The Neo-Fisher Effect Econometric Evidence from Empirical and Optimizing Models

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What is the effect of an interest-rate shock on inflation?

The answer depends on (a) whether the change in the interest rate is expected to be transitory or permanent; and (b) the time horizon.

Effect of an Increase in the Nominal Interest Rate (i) on Inflation (π)

	Long Run Effect on π	**Short** Run Effect on π
Transitory increase in i	0	$\downarrow$
Permanent increase in i	$\uparrow$	$\boxed{\uparrow}$

Entry (2,1) is the Fisher effect.
Entry (2,2) is the Neo-Fisher effect.

This Paper presents an econometric investigation of the effects of permanent and temporary movements in the nominal interest rate on inflation, output, and the real interest rate.

- **Two Frameworks:**

◇ An empirical model

◇ A New-Keynesian model

- Both models estimated on (the same) postwar data.

Main Findings

• A permanent monetary shock that raises the interest rate in the long run causes inflation and the nominal interest rate to increase to their permanently higher levels in the short run (within a year) and entails no output loss.

• A temporary increase in the nominal interest rate causes a fall in inflation and output in the short run.

Preliminaries: Evidence on the Fisher Effect

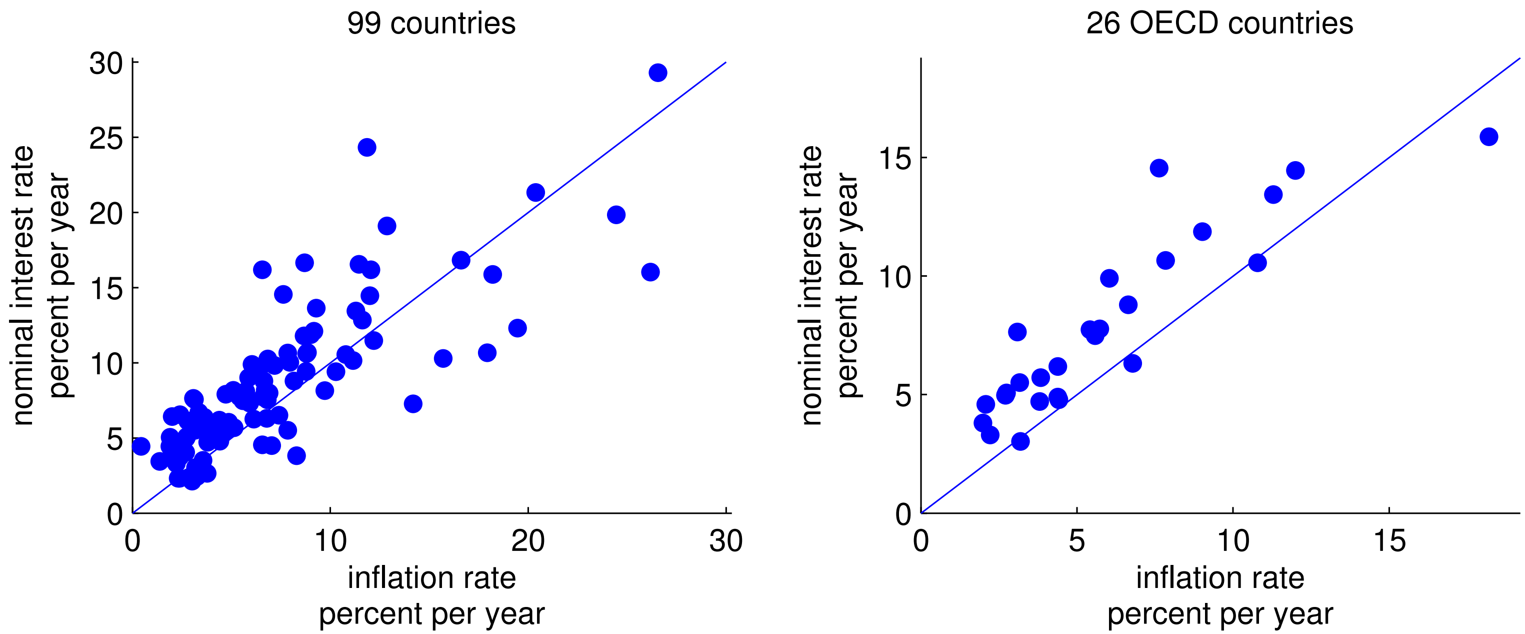
• Let i, r, and π denote average values of the nominal interest rate, the real interest rate, and the inflation rate. Then, assuming that on average expected inflation equals actual inflation, the Fisher equation says that

$$i = r + \pi.$$

• Further assuming that the average real interest rate is primarily determined by real factors (demographics, technology, etc.) and that these factors are more stable than monetary factors across time and space, the Fisher equation implies a positive relationship between the nominal interest rate and the rate of inflation.

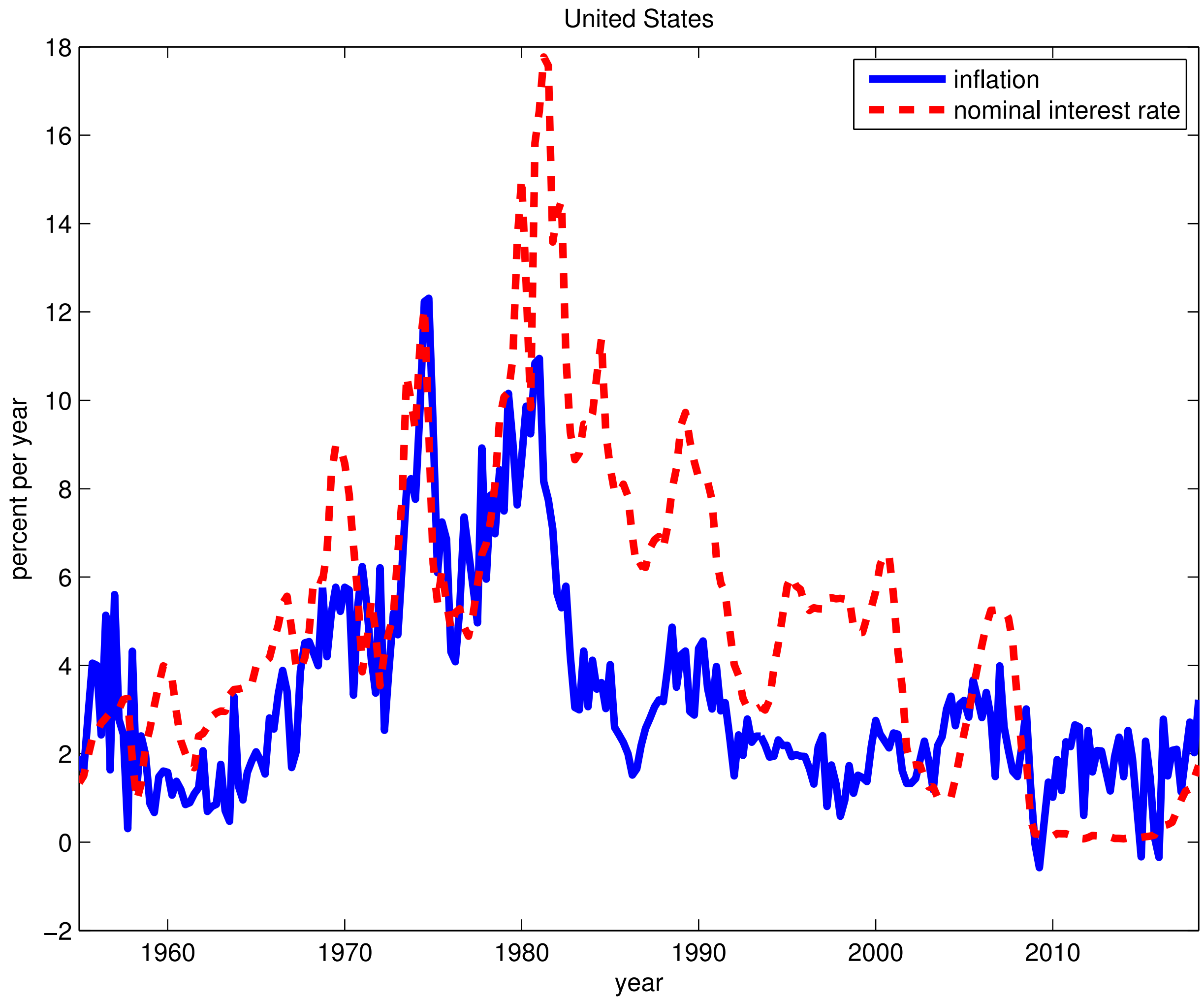
• The following two figures provide cross-sectional and time series evidence consistent with the validity of the Fisher hypothesis in the long run.

Average Inflation and Nominal Interest Rates: Cross-Country Evidence



Notes. Each dot represents one country. The solid line is the 45-degree line. Average sample 1989 to 2012. Source: WDI.

Inflation and the Nominal Interest Rate in the United States



Notes. Quarterly frequency, annualized rates.

The Empirical Model

$$\begin{bmatrix} y_t \\ \pi_t \\ i_t \end{bmatrix} \equiv \begin{bmatrix} \text{log of real output} \\ \text{inflation} \\ \text{policy rate} \end{bmatrix}; \qquad \begin{bmatrix} \widehat{y}_t \\ \widehat{\pi}_t \\ \widehat{i}_t \end{bmatrix} \equiv \begin{bmatrix} y_t - X_t^n \\ \pi_t - X_t^m \\ i_t - X_t^m \end{bmatrix}.$$

$$\begin{bmatrix} \widehat{y}_t \\ \widehat{\pi}_t \\ \widehat{i}_t \end{bmatrix} = B(L) \begin{bmatrix} \widehat{y}_{t-1} \\ \widehat{\pi}_{t-1} \\ \widehat{i}_{t-1} \end{bmatrix} + C \begin{bmatrix} \Delta X_t^m \\ z_t^m \\ \Delta X_t^n \\ z_t^n \end{bmatrix}$$

$$\begin{bmatrix} \Delta X_t^m \\ z_t^m \\ \Delta X_t^n \\ z_t^n \end{bmatrix} = \rho \begin{bmatrix} \Delta X_{t-1}^m \\ z_{t-1}^m \\ \Delta X_{t-1}^n \\ z_{t-1}^n \end{bmatrix} + \psi \begin{bmatrix} \epsilon_t^1 \\ \epsilon_t^2 \\ \epsilon_t^3 \\ \epsilon_t^4 \end{bmatrix}$$

where X_t^m =permanent monetary shock; X_t^n =permanent nonmonetary shock; z_t^m =transitory monetary shock; and z_t^n =transitory nonmonetary shock. Innovations $\epsilon_t^i \sim \text{iid}N(0,1)$, for $i = 1, 2, 3, 4$, and ρ, ψ diagonal.

Observables and Observation Equations

- Δy_t, growth rate of real output per capita.

- $r_t \equiv i_t - \pi_t$, interest-rate-inflation differential.

- $\Delta i_t \equiv i_t - i_{t-1}$, time difference of the nominal interest rate.

We then have the following **observation equations**:

$$
\begin{aligned}
\Delta y_t &= \widehat{y}_t - \widehat{y}_{t-1} + \Delta X^n_t \\
r_t &= \widehat{i}_t - \widehat{\pi}_t \\
\Delta i_t &= \widehat{i}_t - \widehat{i}_{t-1} + \Delta X^m_t
\end{aligned} \tag{1}
$$

Identification Assumptions

• Output (y_t) is cointegrated with the permanent nonmonetary shock (X_t^n).

• Inflation (π_t) is cointegrated with the permanent monetary shock (X_t^m).

• The nominal interest rate (i_t) is cointegrated with the permanent monetary shock (X_t^m).

• **Two Alternative Approaches to Identifying the Transitory Monetary Shock**

(1) A transitory increase in the interest rate ($z_t^m \uparrow$) has a nonpositive impact effect on inflation and output.

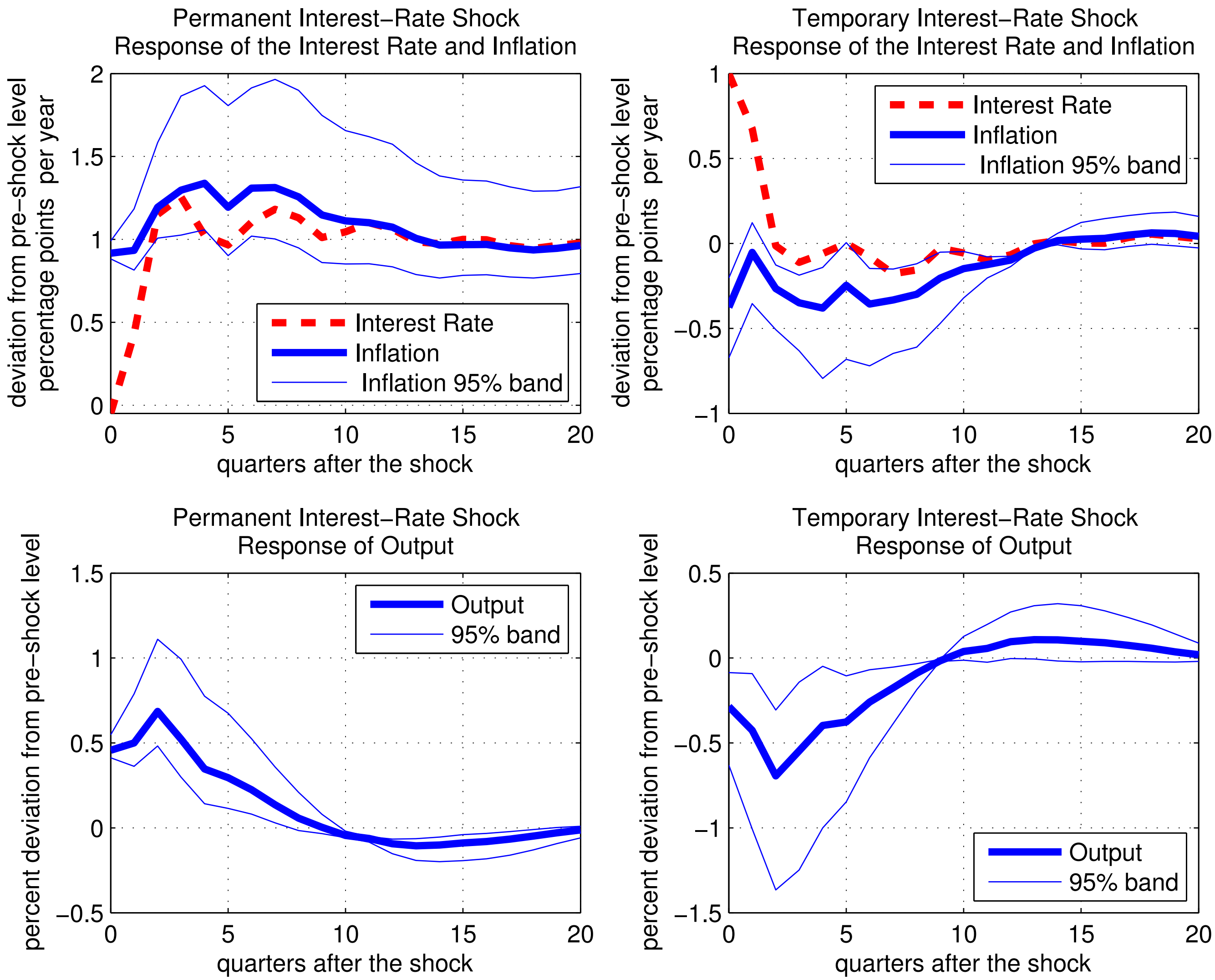
(2) A transitory increase in the interest rate ($z_t^m \uparrow$) has a zero impact effect on inflation and output.

Results are robust to applying either identification scheme.

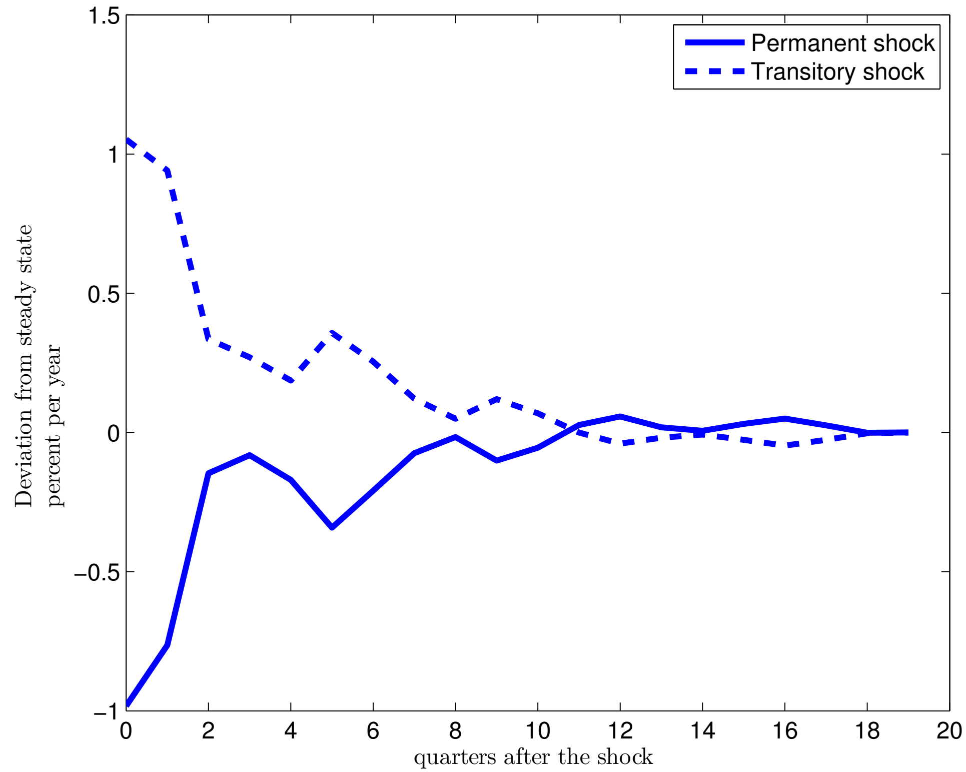
The Neo-Fisher Effect in the Empirical Model

United States, 1954.Q4 to 2018.Q2

Impulse Responses to Interest-Rate Shocks: Empirical Model Estimated on U.S. Data 1954.Q4 to 2018.Q2



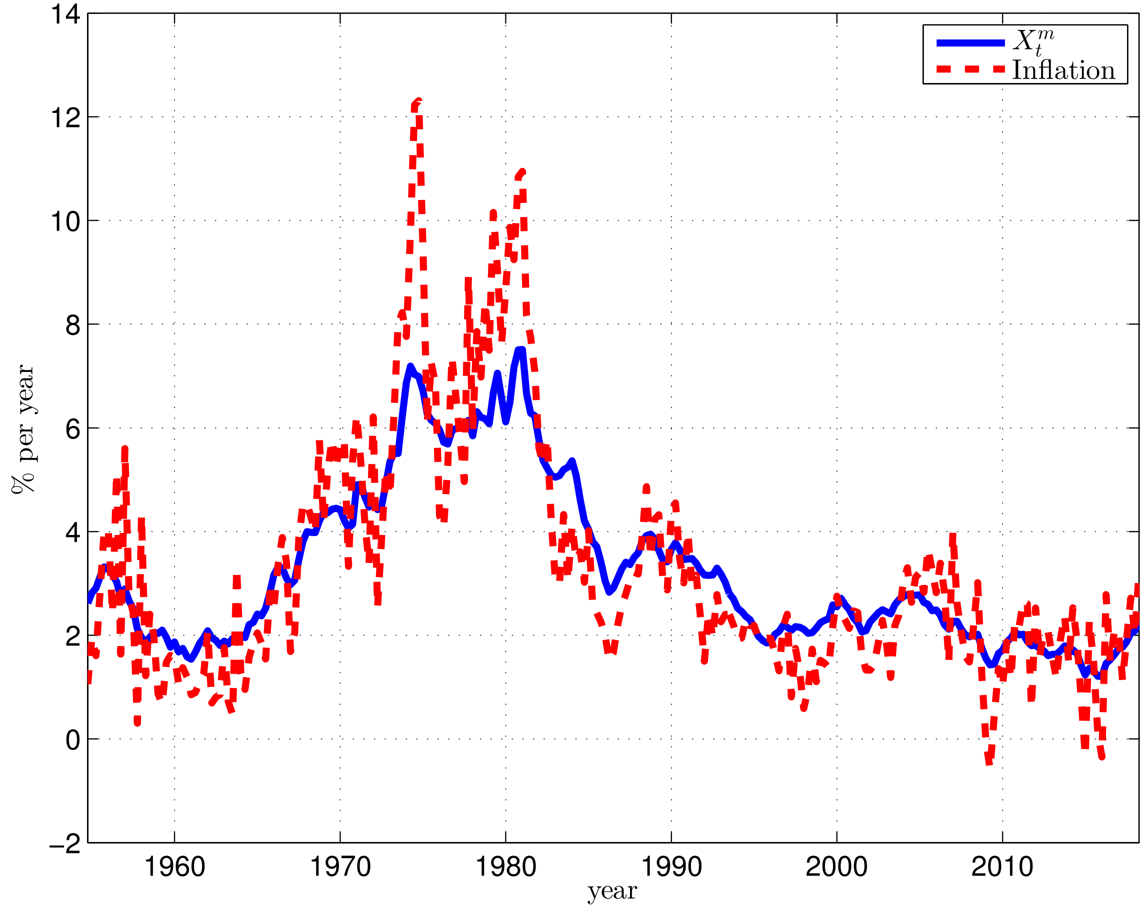
Response of the Real Interest Rate to Permanent and Transitory Interest-Rate Shocks in the Empirical Model



Notes. Posterior mean estimates. The real interest rate is defined as $i_t - E_t\pi_{t+1}$.

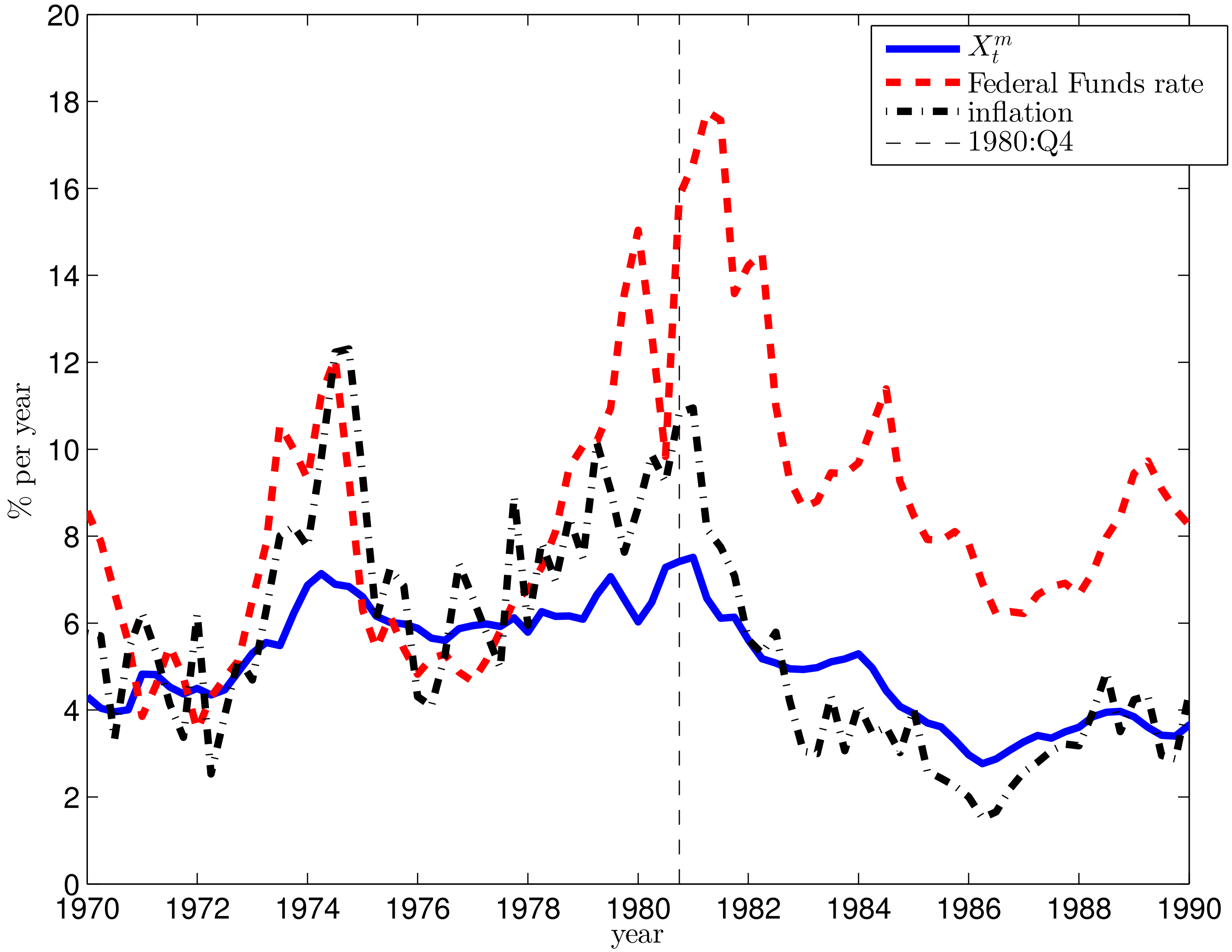
U.S. Inflation and Its Permanent Component

π_t and Inferred l Values of $\mathrm{X}_{\mathrm{t}}^{\mathrm{m}}$



Note. Quarterly frequency. Smoothed using the Kalman filter. Initial value of X_t^m normalized to match observed average inflation.

e Volcker Disinflation Trhough the Lens of the Empirical Mo



Observations on the Volcker Disinflation

• 1980:Q4 (vertical line) is the beginning of the "deliberate disinflation" (Goodfriend and King, 2005).

• The figure says that the Volcker policy was a combination of a large transitory increase in the policy rate and a gradual decrease in its permanent component.

• According to the estimated empirical model, both of these measures are deflationary.

Variance Decomposition: Empirical Model

	Δy_t	$\Delta \pi_t$	Δi_t
Permanent Monetary Shock, ΔX_t^m	9.1	44.6	21.9
Transitory Monetary Shock, z_t^m	2.1	6.2	10.9
Permanent Non-Monetary Shock, ΔX_t^n	49.8	27.9	13.5
Transitory Non-Monetary Shock, z_t^n	39.1	21.4	53.7

Note. Posterior means. The variables Δy_t, $\Delta \pi_t$, and Δi_t denote output growth, the change in inflation, and the change in the nominal interest rate, respectively.

Robustness Checks

(1) Truncating the sample at the beginning of the zero-lower-bound period.

(2) Estimating the empirical model on Japanese data.

(3) Interest rate and inflation cointegrated with cointegrating vector different from $[1 \ -1]$.

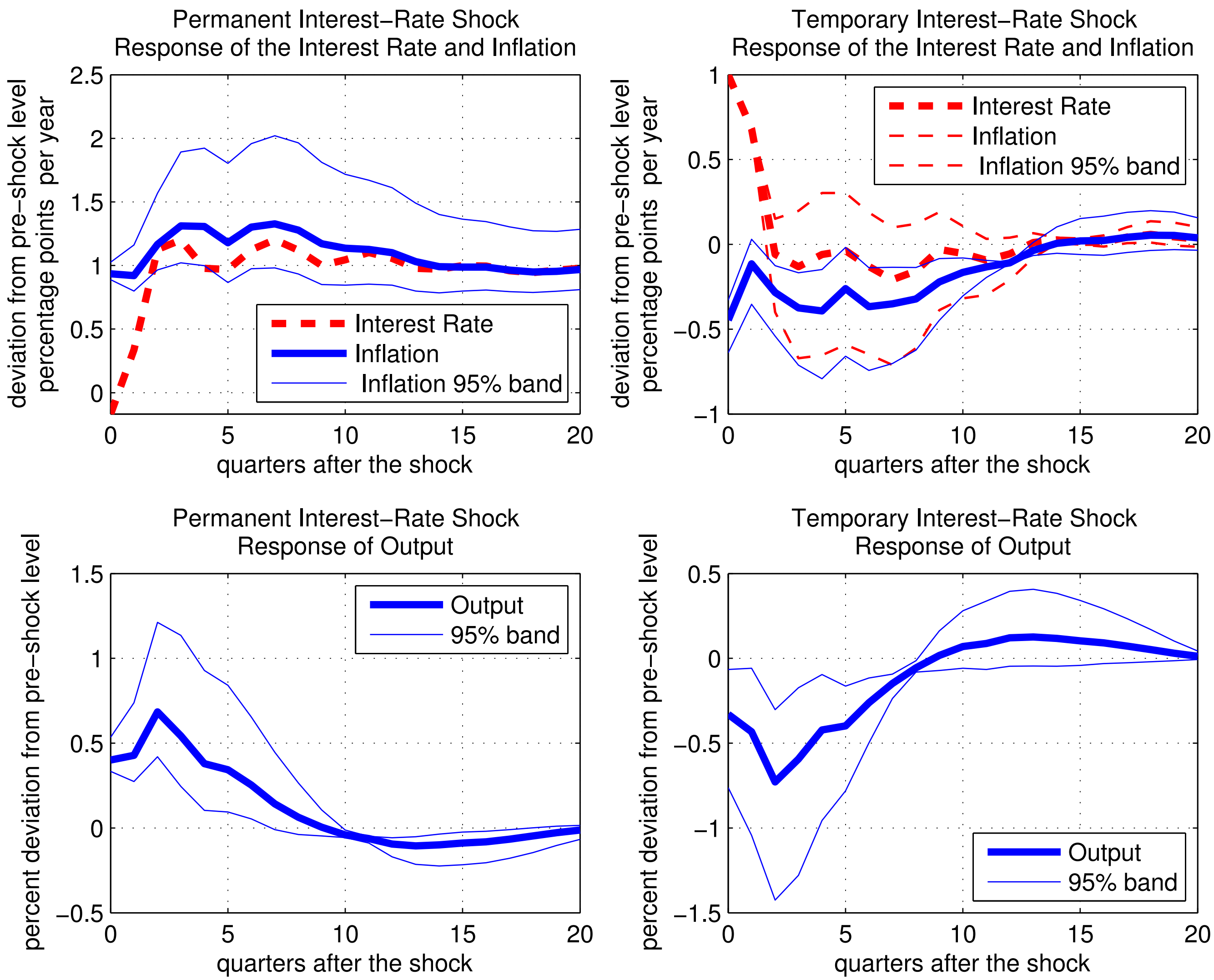
(4) Including the ten-year spread.

(5) Identification of transitory monetary shock: zero impact effect of z_t^m on π_t and y_t.

Robustness Check 1

Truncating the Sample at the Beginning of the Zero-Lower-Bound Period

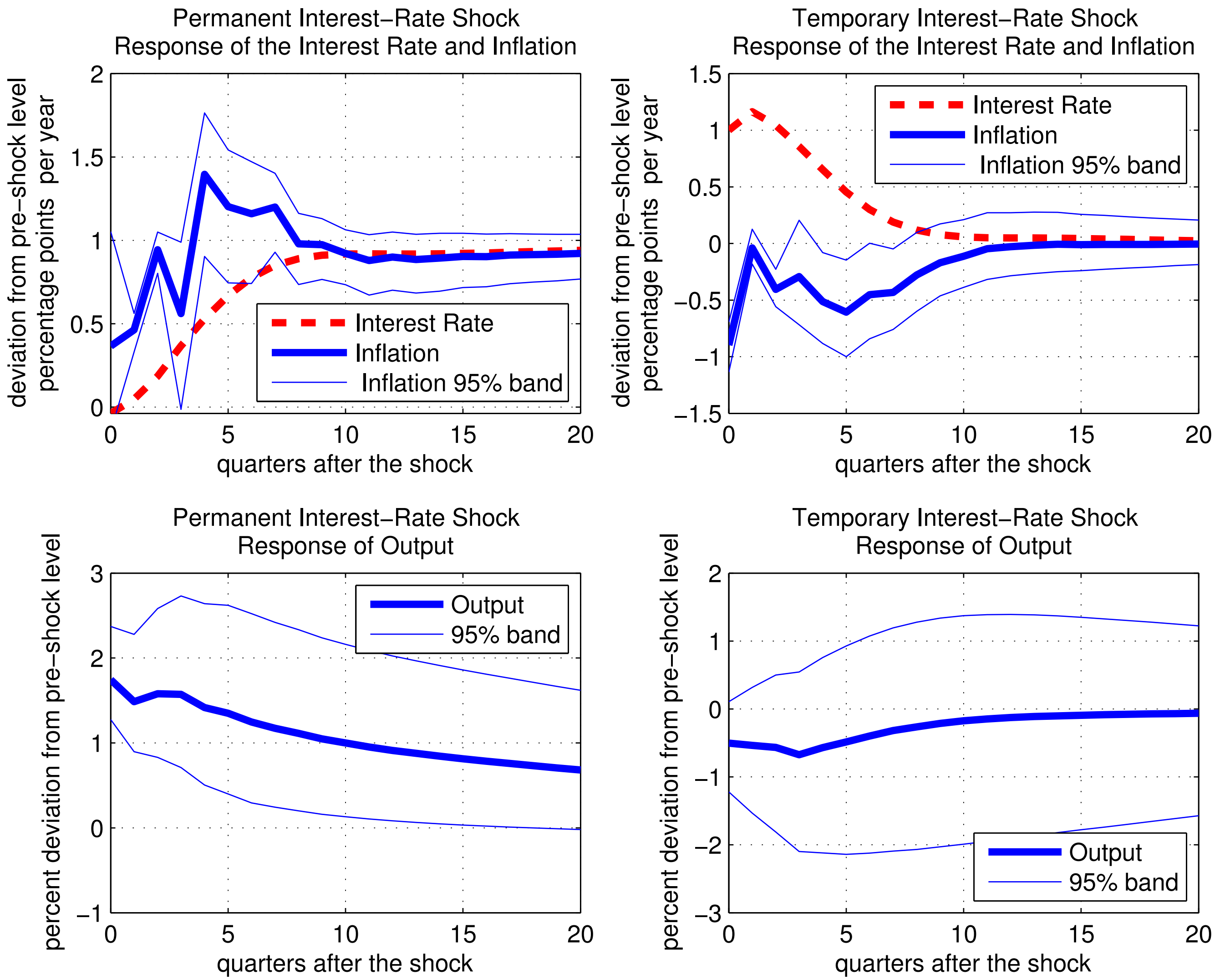
Impulse Responses to Interest-Rate Shocks: Empirical Model, Sample 1954.4 to 2008.4



Robustness Check 2

Estimating the Empirical Model on Japanese Data

Impulse Responses to Interest-Rate Shocks: Empirical Model Estimated on Japanese Data 1955.Q3 to 2016.Q4



Robustness Check 3

Interest rate and inflation cointegrated with cointegrating vector different from $[1\ -1]$.

Consider modifying the empirical model by introducing the parameter α such that

$$i_t - X_t^m \text{ and } \pi_t - \alpha X_t^m$$

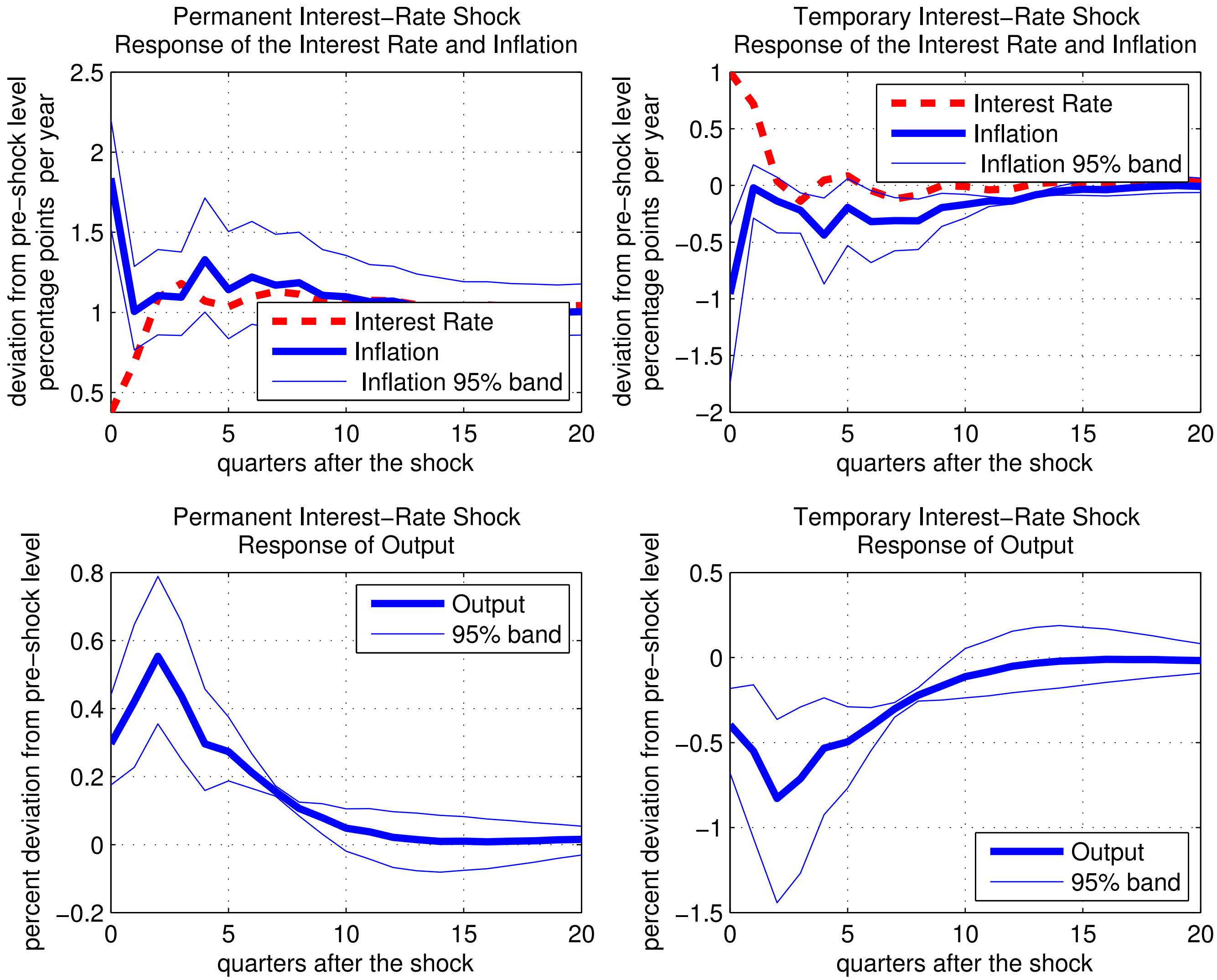
are stationary. The baseline value assumes that $\alpha = 1$ (inflation cointegrated with the nominal interest rate).

Prior: Assume that (α has a normal distribution with mean 1 and standard deviation 0.15.

Observables: We can no longer use $r_t \equiv i_t - \pi_t$ as it is nonstationary when $\alpha \neq 1$. Instead, we use $\Delta\pi_t \equiv \pi_t - \pi_{t-1}$. The other two observables continue to be Δy_t and Δi_t.

Posterior: mean(α) = 0.9401; std(α) = 0.1263,
$[5\%, 95\%]$ = [0.7323 1.1513].

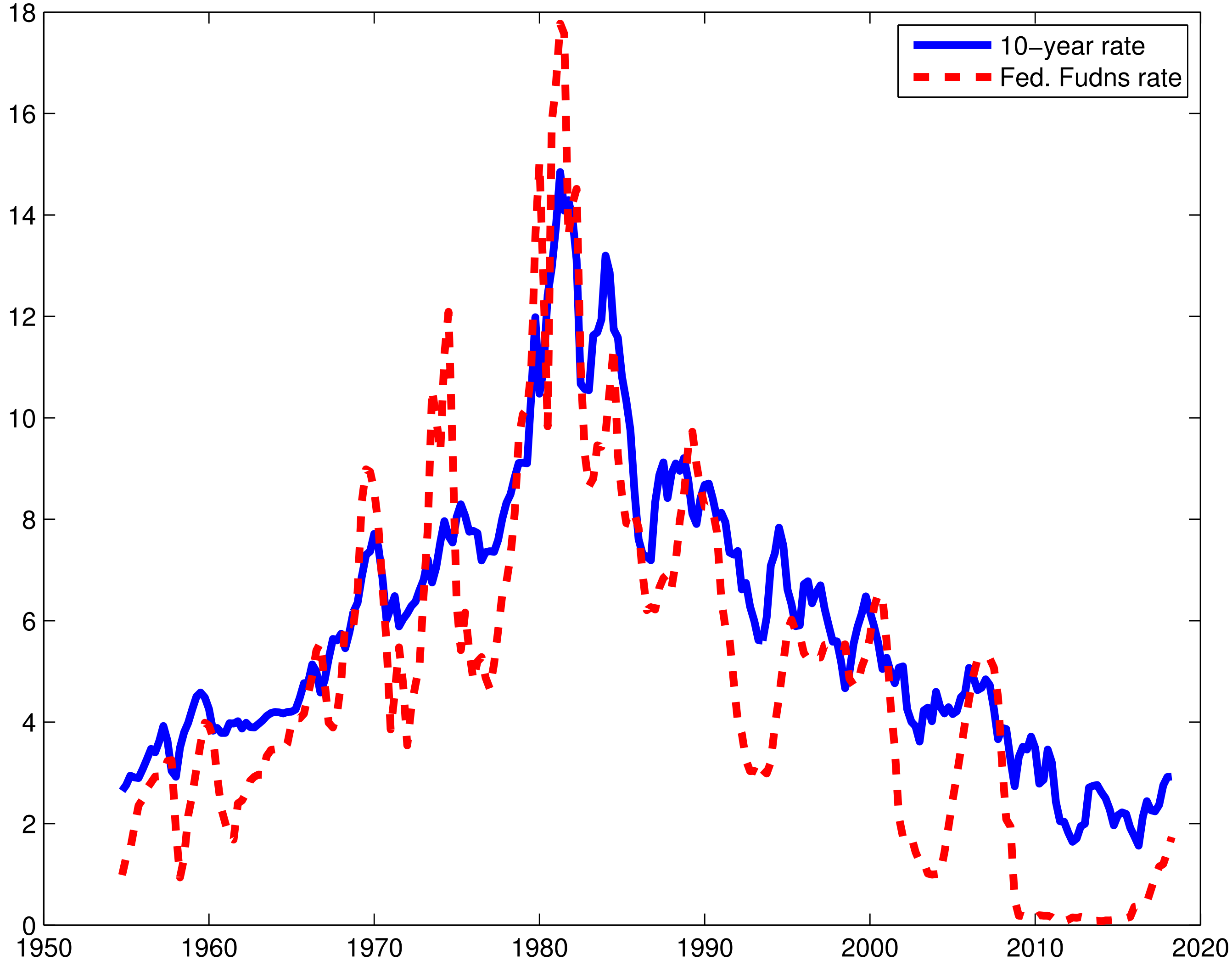
Impulse Responses to Interest-Rate Shocks: Empirical Model π_t cointegrated with αi_t



Robustness Check 4

Including the Ten-Year Spread

The Ten-Year Rate nd the Federal Funds Rate



Note. Quarterly frequency.

Expanding the Empirical Model

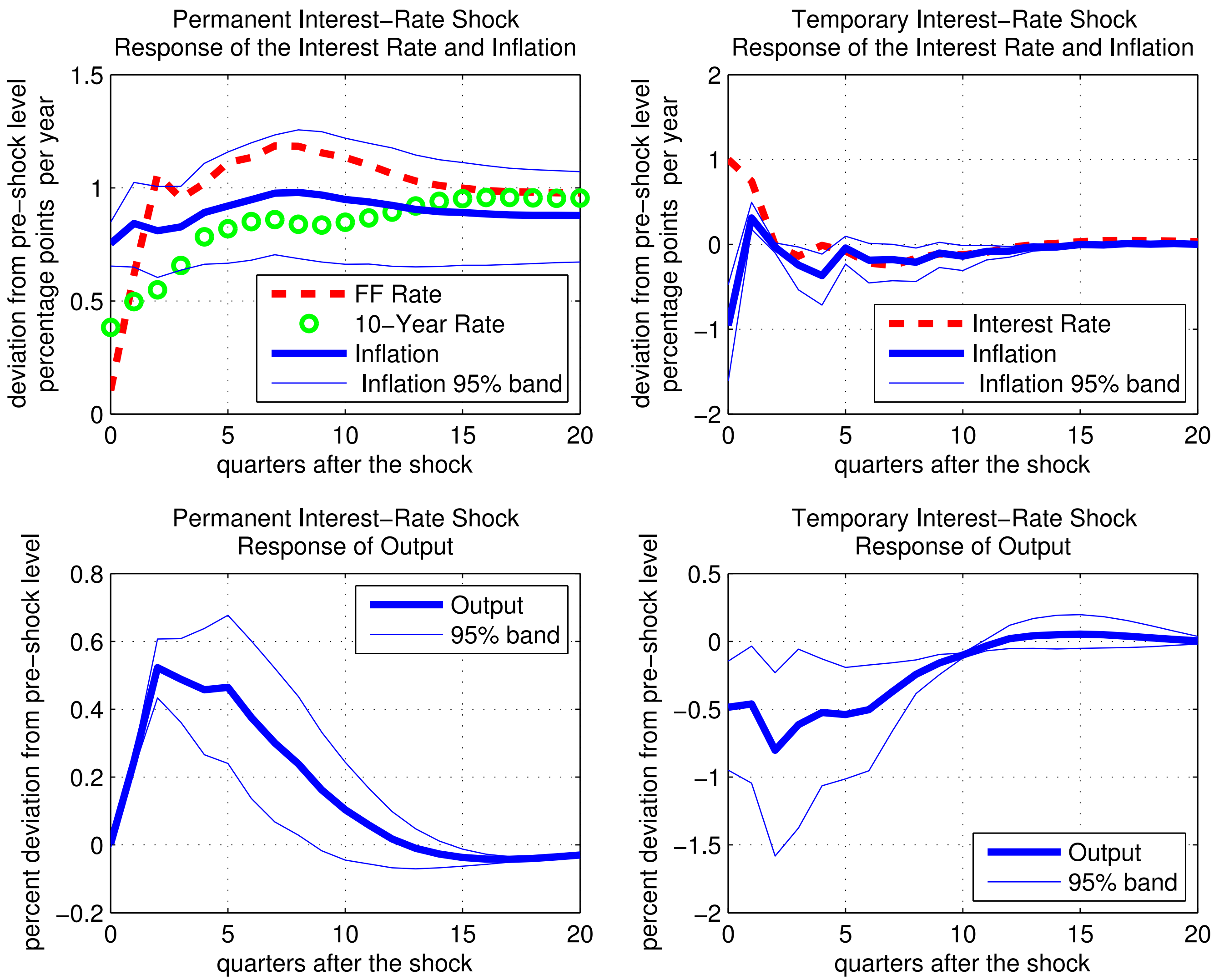
Stationary variables;

$y_t - X_t^n$; $\pi_t - \alpha X_t^m$, $i_t - X_t^m$, and $i_t^{10} - X_t^m$, where i_t^{10} is the ten-year rate, and α is a parameter.

Observables:

Δy_t, $\Delta \pi_t$, Δi_t, and $i_t^{10} - i_t$.

Impulse Responses to Interest-Rate Shocks Including the Ten-Year Spread

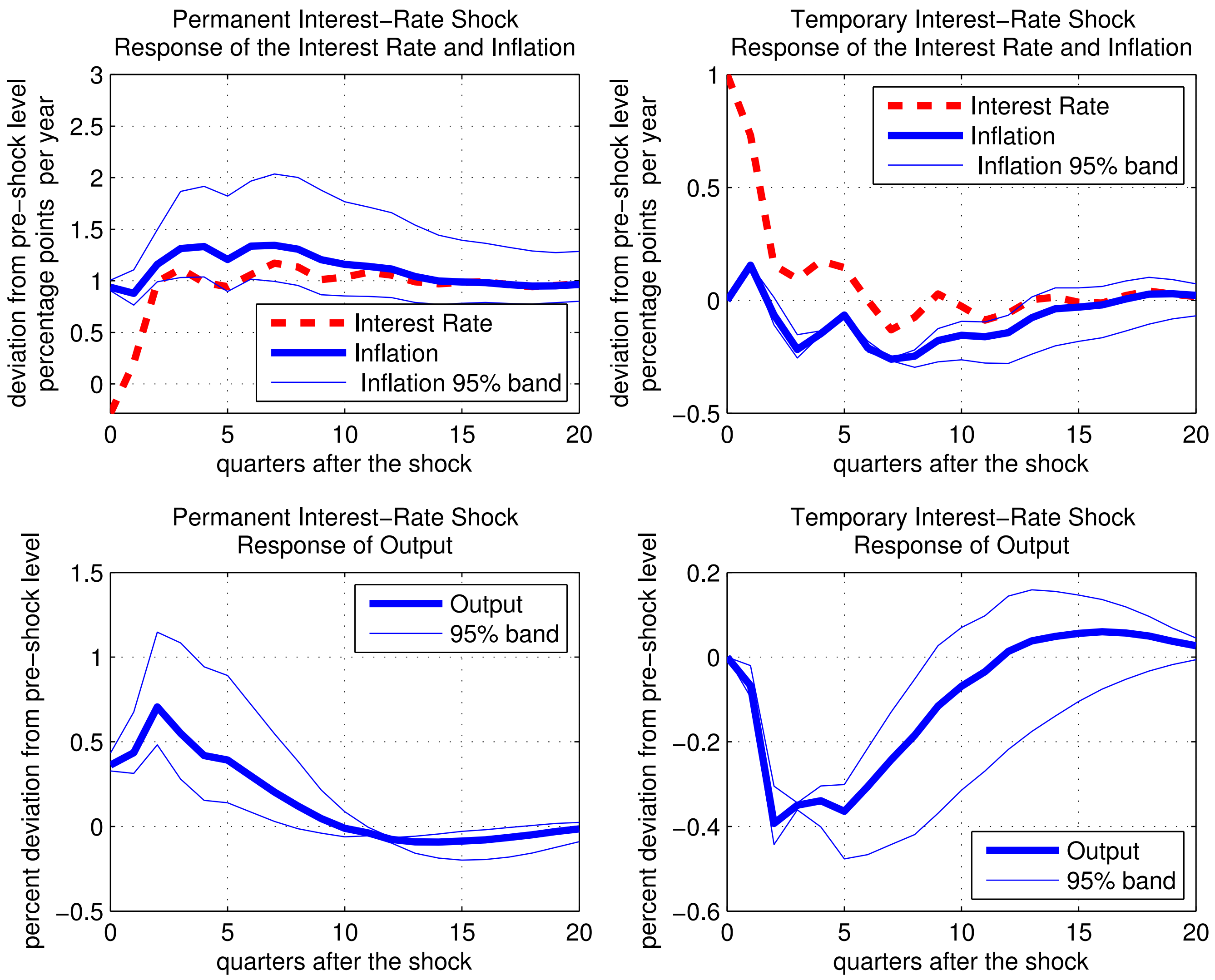


Robustness Check 5

Alternative Identification of the Transitory Monetary Shock

An innovation in z_t^m has a zero impact effect on π_t and y_t.

Impulse Responses to Interest-Rate Shocks
Zero-Impact-Effect Identification



A Standard New-Keynesian Model with Permanent Inflation-Target Shocks

Households

$$\max\ E_0 \sum_{t=0}^{\infty} \beta^t e^{\xi_t} \left\{ \frac{\left[(C_t - \delta \widetilde{C}_{t-1})(1 - e^{\theta_t} h_t)^{\chi}\right]^{1-\sigma} - 1}{1-\sigma} \right\},$$

subject to

$$\int_0^1 P_{it} C_{it} di + \frac{B_{t+1}}{1+I_t} + T_t = B_t + W\_t h_t + \Phi_t,$$

$$C_t = \left[\int_0^1 C_{it}^{1-1/\eta} di\right]^{\frac{1}{1-1/\eta}},$$

where C_{it} =consumption of variety i; C_t = consumption of composite good; $\widetilde{C}_t$ = cross-sectional average of C_t; h_t =hours worked; B_t =nominal bond; I_t =nominal interest rate; P_{it} =price of variety i; W_t =nominal wage; Φ_t =nominal profit income; T_t =nominal lump-sum taxes; ξ_t =preference shock; θ_t =labor-supply shock.

Firms

$$\max\ E_0 \sum_{t=0}^{\infty} q_t \left[\frac{P_{it}}{P_t} C_{it} - \frac{W_t}{P_t} h_{it} - \frac{\phi}{2} X_t \left(\frac{P_{it}/P_{it-1}}{1+\widetilde{\Pi}_t} - 1 \right)^2 \right],$$

subject to

$$Y_{it} \geq C_{it}$$

$$C_{it} = C_t \left(\frac{P_{it}}{P_t} \right)^{-\eta},$$

$$Y_{it} = e^{z_t} X_t h_{it}^{\alpha},$$

where P_{it} = price of variety i; P_t = price of composite good; h_{it} =hours employed by firm i; q_t =discount factor; Y_{it} =output of firm i; X_t =permanent tech. shock; z_t =transitory tech. shock; $\Pi_t \equiv P_t/P_{t-1} - 1$ = inflation; $\widetilde{\Pi}_t \approx \gamma_m \widetilde{\Pi}_{t-1} + (1-\gamma_m)\Pi_t$ = weighted average of current and past inflation rates.

Monetary Policy

$$\frac{1+I_t}{\Gamma_t} = A\left(\frac{1+\Pi_t}{\Gamma_t}\right)^{\alpha_\pi}\left(\frac{Y_t}{X_t}\right)^{\alpha_y} e^{z_t^m},$$

$$\Gamma_t = X_t^m e^{z_t^{m2}}.$$

where
z_t^m = stationary interest-rate shock,
Γ_t = inflation trend.
X_t^m = permanent component of inflation trend, with $\Delta \ln X_t^m$ stationary.
z_t^{m2} = stationary component of inflation trend.

Fiscal Policy: Passive (or Ricardian). No government consumption.

Estimation

- Same time series and sample as in the estimation of the empirical model.

- Estimate a subset of the model's paramters and calibrate the rest.

- Apply likelihood-based Bayesian techniques (same as in the estimation of the empirical model).

Calibrated Parameters in the New Keynesian Model

Parameter	Value	Description
β	0.9982	subjective discount factor
σ	2	inverse of intertemp. elast. subst.
η	6	intratemporal elast. of subst.
α	0.75	labor semielast. of output
g	0.004131	mean output growth rate
θ	0.4055	preference parameter
χ	0.625	preference parameter

Note. The time unit is one quarter.

Prior and Posterior Parameter Distributions: New Keynesian Model

	Prior Distribution			Posterior Distribution			
Param.	Distrib.	Mean	Std	Mean	Std	5%	95%
ϕ	Gamma	50	20	146	31.9	96.8	201
α_π	Gamma	1.5	0.25	2.32	0.221	1.98	2.7
α_y	Gamma	0.125	0.1	0.188	0.123	0.0336	0.422
γ_m	Uniform	0.5	0.289	0.606	0.0762	0.475	0.724
γ_I	Uniform	0.5	0.289	0.242	0.142	0.053	0.517
δ	Uniform	0.5	0.289	0.258	0.0531	0.173	0.348
ρ_ξ	Beta	0.7	0.2	0.915	0.0234	0.874	0.95
ρ_θ	Beta	0.7	0.2	0.708	0.21	0.317	0.98
ρ_z	Beta	0.7	0.2	0.7	0.214	0.302	0.978
ρ_g	Beta	0.3	0.2	0.221	0.108	0.0557	0.41
$\rho_{\Delta X^m}$	Beta	0.3	0.2	0.248	0.166	0.0295	0.562
ρ_{zm}	Beta	0.3	0.2	0.306	0.184	0.0526	0.654
ρ_{zm2}	Beta	0.7	0.2	0.796	0.205	0.33	0.975
σ_ξ	Gamma	0.01	0.01	0.0287	0.00602	0.0212	0.0398
σ_θ	Gamma	0.01	0.01	0.00164	0.00138	0.000115	0.00435
σ_z	Gamma	0.01	0.01	0.00122	0.000974	8.66e-05	0.00312
σ_g	Gamma	0.01	0.01	0.00758	0.000944	0.00593	0.00905
$\sigma_{\Delta X^m}$	Gamma	0.0025	0.0025	0.000848	0.000474	8.48e-05	0.00159
σ_{zm}	Gamma	0.0025	0.0025	0.000832	0.000465	7.96e-05	0.00152
σ_{zm2}	Gamma	0.0025	0.0025	0.00131	0.000733	0.000138	0.00248

Observations on Estimation

• In general, parameters are estimated with significant uncertainty (common feature of estimated small optimizing macro models).

• Nonetheless, the estimation is successful along two dimensions:

⋄ The data speaks with a strong voice with respect to the degrees of price stickiness, ϕ, and habit formation, δ, which define the propagation of nominal and real shocks.

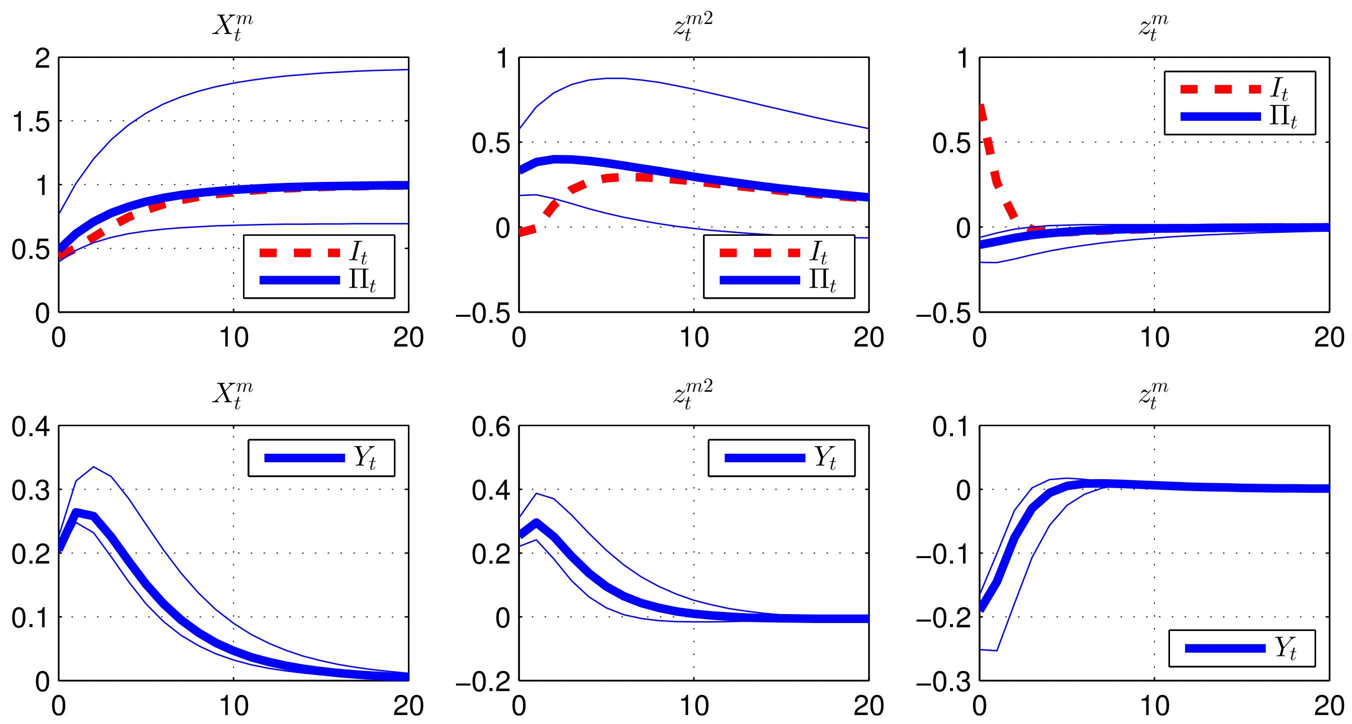
⋄ The optimizing model predicts a contribution of inflation-trend shocks to inflation changes similar to that predicted by the empirical model (see the next slide).

Variance Decomposition: New Keynesian Model

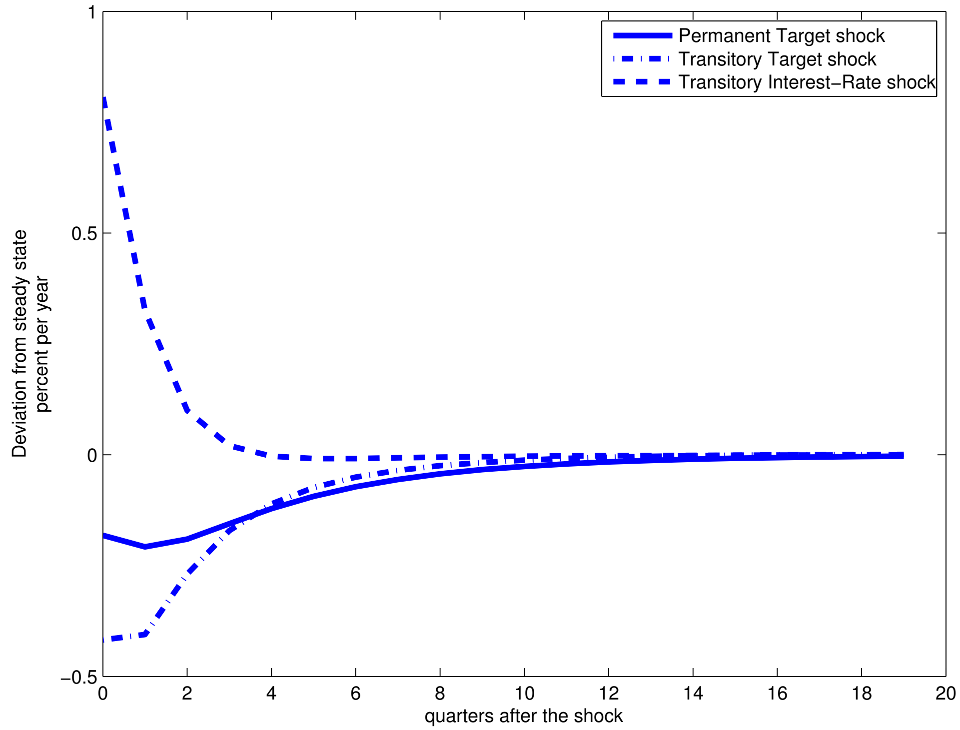
	Δy_t	$\Delta \pi_t$	Δi_t
Permanent Trend-Inflation Shock, $\Delta \ln X_t^m$	2.4	30.1	7.6
Transitory Trend-Inflation Shock, z_t^{m2}	4.3	22.2	5.1
Transitory interest-Rate Shock, z_t^m	1.2	1.2	14.2
Permanent Productivity Shock, g_t	79.5	0.8	1.6
Transitory Productivity Shock, z_t	0.5	2.8	2.6
Preference Shock, ξ_t	11.5	40.0	66.3
Labor-Supply Shock, θ_t	0.6	2.8	2.6

Notes. Posterior means. The variables Δy_t, $\Delta \pi_t$, and Δi_t denote output growth, the change in inflation, and the change in the nominal interest rate, respectively. Replication code: `table_vardecomp.m` in `optimizing_model.zip`.

Impulse Responses to Interest-Rate Shocks: New Keynesian Model Estimated on U.S. Data 1954.Q4 to 2018.Q2



Response of the Real Interest Rate to Permanent and Transitory Interest-Rate Shocks in the New-Keynesian Model



Notes. Posterior mean estimates. The real interest rate is defined as $i_t - E_t\pi_{t+1}$.

Observations on the Previous Three Figures

The main results from the empirical model carry over to the optimizing model:

• In response to a permanent increase in the interest rate, inflation converges to its higher long-run value in the short run.

• The adjustment takes place in the context of low real rates and does not cause output loss.

• A temporary increase in the nominal interest rate triggers a fall in inflation, an increase in real rates, and a contraction in real activity.

Robustness Checks

(1) Truncating the sample at the beginning of the zero-lower-bound period.

(2) Estimate the empirical model on Japanese data.

(3) Add a second transitory monetary shock with high persistence to compete for the data with the permanent monetary shock.

(4) Allow for long memory indexation, by drawing γ_m from the lowest decile of its posterior distribution.

Final Remarks

Discussions of how monetary policy can lift an economy out of chronic below-target inflation are almost always based on the logic of how transitory interest-rate shocks affect real and nominal variables.

Within this logic, a central bank trying to reflate a low-inflation economy will tend to set interest rates as low as possible.

Soon enough these economies find themselves with zero nominal rates and with the low-inflation problem not going away.

At some point, the Fisher effect kicks in, perpetuating the low-interest-rate low-inflation environment.

In this paper, I estimate an empirical model and an optimizing model with temporary and permanent monetary shocks using U.S. and Japanese data. The estimated models produce dynamics consistent with the neo-Fisherian prediction that a credible and gradual increase of nominal interest rates to normal levels can generate a quick reflation of the economy with low real interest rates and no output loss.

EXTRAS

Extras Empirical Model

Measurement Errors

I assume that Δy_t, r_t, and Δi_t are observed with error. Letting o_t be the vector of variables observed in quarter t, I assume that

$$o_t = \begin{bmatrix} \Delta y_t \times 100 \\ r_t \\ \Delta i_t \end{bmatrix} + \mu_t \qquad (2)$$

where μ_t is a 3-by-1 vector of measurement errors distributed i.i.d. $N(\emptyset, R)$, with R diagonal.

State-Space Form

Let

$$\widehat{Y}_t \equiv \begin{bmatrix} \widehat{y}_t \\ \widehat{\pi}_t \\ \widehat{i}_t \end{bmatrix}, \quad u_t \equiv \begin{bmatrix} \Delta X_t^m \\ z_t^m \\ \Delta X_t^n \\ z_t^n \end{bmatrix}, \quad \text{and } \xi_t \equiv \begin{bmatrix} \widehat{Y}_t \\ \widehat{Y}_{t-1} \\ \vdots \\ \widehat{Y}_{t-L+1} \\ u_t \end{bmatrix}.$$

Then the system can be written as follows:

$$\xi_{t+1} = F\xi_t + P\epsilon_{t+1}$$

$$o_t = H'\xi_t + \mu_t,$$

where the matrices F, P, and H are known functions of B_i, $i = 1, \ldots L$, C, ρ, and ψ.

This representation allows for the use of the Kalman filter to evaluate the likelihood function.

Data and Estimation Technique

- The data are quarterly observations of the the U.S. growth rate of output per capita, the nominal-interest-rate-inflation differential, and the change in the nominal interest rate.

- Sample 1954.4 to 2018.2. Ouput is proxied by real GDP per capita. Inflation is measured by the growth rate of the Implicit GDP Deflator. The nominal interest rate is the Effective Federal Funds Rate.

- Robustness: Also estimate the model on Japanese data from 1955.Q3 to 2016.Q4.

- The model is estimated with 4 lags using Bayesian techniques.

Priors

• In the spirit of the Minnesota Prior (MP), I assume that at the prior mean the elements of $\widehat{Y}_t$ follow univariate AR(1) processes ($B_1(j,k) = 0\ \forall j \neq k$, $B_i = 0\ \forall i > 1$).

• Also as in the MP, I impose higher prior standard deviations on the diagonal elements of B_1 than on the remaining elements of B_i for $i = 1, \ldots, L$.

• I assume that the prior distribution of C_{21}, governing the impact effect of a permanent interest-rate shock on inflation, is $N(-1, 1)$. The mean of -1 implies a prior belief that the impact effect of a permanent interest rate shock on inflation, given by $1 + C_{21}$, can be positive or negative with equal probability.

• I impose nonnegative serial correlations on exogenous shocks $\rho_{ii} \geq 0$, with beta distributions.

• The table on the next slide provides a full description of the assumed prior distributions.

Prior Distributions

Parameter	Distribution	Mean.	Std. Dev.
Main diagonal elements of B_1	Normal	0.95	0.5
Other elements of B	Normal	0	0.25
C_{21}, C_{31}	Normal	-1	1
$-C_{12}, -C_{22}$	Gamma	1	1
Other elements of C	Normal	0	1
$\psi_{ii},\ i = 1, 2, 3, 4$	Gamma	1	1
$\rho_{ii},\ i = 1, 2, 3$	Beta	0.3	0.2
ρ_{44}	Beta	0.7	0.2
R_{ii}	Uniform	$\frac{\text{var}(o_t)}{10\times 2}$	$\frac{\text{var}(o_t)}{10\times\sqrt{12}}$

Impulse Responses

• Point estimates are means of a random sample of size 100 thousand with replacement from an MCMC chain of length 1 million of draws from the posterior distribution of impulse responses.

• 95-percent asymmetric error bands are computed using the Sims-Zha method.

• **Transitory Interest-Rate Shock:** Initial shock is set so that the impact effect on the nominal interest rate is 1 annual percentage point.

• **Permanent Interest-Rate Shock:** Initial shock is set so that the posterior-mean long-run increase in the nominal interest rate is 1 percent.

Robustness Check in the Empirical Model

Correlated Monetary and Real Permanent Components

Evolution of the Driving Forces

$$\begin{bmatrix} \Delta X_t^m \\ \Delta X_t^n \\ z_t^m \\ z_t^n \end{bmatrix} = \rho \begin{bmatrix} \Delta X_{t-1}^m \\ \Delta X_{t-1}^n \\ z_{t-1}^m \\ z_{t-1}^n \end{bmatrix} + \Gamma \begin{bmatrix} \epsilon_t^1 \\ \epsilon_t^2 \\ \epsilon_t^3 \\ \epsilon_t^4 \end{bmatrix}$$

In the baseline specification, ρ is restricted to be diagonal. Assume now that $\rho_{1,3}$ $\rho_{3,1}$ may be nonzero.

Assume Beta prior distributions for $0.5 + \rho_{1,3}$ and $0.5 + \rho_{3,1}$ with mean 0.5 and standard deviaiton 0.2.

Posterior means: $\rho_{13} = -0.057$ and $\rho_{31} = 0.12$.

Impulse Responses to Interest-Rate Shocks: Empirical Model, Correlated X_t^m and X_t^n