

# The Return of the Gibson Paradox

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Conference to honor Warren Weber

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# Introduction

- Previous work suggested a decline in inflation persistence (e.g. Cogley, Sargent, and Primiceri 2010)
- If so, Barsky's (*JME* 1987) analysis says we should anticipate a return of Gibson's paradox.
- We show that Gibson's paradox has returned, and we use a new-Keynesian model to explain why.

## Gibson's paradox

- Prior to WWI, nominal interest rates were highly correlated with the price level but uncorrelated with inflation.
- Keynes (1930) called it Gibson's paradox in honor of A.H. Gibson (1923), whom Keynes said first detected the pattern.
- Keynes and Gibson interpreted this as contradicting the Fisher equation, as did later authors.

## Gibson's paradox (con't.)

- Friedman and Schwartz (1982): “The relation holds over neither World War I nor World War II. It is dubious whether it holds for the post-World War II period, particularly since the middle 1960s. For the period our data cover, it holds clearly and unambiguously only for the period from 1880 to 1914, and less clearly for the interwar period.”
- Barksy (1987) corroborates Friedman and Schwartz's findings and shows that Gibson's paradox vanished by the early 1970s.
- Barksy also demonstrates that the paradox is closely linked to inflation persistence, appearing when inflation is weakly persistent and disappearing when it is strongly persistent.

# Characterizing Gibson's paradox, 1

- We characterize the Gibson paradox in terms of low-frequency comovements between inflation and nominal interest within a finite-dimensional vector autoregression.
- Let  $\{y_t, z_t\}$  be a mean-zero covariance-stationary random process.
- For us,  $y_t$  is an interest rate,  $R_t$  and  $z_t$  is an inflation rate,  $\pi_t$ .

## Characterizing Gibson's paradox, 2

- We consider the infinite-order least-squares projection of  $y_t$  onto past, present, and future values of  $z_t$ ,

$$y_t = \sum_{j=-\infty}^{\infty} h_j z_{t-j} + \epsilon_t, \quad (1)$$

where  $\epsilon_t$  satisfies the orthogonality conditions

$$E\epsilon_t z_{t-j} = 0 \quad \forall j.$$

- We study the sum of distributed-lag coefficients,

$$\tilde{h}(0) = \sum_{j=-\infty}^{\infty} h_j. \quad (2)$$

## Lucas-Whiteman characterization

- The Gibson paradox is an apparent failure of Fisher equation.
- Lucas (1980) characterized the Fisher equation by plotting moving averages of an interest rate against a moving average of an inflation rate: he took their lying on a 45 degree line to vindicate Fisher.
- Whiteman (1984) showed  $\tilde{h}(0) \approx 1$  means that Lucas's graphs of moving averages of interest rate plotted against moving average of inflation lie on 45 degree line.
- We use  $\tilde{h}(0) \approx 0$  to characterize the Gibson paradox.

## Gibson's paradox in frequency domain

- Let  $S_y(\omega)$  and  $S_z(\omega)$  be spectral densities of  $y$  and  $z$ , and let  $S_{yz}(\omega)$  be the cross-spectrum.
- The Fourier transform of  $\{h_j\}$  can be expressed as

$$\tilde{h}(\omega) = \sum_{j=-\infty}^{\infty} h_j e^{-i\omega j} = \frac{S_{yz}(\omega)}{S_z(\omega)}. \quad (3)$$

- The sum of distributed-lag coefficients is

$$\tilde{h}(0) = \sum_{j=-\infty}^{\infty} h_j = \frac{S_{yz}(0)}{S_z(0)}. \quad (4)$$

- We use this formula because the spectral density matrix is easy to calculate for VARs and DSGE models.

## Interpreting $\tilde{h}(0)$

- $\tilde{h}(0)$  is the coefficient in a regression of zero-frequency component of  $R$  on zero-frequency components of  $\pi$ .
- The Gibson paradox emerges when  $\tilde{h}(0)$  is zero or negative and vanishes when  $\tilde{h}(0)$  is 1.
- No paradox: A coefficient of 1 means that a persistent increase in  $\pi$  is associated with a persistent increase in  $R$  of the same amount, in accordance with the Fisher relation.
- A paradox emerges when  $\pi$  isn't persistent.
  - E.g., suppose  $\pi$  is white noise, so that expected inflation is constant.
  - All variation in  $\pi$  is unexpected, hence noise for the Fisher relation.
  - Noise in the regressor biases its coefficient toward zero.

# Smoothness prior

- Vacuity of restriction for infinite dimensional VAR.
- Cross-frequency and cross-equation restrictions.
- Smoothness of  $\tilde{h}(\omega)$  across frequencies  $\omega \in [-\pi, \pi]$  is implied by finite dimensional VAR.

# Inflation persistence

- Following Barsky (1987), we also want to keep our eye on inflation persistence.
- We measure inflation persistence by its first-order autocorrelation,  $FACF_{\pi}$ .
- Similar results emerge using the normalized spectrum at frequency zero.

# Empirical evidence on the return of Gibson's paradox

- We estimate a time-varying VAR a la Cogley and Sargent (2005) and Primiceri (2005)
- Data: inflation, nominal interest, output growth, and money growth for 1968.Q1-2007.Q4.
- Earlier data are used as a training sample for eliciting a prior.
- To ignore effects of the financial crisis, the sample ends at 2007.Q4.

## VAR with drifts

$$\begin{aligned} Y_t &= B_{0,t} + B_{1,t}Y_{t-1} + \dots + B_{p,t}Y_{t-p} + \epsilon_t \\ &\equiv X_t' \theta_t + \epsilon_t. \end{aligned}$$

- Drifting coefficients:

$$\theta_t = \theta_{t-1} + \eta_t,$$

where  $\eta_t \sim N(0, Q)$  (plus reflecting barriers).

- Drifting volatilities:

Innovations  $\epsilon_t$  are normally distributed with mean zero and a time-varying covariance matrix  $\Omega_t$  that obeys

$$\text{Var}(\epsilon_t) \equiv \Omega_t = A_t^{-1} H_t (A_t^{-1})' \quad (5)$$

## VAR, cont'd

Time-varying matrices  $H_t$  and  $A_t$ :

$$H_t \equiv \begin{bmatrix} h_{1,t} & 0 & 0 & 0 \\ 0 & h_{2,t} & 0 & 0 \\ 0 & 0 & h_{3,t} & 0 \\ 0 & 0 & 0 & h_{4,t} \end{bmatrix}, \quad A_t \equiv \begin{bmatrix} 1 & 0 & 0 & 0 \\ \alpha_{21,t} & 1 & 0 & 0 \\ \alpha_{31,t} & \alpha_{32,t} & 1 & 0 \\ \alpha_{41,t} & \alpha_{42,t} & \alpha_{43,t} & 1 \end{bmatrix}$$

with  $h_{i,t}$  being geometric random walks:

$$\ln h_{i,t} = \ln h_{i,t-1} + \nu_{i,t}$$

## VAR, cont'd

$$\alpha_t = \alpha_{t-1} + \tau_t$$

where  $\alpha_t \equiv [\alpha_{21,t}, \alpha_{31,t}, \dots, \alpha_{43,t}]'$ .  $[u_t', \eta_t', \tau_t', \nu_t']'$  is distributed as

$$\begin{bmatrix} u_t \\ \eta_t \\ \tau_t \\ \nu_t \end{bmatrix} \sim N(0, V), \quad V = \begin{bmatrix} I_4 & 0 & 0 & 0 \\ 0 & Q & 0 & 0 \\ 0 & 0 & S & 0 \\ 0 & 0 & 0 & Z \end{bmatrix}$$

and

$$Z = \begin{bmatrix} \sigma_1^2 & 0 & 0 & 0 \\ 0 & \sigma_2^2 & 0 & 0 \\ 0 & 0 & \sigma_3^2 & 0 \\ 0 & 0 & 0 & \sigma_4^2 \end{bmatrix},$$

where  $u_t$  is such that  $\epsilon_t \equiv A_t^{-1} H_t^{\frac{1}{2}} u_t$ .

## Empirical evidence (con't.)

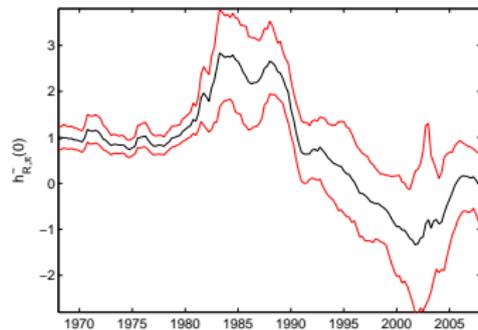
- We describe the evolution of low-frequency comovements between inflation and nominal interest by constructing a local-to-date  $t$  approximation of the sum of projection coefficients,

$$\tilde{h}_{R\pi,t|T}(0) = \frac{S_{R\pi,t|T}(0)}{S_{\pi,t|T}(0)}, \quad (6)$$

using smoothed estimates of the time-varying VAR conditioned on the full sample.

- We also construct a local-to-date  $t$  approximation to the first-order autocorrelation for inflation  $FACF_{\pi}$  implied by the VAR.

INFLATION AND NOMINAL INTEREST RATE: LONG-RUN LINK



INFLATION PERSISTENCE

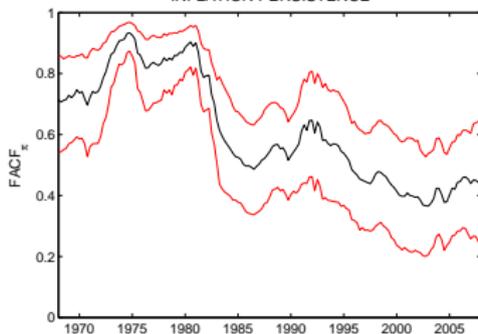


Figure: Median and 68% central posterior bands for  $\tilde{h}_{R,\pi}(0)$  (top panel) and  $FACF_{\pi}$  (bottom panel).

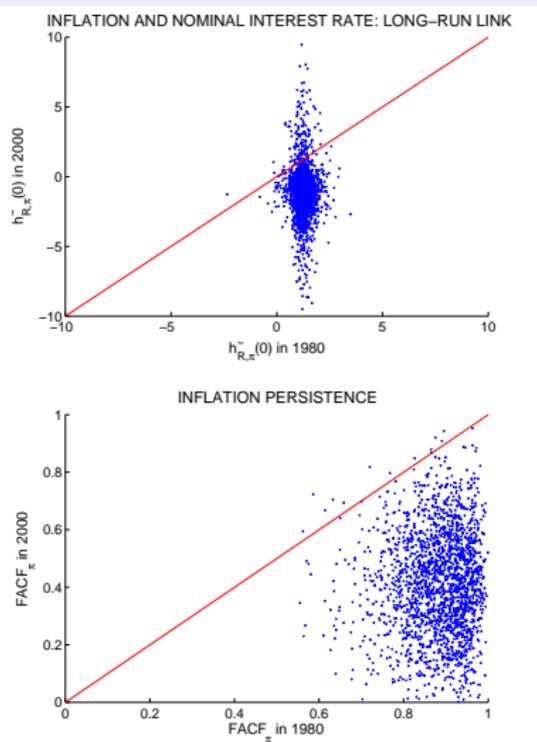


Figure: Joint posterior distributions for  $\tilde{h}_{R,\pi}(0)$  (top panel) and  $FACF_{\pi}$  (bottom panel), 1980-2000.

## Empirical evidence (con't.)

- No Gibson paradox is evident in the 1970s or 1980s, when the sum of lag coefficients is near or above 1.
- A Gibson paradox reappears after 1995, when  $h_{R\pi,t|T}(0)$  falls to the neighborhood of 0.
- Indeed, for the year 2000, the preponderance of probability mass lies below 0.
- Consistent with Barsky (1987), the paradox emerges when inflation is weakly persistent and vanishes when it is strongly persistent.

# A structural interpretation

## Game plan

- Estimate a new Keynesian model for two subperiods, 1968.Q1-1983.Q4 and 1995.Q1-2007.Q4
- Verify that it approximates  $\tilde{h}_{R,\pi}(0)$  and  $FACF_{\pi}$  for the periods before 1980 and after 1995.
- Conduct a number of structural counterfactuals to identify what caused the return of Gibson's paradox

## A new Keynesian model

Inspired by Rotemberg (1982) and Ireland (2004)

$$\pi_t = \beta(1 - \alpha_\pi) E_t \pi_{t+1} + \beta \alpha_\pi \pi_{t-1} + \kappa x_t - \frac{1}{\tau} e_t$$

$$x_t = (1 - \alpha_x) E_t x_{t+1} + \alpha_x x_{t-1} - \sigma(R_t - E_t \pi_{t+1}) + \sigma(1 - \xi)(1 - \rho_a) a_t$$

$$\Delta m_t = \pi_t + z_t + \frac{1}{\sigma\gamma} \Delta x_t - \frac{1}{\gamma} \Delta R_t + \frac{1}{\gamma} (\Delta \chi_t - \Delta a_t)$$

$$\tilde{y}_t = x_t + \xi a_t$$

$$\Delta \tilde{y}_t = \tilde{y}_t - \tilde{y}_{t-1} + z_t$$

$$e_t = \rho_e e_{t-1} + \varepsilon_{et}, \text{ with } \varepsilon_{et} \sim N(0, \sigma_e^2)$$

$$a_t = \rho_a a_{t-1} + \varepsilon_{at}, \text{ with } \varepsilon_{at} \sim N(0, \sigma_a^2)$$

$$\chi_t = \rho_\chi \chi_{t-1} + \varepsilon_{\chi t}, \text{ with } \varepsilon_{\chi t} \sim N(0, \sigma_\chi^2)$$

$$\Delta \ln(Z_t) \equiv z_t = \varepsilon_{zt}, \text{ with } \varepsilon_{zt} \sim N(0, \sigma_z^2)$$

## A new Keynesian model (con't.)

- Variables (expressed as log deviations from steady-state values)

$\pi_t$  = inflation

$R_t$  = nominal interest rate

$\Delta m_t$  = money growth

$x_t$  = output gap

$\tilde{y}_t$  = detrended output

$\Delta \tilde{y}_t$  = output growth

- Shocks

$e_t$  = markup

$a_t$  = aggregate demand (preference)

$\chi_t$  = money demand

$Z_t$  = technology

## A new Keynesian model (con't.)

- Parameters

$\beta$  = discount factor

$\alpha_\pi$  = indexation of prices to past inflation

$\alpha_x$  = habit formation

$\kappa$  = slope of the Phillips curve

$\sigma$  = elasticity of intertemporal substitution

$\tau$  = cost of adjusting prices

$\xi$  = inverse elasticity of labor supply

$\gamma$  = inverse interest elasticity of money demand

## A new Keynesian model (con't.)

### Monetary policy

- A monetary-aggregate rule for 1968.Q1-1983.Q4

$$\Delta m_t = \rho_m \Delta m_{t-1} + (1 - \rho_m) (\phi_\pi \pi_t + \phi_x x_t) + \varepsilon_{mt}, \quad \varepsilon_{mt} \sim N(0, \sigma_m^2)$$

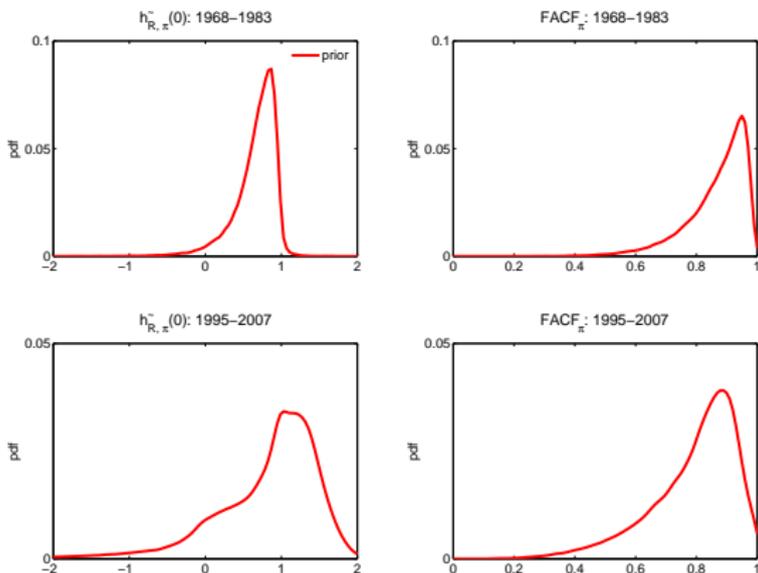
- An interest-rate rule for 1995.Q1-2007.Q4

$$R_t = \rho_r R_{t-1} + (1 - \rho_r) (\psi_\pi \pi_t + \psi_x x_t) + \varepsilon_{Rt}, \quad \varepsilon_{Rt} \sim N(0, \sigma_R^2)$$

## Prior predictive analysis

- Priors for the two subsamples will be shown momentarily.
- Although priors for structural parameters and shocks are the same across subsamples, priors on policy coefficients differ because the policy instruments differ.
- This alters the implied priors for  $\tilde{h}_{R,\pi}(0)$  and  $FACF_{\pi}$ .
- We therefore want to demonstrate that
  - The model is capable of matching  $\tilde{h}_{R,\pi}(0)$  and  $FACF_{\pi}$  for *some* parameters in the support of the respective priors.
  - The priors do not hardwire our findings.

## Prior predictive analysis (con't.)



Centered 90 percent credible sets

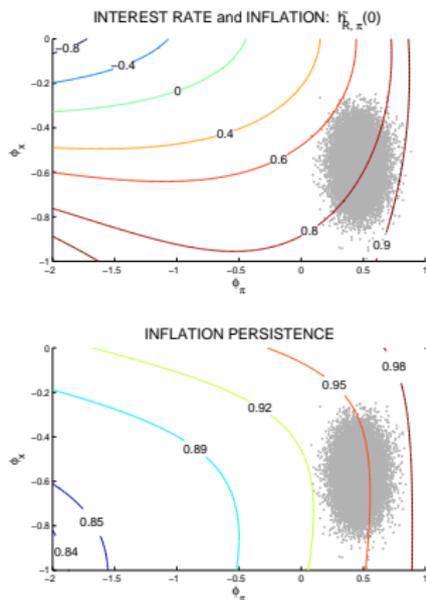
- $\tilde{h}_{R,\pi}(0)$ : (0.13,0.96) and (-0.62,1.6)
- $FACF_{\pi}$ : (0.67,0.97) and (0.51,0.96)

# Prior and posterior densities - 1968Q1-1983Q4

description	coefficient	Prior				Posterior		
		density	domain	mean	[5 <sup>th</sup> ; 95 <sup>th</sup> ]	mean	[5 <sup>th</sup> ; 95 <sup>th</sup> ]	[5 <sup>th</sup> ; 95 <sup>th</sup> ]
discount factor	$\beta$	beta	[0,1]	0.99	[0.981 ; 0.997]	0.989	[0.980 ; 0.997]	[0.980 ; 0.997]
NKPC backward-looking component	$\alpha_\pi$	beta	[0,1]	0.5	[0.171 ; 0.826]	0.864	[0.765 ; 0.972]	[0.765 ; 0.972]
NKPC slope	$\kappa$	gamma	$\mathbb{R}^+$	0.15	[0.104 ; 0.202]	0.108	[0.070 ; 0.141]	[0.070 ; 0.141]
price adjustment cost	$\tau$	gamma	$\mathbb{R}^+$	3	[1.560 ; 4.811]	2.706	[1.427 ; 3.987]	[1.427 ; 3.987]
IS curve backward-looking component	$\alpha_\chi$	beta	[0,1]	0.5	[0.171 ; 0.826]	0.390	[0.335 ; 0.446]	[0.335 ; 0.446]
elasticity of intertemporal substitution	$\sigma$	gamma	$\mathbb{R}^+$	0.15	[0.104 ; 0.202]	0.100	[0.069 ; 0.131]	[0.069 ; 0.131]
inverse of labour supply elasticity	$\xi$	gamma	$\mathbb{R}^+$	3	[1.560 ; 4.811]	2.123	[1.282 ; 2.923]	[1.282 ; 2.923]
interest elasticity of money demand	$\gamma$	gamma	$\mathbb{R}^+$	3	[1.560 ; 4.811]	2.705	[2.124 ; 3.248]	[2.124 ; 3.248]
money growth response to inflation	$\phi_\pi$	normal	$\mathbb{R}$	0.5	[0.335 ; 0.665]	0.466	[0.305 ; 0.625]	[0.305 ; 0.625]
money growth response to output gap	$\phi_\chi$	normal	$\mathbb{R}$	-5	[-.665 ; -.335]	-.566	[-.721 ; -.398]	[-.721 ; -.398]
money growth smoothing	$\rho_m$	beta	[0,1]	0.5	[0.171 ; 0.826]	0.598	[0.478 ; 0.752]	[0.478 ; 0.752]
persistence of mark up shock	$\rho_e$	beta	[0,1]	0.5	[0.171 ; 0.826]	0.136	[0.021 ; 0.246]	[0.021 ; 0.246]
persistence of demand shock	$\rho_a$	beta	[0,1]	0.5	[0.171 ; 0.826]	0.926	[0.872 ; 0.983]	[0.872 ; 0.983]
persistence money demand shock	$\rho_\chi$	beta	[0,1]	0.5	[0.171 ; 0.826]	0.656	[0.396 ; 0.910]	[0.396 ; 0.910]
standard deviation of mark up shock	$\sigma_e$	inv. gamma	$\mathbb{R}^+$	0.01	[0.004 ; 0.022]	.0098	[.0050 ; .0146]	[.0050 ; .0146]
standard deviation of demand shock	$\sigma_a$	inv. gamma	$\mathbb{R}^+$	0.01	[0.004 ; 0.022]	.0045	[.0030 ; .0060]	[.0030 ; .0060]
standard deviation of money demand shock	$\sigma_\chi$	inv. gamma	$\mathbb{R}^+$	0.01	[0.004 ; 0.022]	.0062	[.0032 ; .0093]	[.0032 ; .0093]
standard deviation of technology shock	$\sigma_z$	inv. gamma	$\mathbb{R}^+$	0.01	[0.004 ; 0.022]	.0063	[.0047 ; .0078]	[.0047 ; .0078]
standard deviation of policy shock	$\sigma_m$	inv. gamma	$\mathbb{R}^+$	0.01	[0.004 ; 0.022]	.0082	[.0069 ; .0095]	[.0069 ; .0095]
long-run link inflation-nominal interest rate	implied $\tilde{h}_R, \pi(0)$		$\mathbb{R}$	0.664	[0.134 ; 0.960]	0.788	[0.621 ; 0.924]	[0.621 ; 0.924]
inflation persistence	implied $FACF_\pi$		$\mathbb{R}$	0.867	[0.667 ; 0.973]	0.947	[0.911 ; 0.975]	[0.911 ; 0.975]

Note: Based on 1,000,000 posterior draws using the Metropolis-Hastings algorithm.

## The first subsample (con't.)



**Figure:** The scatter plots depict distributions of the features  $\tilde{h}_{R,\pi}(0)$  and  $FACF_\pi$  swept out by sampling from the joint posterior distribution of the response coefficients of money growth to inflation and the output gap. All other parameters are fixed at the posterior mean.

## Factors contributing to high inflation persistence during the first subsample

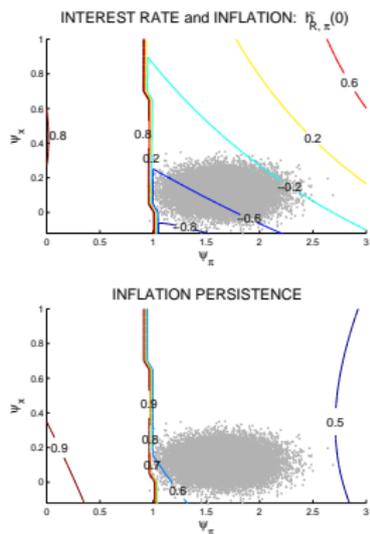
- A high degree of intrinsic inflation persistence,  $\alpha_\pi = 0.86$
- A positive policy response of money growth to inflation,  $\phi_\pi = 0.47$
- A negative policy response of money growth to output,  $\phi_x = -0.57$ , combined with a preponderance of markup shocks. These move output and inflation in opposite directions.

# Prior and posterior densities - 1995Q1-2007Q4

description	coefficient	Prior				Posterior		
		density	domain	mean	[5 <sup>th</sup> ; 95 <sup>th</sup> ]	mean	[5 <sup>th</sup> ; 95 <sup>th</sup> ]	[5 <sup>th</sup> ; 95 <sup>th</sup> ]
discount factor	$\beta$	beta	[0,1]	0.99	[0.981 ; 0.997]	0.990	[0.982 ; 0.998]	[0.982 ; 0.998]
NKPC backward-looking component	$\alpha\pi$	beta	[0,1]	0.5	[0.171 ; 0.826]	0.133	[0.022 ; 0.236]	[0.022 ; 0.236]
NKPC slope	$\kappa$	gamma	$\mathbb{R}^+$	0.15	[0.104 ; 0.202]	0.138	[0.092 ; 0.185]	[0.092 ; 0.185]
price adjustment cost	$\tau$	gamma	$\mathbb{R}^+$	3	[1.560 ; 4.811]	4.009	[2.538 ; 5.472]	[2.538 ; 5.472]
IS curve backward-looking component	$\alpha_X$	beta	[0,1]	0.5	[0.171 ; 0.826]	0.179	[0.068 ; 0.286]	[0.068 ; 0.286]
elasticity of intertemporal substitution	$\sigma$	gamma	$\mathbb{R}^+$	0.15	[0.104 ; 0.202]	0.112	[0.073 ; 0.151]	[0.073 ; 0.151]
inverse of labour supply elasticity	$\xi$	gamma	$\mathbb{R}^+$	3	[1.560 ; 4.811]	0.972	[0.526 ; 1.393]	[0.526 ; 1.393]
interest elasticity of money demand	$\gamma$	gamma	$\mathbb{R}^+$	3	[1.560 ; 4.811]	2.344	[1.658 ; 3.033]	[1.658 ; 3.033]
interest rate response to inflation	$\psi\pi$	truncated normal	$\mathbb{R}$	1.5	[1.010 ; 1.990]	1.653	[1.276 ; 2.040]	[1.276 ; 2.040]
interest rate response to output gap	$\psi_X$	normal	$\mathbb{R}$	.125	[0.000 ; 0.250]	0.117	[0.012 ; 0.222]	[0.012 ; 0.222]
interest rate smoothing	$\rho_r$	beta	[0,1]	0.5	[0.171 ; 0.826]	0.838	[0.787 ; 0.888]	[0.787 ; 0.888]
persistence of mark up shock	$\rho_e$	beta	[0,1]	0.5	[0.171 ; 0.826]	0.474	[0.234 ; 0.705]	[0.234 ; 0.705]
persistence of demand shock	$\rho_a$	beta	[0,1]	0.5	[0.171 ; 0.826]	0.921	[0.868 ; 0.979]	[0.868 ; 0.979]
persistence money demand shock	$\rho_\chi$	beta	[0,1]	0.5	[0.171 ; 0.826]	0.638	[0.342 ; 0.951]	[0.342 ; 0.951]
standard deviation of mark up shock	$\sigma_e$	inv. gamma	$\mathbb{R}^+$	0.01	[0.004 ; 0.022]	.0050	[.0031 ; .0067]	[.0031 ; .0067]
standard deviation of demand shock	$\sigma_a$	inv. gamma	$\mathbb{R}^+$	0.01	[0.004 ; 0.022]	.0044	[.0027 ; .0061]	[.0027 ; .0061]
standard deviation of money demand shock	$\sigma_\chi$	inv. gamma	$\mathbb{R}^+$	0.01	[0.004 ; 0.022]	.0052	[.0030 ; .0072]	[.0030 ; .0072]
standard deviation of technology shock	$\sigma_z$	inv. gamma	$\mathbb{R}^+$	0.01	[0.004 ; 0.022]	.0042	[.0034 ; .0050]	[.0034 ; .0050]
standard deviation of policy shock	$\sigma_m$	inv. gamma	$\mathbb{R}^+$	0.01	[0.004 ; 0.022]	.0021	[.0017 ; .0025]	[.0017 ; .0025]
long-run link inflation-nominal interest rate	implied $\tilde{h}_{R,\pi}(0)$		$\mathbb{R}$	0.760	[-0.623 ; 1.623]	-0.278	[-1.386 ; 1.160]	[-1.386 ; 1.160]
inflation persistence	implied $FACF_\pi$		$\mathbb{R}$	0.792	[0.509 ; 0.960]	0.585	[0.415 ; 0.732]	[0.415 ; 0.732]

Note: Based on 1,000,000 posterior draws using the Metropolis-Hastings algorithm.

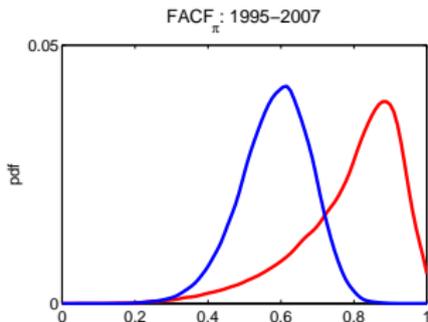
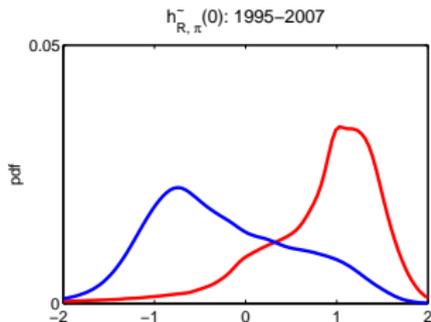
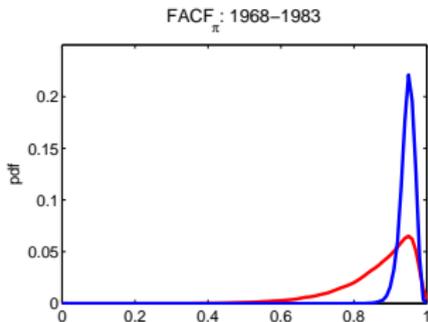
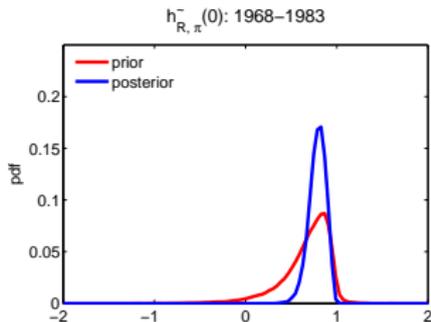
## The second subsample (con't.)



**Figure:** The scatter plots depict distributions of the features  $\tilde{h}_{R,\pi}(0)$  and  $FACF_{\pi}$  swept out by sampling from the joint posterior distribution of the response coefficients of the interest rate to inflation and the output gap. All other parameters are fixed at the posterior mean.

# Posteriors for $\tilde{h}_{R,\pi}(0)$ and $FACF_{\pi}$

Densities for  $\tilde{h}_{R,\pi}(0)$  and  $FACF_{\pi}$  both move to the left in the later subsample.



## Differences between the two subsamples

In the second subsample,

- Most of the shocks are less volatile, and hard-to-manage markup shocks account for a smaller proportion of output variation.
- There is less intrinsic inflation persistence, with  $\alpha_\pi$  falling from 0.86 to 0.13.
- The monetary-policy rule satisfies the Taylor principle and engages in a high degree of interest smoothing.

# Counterfactuals

## Outline

- Good-luck hypothesis: Swap the shock processes in the two subsamples.
- Good-policy hypothesis: Swap the monetary-policy rules in the two subsamples.
- Examine changes in private-sector parameters other than those governing the shocks.

## The good-luck hypothesis

	<i>Great Inflation</i>		<i>Post-1995</i>	
	$\tilde{h}_{R,\pi}(0)$	$FACF_{\pi}$	$\tilde{h}_{R,\pi}(0)$	$FACF_{\pi}$
Baseline Model	0.79	0.94	-0.51	0.55
Swap shock variances	0.83	0.93	-1.31	0.63

- Replacing the shock variances in the baseline model with those from the other subsample is unsuccessful.
- A Gibson paradox remains absent in the first subsample and still reappears in the second.
- It follows that the Gibson paradox can't be explained by altered shock variances.

## The good-policy hypothesis

	<i>Great Inflation</i>		<i>Post-1995</i>	
	$\tilde{h}_{R,\pi}(0)$	$FACF_{\pi}$	$\tilde{h}_{R,\pi}(0)$	$FACF_{\pi}$
Baseline Model	0.79	0.94	-0.51	0.55
Swap policies	0.05	0.92	0.24	0.63

- Replacing the policy rule in the baseline model with that of the other subsample is partially but not entirely successful.
- Under the post-1995 monetary policy, a Gibson paradox would have emerged in the first subsample, but inflation would have been too persistent.
- Under the 1970s monetary policy, the Gibson regression coefficient  $\tilde{h}(0)$  and inflation autocorrelation would both have been higher in the second subsample.
- It follows that there is more to the story than just a change in monetary policy, at least if we interpret things narrowly.

## Changes in NKPC parameters

	<i>Great Inflation</i>		<i>Post-1995</i>	
	$\tilde{h}_{R,\pi}(0)$	$FACF_{\pi}$	$\tilde{h}_{R,\pi}(0)$	$FACF_{\pi}$
Baseline Model	0.79	0.94	-0.51	0.55
Swap NKPCs	0.38	0.74	1.01	0.89

- Replacing NKPC parameters in the baseline model with those from the other subsample is also partially successful.
  - The Gibson regression coefficient  $\tilde{h}(0)$  would have been lower in the 1970s and inflation less persistent with the post-1995 NKPC.
  - A Gibson paradox would not have reappeared after 1995 and inflation would have been more persistent with the NKPC of the 1970s.
- The key change is the decline in  $\alpha_{\pi}$  from 0.86 to 0.13, which reduces the degree of intrinsic inflation persistence.

## A failure of invariance?

- Why did NKPC parameters change?
- Hard to say, because the model treats them as primitives.
- One respectable interpretation, however, is that they changed *because* of the change in policy.
- In particular, the significant decline in estimates of  $\alpha_\pi$  after the Volcker disinflation might be taken as prima facie evidence that it is not structural in the sense of Lucas (1976).
- If that is so, then both NKPC and policy coefficients must be swapped in order properly to assess the effects of a change in monetary policy.

## NKPC plus Policy

	<i>Great Inflation</i>		<i>Post-1995</i>	
	$\tilde{h}_{R,\pi}(0)$	$FACF_{\pi}$	$\tilde{h}_{R,\pi}(0)$	$FACF_{\pi}$
Baseline Model	0.79	0.94	-0.51	0.55
Swap NKPC + Policies	-0.67	0.68	0.81	0.94

- Swapping both NKPC and policy parameters completes our accounting.
- A Gibson paradox would have emerged in the 1970s and inflation would have been less persistent under the post-1995 monetary policy and NKPC.
- A Gibson paradox would not have reappeared after 1995 and inflation would have been more persistent under the 1970s monetary policy and NKPC.

## Conclusion

- Our counterfactuals point to a change in monetary policy – broadly interpreted – as being the main reason for the return of Gibson's paradox.
- To make this work, we must invoke an unmodeled nonlinearity linking NKPC parameters to parameters of the monetary policy rule.
- Although plausible, we are uncomfortable about manipulating the model in this way, for those parameters are usually presumed to be structural.
- As such, they are critical for determining the properties of inflation, both directly and through their influence on monetary policy.
- To the extent that these key parameters fail to be invariant, we worry about the model's reliability for predicting the consequences of policies unseen in the samples used for estimation.