

  $EG(\cdot)$ is the *expected gain* from adjustment

$$EG(P, A', \Omega') \equiv \lambda \left[\frac{D(P, A', \Omega')}{W(\Omega')} \right] D(P, A', \Omega')$$

$$D(P, A', \Omega') \equiv \max_P V(P, A', \Omega') - V(P, A', \Omega')$$

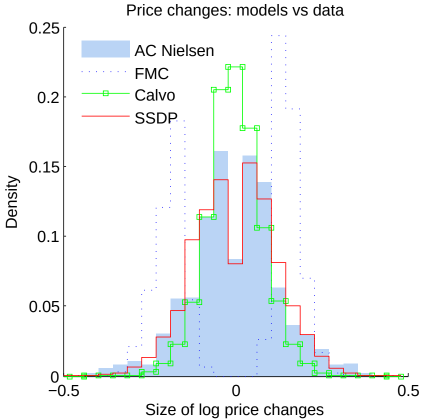
Model: adjustment function

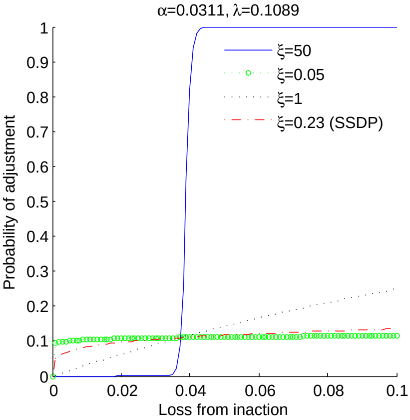
- $\lambda(L)$ increases with the gain from adjustment L
- In particular, we postulate

$$\lambda(L) \equiv \frac{\bar{\lambda}}{(1-\bar{\lambda}) + \bar{\lambda}(\alpha/L)^{\xi}}$$

- where L is the relevant state
- With $\xi \to 0$, $\lambda(L) = \bar{\lambda}$ Calvo
- With $\xi \to \infty$, $\lambda(L) = \mathbf{1}\{L \geq \alpha\}$ Fixed menu cost

Model: adjustment function and histogram fit





Model: monetary policy and government spending

- The monetary authority follows a Taylor rule

$$\frac{R_t}{R^*} = \left[\left(\frac{P_t/P_{t-1}}{\Pi^*}\right)^{\phi_\pi}\right]^{1-\phi_R}\left(\frac{R_{t-1}}{R^*}\right)^{\phi_R}\prod_{i=1}^{T}\exp(\varepsilon^R_{t-i})$$

  where ε^R_{t-i} are anticipated shocks

- Government spending

$$\log\left(\frac{G_t}{G^*}\right) = \rho_G \log\left(\frac{G_{t-1}}{G^*}\right) + \varepsilon^G_t$$

  with $\varepsilon^G_t \sim N(0, \sigma^2_G)$.

Calibration

Discount factor	$\beta^{-12} = 1.04$	Golosov-Lucas (2007)
CRRA	$\gamma = 2$	Ibid.
Elast. of subst.	$\epsilon = 7$	Ibid.
Labor supply elast.	$\psi = 1$	
Inflation target	$\Pi^* = 1$	AC Nielsen
Inflation reaction	$\phi_\pi = 2$	
Length of CIR period	$T = \{24, 36\}$	Erceg and Linde (2014)
Persistence of G_t	$\rho_G = 0.9$	Ibid.
Persistence of A_{it}	$\rho_A = 0.9$	Costain-Nakov (2011)
Std. dev. of A_{it}	$\sigma_A = 0.1$	Ibid.
State dependence	$\xi = \{0, 0.23, 1\}$	Ibid.
Fixed menu cost	$\alpha = 0.04$	Ibid.
Calvo frequency	$\bar{\lambda} = 0.1$	Nakamura-Steinsson (2008)

Preliminaries: textbook Calvo model

- The flexible price multiplier is (Woodford, 2011)

$$\Gamma = \frac{\gamma}{\gamma + \psi} \leq 1$$

- Log-linearized consumption Euler equation $\left(g_t = \frac{G_t - \bar{G}}{\bar{Y}}; \sigma = \gamma^{-1}\right)$:

$$y_t - g_t = E_t\left(y_{t+1} - g_{t+1}\right) - \sigma\left(i_t - E_t\pi_{t+1} - \bar{r}\right)$$

- Phillips curve

$$\pi_t = \kappa \sum_{j=0}^{\infty} \beta^j E_t(y_t - \Gamma g_t),$$

where $\kappa = (1-\alpha)(1-\alpha\beta)(\gamma+\psi)/\alpha$

Preliminaries: textbook Calvo model with Taylor rule

- Under a simple Taylor rule we have

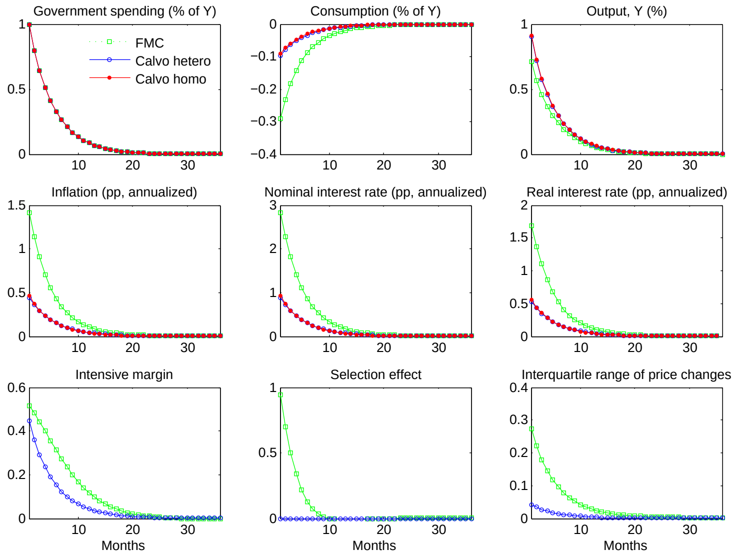
$$\gamma\left(\mu^{TR}-1\right)g_t=(\phi_\pi-1)\left(p_t-\lim_{T\to\infty}E_t p_{t+T}\right)$$

- Solution

$$\mu^{TR}=1+\frac{-\left(\frac{\phi_\pi-\rho}{1-\beta\rho}\kappa+\phi_C\right)(1-\Gamma)}{(1-\rho)\gamma+\left(\frac{\phi_\pi-\rho}{1-\beta\rho}\kappa+\phi_C\right)}<1$$

- Higher κ (more flexibility) leads to smaller μ^{TR}

Results: idiosyncratic shocks + Taylor rule: FMC vs Calvo



Preliminaries: textbook Calvo model with CIR

- Dynamics under CIR/ZLB

$$\begin{aligned}\gamma\left(y_t - g_t\right) &= \gamma E_t\left(y_{t+1} - g_{t+1}\right) + E_t\pi_{t+1} \\ y_t - \Gamma g_t &= \frac{\pi_t - \beta E_t\pi_{t+1}}{\kappa}\end{aligned}$$

- General solution

$$y_t - g_t = \frac{\kappa\left(1-\Gamma\right)\rho}{\left(1-\rho\right)\left(1-\beta\rho\right)\gamma - \kappa\rho} g_t + a_1\lambda_1^t + a_2\lambda_2^t$$

Preliminaries: Woodford's special stochastic case

- Focus on case $\Delta = (1-\rho)(1-\beta\rho)\gamma - \kappa\rho > 0$
- Then $\lambda_1, \lambda_2 > 1$ and so setting $a_1, a_2 = 0$ ensures a unique bounded solution:

$$y_t = g_t + \frac{\kappa(1-\Gamma)\rho}{\Delta} g_t = \mu^{ZLB} g_t$$

- Paradox of flexibility: as $\kappa \uparrow$, $\Delta \to 0^+$ then $\mu^{ZLB} \to +\infty$
- Ohanian: paradox is limited to $\Delta > 0$, otherwise for larger κ, μ^{ZLB} is not well defined due to multiplicity of equilibria

Preliminaries: Erceg and Linde's perfect foresight solution

- Difference equations valid only up to T; thereafter CB follows its policy rule which determines equilibrium upon liftoff:

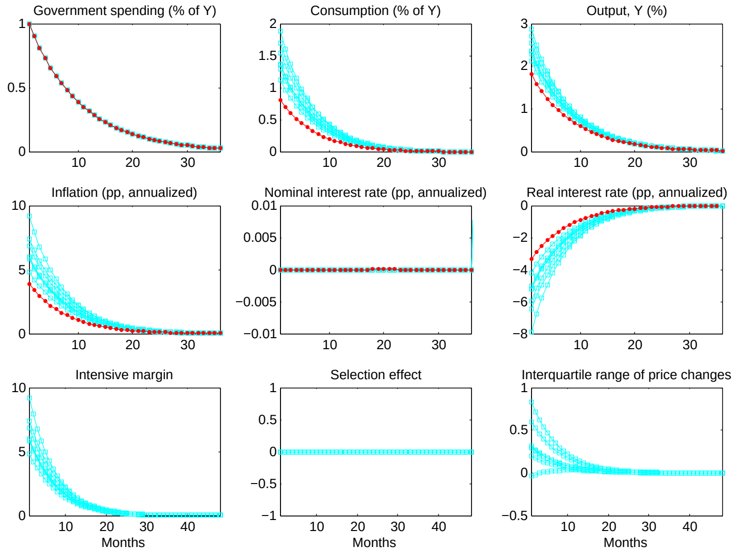
$$
\begin{aligned}
y_t \quad = \quad & \mu^{ZLB} g_t - \frac{\kappa\left(1-\Gamma\right)\rho}{\Delta}\frac{1-\rho\beta\lambda_1}{1-\beta\lambda_1^2}\left(\frac{\rho}{\lambda_1}\right)^{T-t} g_t + \\
& \frac{\pi_{T+1}+\left(1-\beta\lambda_1\right)\gamma\left(y_{T+1}-g_{T+1}\right)}{\left(1-\beta\lambda_1^2\right)\gamma\lambda_1^{T-t}},
\end{aligned}
$$

- When T sufficiently large and κ such that $\Delta \to 0^+$, solution close to $\mu^{ZLB}(\rho < \lambda_1 < 1)$

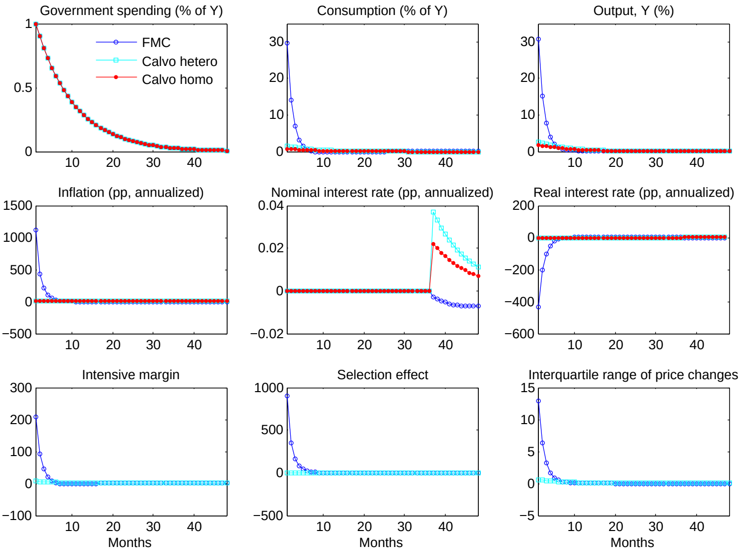
- For κ larger, such that $\Delta < 0$, $\rho/\lambda_1 > 1$, backward explosion

- The multiplier grows with T, and the Paradox of flexibility is established for any κ

Results: Calvo + idiosyncratic shocks + CIR



Results: FMC + idiosyncratic shocks + CIR



Conclusions

- Large amplification of shocks with CIR/ZLB is present also with SDP
- With active monetary policy under SDP fiscal multiplier is closer to flexible-prices (smaller) than Calvo
- But with CIR/ZLB it can be much larger, "paradox of flexibility"
- With CIR firm-level shocks increase aggregate price level responsiveness even in the Calvo model