Exchange Rates and Uncovered Interest Differentials: The Role of Permanent Monetary Shocks

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Motivation

• Existing empirical work assumes that monetary shocks come in only one flavor.

• However, recent work has shown that it is important to distinguish between transitory and permanent monetary disturbances. Permanent monetary policy shocks, i.e., shocks to long-run inflation expectations, have been shown to be at least as important as transitory monetary policy shocks for explaining the dynamics of changes in output, inflation, and the nominal interest rate in the United States.

• Motivated by these findings, the present paper estimates the effects of monetary policy shocks on exchange rates within an empirical framework that distinguishes transitory from permanent monetary shocks.

This paper finds that:

- permanent monetary shocks explain the majority of short-run movements in nominal exchange rates.

- there is no exchange-rate overshooting in response to monetary shocks, suggesting that existing overshooting results may be the consequence of confounding permanent and transitory impulses.

- transitory tightenings cause deviations from uncovered interest-rate parity in favor of domestic assets, whereas permanent tightenings cause deviations in favor of foreign assets.

Previous related literature

Dornbusch (1976): Exchange Rate Overshooting

UIP: $$(1+i_t) = (1+i_t^*)\left(\frac{S_{t+1}}{S_t}\right)$$

Money demand: $$\frac{M_t}{P_t} = L(i_t, Y)$$

Long-run neutrality: $P_t = S_t P_t^*$

i_t = domestic nominal interest rate.

i_t^* = foreign nominal interest rate.

S_t = domestic currency price of one unit of foreign currency.

M_t = domestic money supply.

P_t = domestic price level.

Experiment: A contractionary monetary shock, $M_0 \downarrow$.

Empirical Evidence on Exchange Rate Overshooting

A large number of papers has tested the validity of Dornbusch's overshooting result conditional on monetary shocks. Two findings emerge:

1.) A monetary tightening causes an appreciation of the domestic currency with an overshooting effect either on impact (Kim and Roubini, 2000; Faust and Rogers, 2003; Kim, Moon, and Velasco, 2017) or with a delay (Eichenbaum and Evans, 1995; Scholl and Uhlig, 2008). Main difference across these papers is how the monetary policy shock is identified.

2.) UIP, conditional on a monetary shock, fails, contradicting a key assumption of Dornbusch's model. Specifically, a domestic tightening generates excess returns on domestic assets.

Related Studies on the Effects of Permanent Monetary Policy Shocks on Exchange Rates

- De Michelis and Iacoviello (2016) estimate the effects of permanent monetary disturbances and find that in response to an increase in the U.S. inflation target, the U.S. real exchange temporarily depreciates.

Empirical Model

The empirical model is an extension of Uribe (2018).

The following variables are assumed to be nonstationary

$$\begin{bmatrix} y_t \\ \pi_t \\ i_t \\ \epsilon_t \\ i_t^* \end{bmatrix} = \begin{bmatrix} \text{log of real US output} \\ \text{US inflation} \\ \text{US nominal interest rate} \\ \text{change in dollar exchange rate} \\ \text{foreign nominal interest rate} \end{bmatrix}$$

stationary, but unobservable, variables:

$$\begin{bmatrix} \widehat{y}_t \\ \widehat{\pi}_t \\ \widehat{i}_t \\ \widehat{\epsilon}_t \\ \widehat{i}_t^* \end{bmatrix} \equiv \begin{bmatrix} y_t - X_t \\ \pi_t - X_t^m \\ i_t - X_t^m \\ \epsilon_t - X_t^m + X_t^{m*} \\ i_t^* - X_t^{m*} \end{bmatrix}.$$

AR(L) in latent variables

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

$$\begin{bmatrix} \Delta X^m_t \\ z^m_t \\ \Delta X_t \\ z_t \\ \Delta X^{m*}_t \end{bmatrix} = \rho \begin{bmatrix} \Delta X^m_{t-1} \\ z^m_{t-1} \\ \Delta X_{t-1} \\ z_{t-1} \\ \Delta X^{m*}_{t-1} \end{bmatrix} + \psi \begin{bmatrix} \nu^1_t \\ \nu^2_t \\ \nu^3_t \\ \nu^4_t \\ \nu^5_t \end{bmatrix},$$

where X^m_t = permanent monetary shock; z^m_t = transitory monetary shock; X_t = permanent nonmonetary shock; z_t = transitory nonmonetary shock; and X^{m*}_t = foreign permanent monetary shock. Innovations $\nu^i_t \sim$ iid $\mathcal{N}(0,1)$, for $i = 1, \ldots, 5$, ρ and ψ are diagonal 5×5 matrices. (To simplify the exposition constants are omitted.)

5 Observables and corresponding observation equations

(1) $\Delta y_t \equiv y_t - y_{t-1}$, time difference of domestic real output.
(2) $r_t \equiv i_t - \pi_t$, interest-rate-inflation differential.
(3) $\Delta i_t \equiv i_t - i_{t-1}$, time difference of domestic nominal rate.
(4) $\Delta \epsilon_t \equiv \epsilon_t - \epsilon_{t-1}$, time difference of devaluation rate.
(5) $\Delta i^*_t \equiv i^*_t - i^*_{t-1}$, time difference of foreign nominal rate.

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

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

Measurement Errors

$$o_t = \begin{bmatrix} \Delta y_t \\ r_t \\ \Delta i_t \\ \Delta \epsilon_t \\ \Delta i_t^* \end{bmatrix} + \mu_t \tag{2}$$

where μ_t is a 5-by-1 vector of measurement errors distributed i.i.d. $N(\emptyset, R)$, with R diagonal.

Let

$$\widehat{Y}_t \equiv \begin{bmatrix} \widehat{y}_t \\ \widehat{\pi}_t \\ \widehat{i}_t \\ \widehat{\epsilon}_t \\ \widehat{i}_t^* \end{bmatrix}; \quad u_t \equiv \begin{bmatrix} \Delta X_t^m \\ z_t^m \\ \Delta X_t \\ z_t \\ \Delta X_t^{m*} \end{bmatrix}; \quad \nu_t \equiv \begin{bmatrix} \nu_t^1 \\ \nu_t^2 \\ \nu_t^3 \\ \nu_t^4 \\ \nu_t^5 \end{bmatrix}$$

Assuming a lag length of L months, the empirical model can be written as

$$\widehat{Y}_t = \sum_{i=1}^{L} B_i \widehat{Y}_{t-i} + C u_t \tag{3}$$

$$u_t = \rho u_{t-1} + \psi \nu_t \tag{4}$$

State Space Form

Let

$$\xi_t \equiv \begin{bmatrix} \widehat{Y}_t \\ \widehat{Y}_{t-1} \\ \vdots \\ \widehat{Y}_{t-L+1} \\ u_t \end{bmatrix}$$

Then the system composed of equations (1), (2), (3), and (4) can be written as

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

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

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

To estimate the effects of temporary and permanent monetary shocks on the **real exchange rate**, e_t,

$$e_t \equiv \ln\left(\frac{S_t P_t^*}{P_t}\right)$$

we replace $\widehat{\epsilon}_t$ with $\epsilon_t^r \equiv e_t - e_{t-1}$ in $\widehat{Y}_t$ and we replace the change in the nominal depreciation rate with the level of the real depreciation rate in o_t, that is, we replace $\Delta\epsilon_t$ with ϵ_t^r in o_t.

Estimation

The model to be estimated then is

$$\xi_{t+1} = F\xi_t + P\nu_{t+1}; \quad \text{with } \nu_t \sim iid\, \mathcal{N}(0, I),$$

$$o_t = H'\xi_t + \mu_t; \quad \text{with } \mu_t \sim iid\, \mathcal{N}(0, R),$$

The state vector ξ_t is latent.

The arrays F, P, H, R are what we want to estimate.

The vector o_t is observable.

The model is estimated using Bayesian techniques.

The Kalman filter is used to evaluate the likelihood function.

Identification Assumptions

1. Output (y_t) is cointegrated with the permanent nonmonetary shock (X_t).

2. Inflation (π_t) and the nominal interest rate (i_t) are cointegrated with the permanent monetary shock (X_t^m).

3. The foreign nominal interest rate (i_t^*) is cointegrated with the foreign permanent monetary shock (X_t^{m*}).

4. The depreciation rate (ϵ_t) is cointegrated with ($X_t^m - X_t^{m*}$).

5. A transitory monetary shock that increases the interest rate ($z_t^m \uparrow$) has a nonpositive impact effect on output and inflation: $C_{12}, C_{22} \leq 0$. (Implemented via prior distribution.)

Prior Distributions

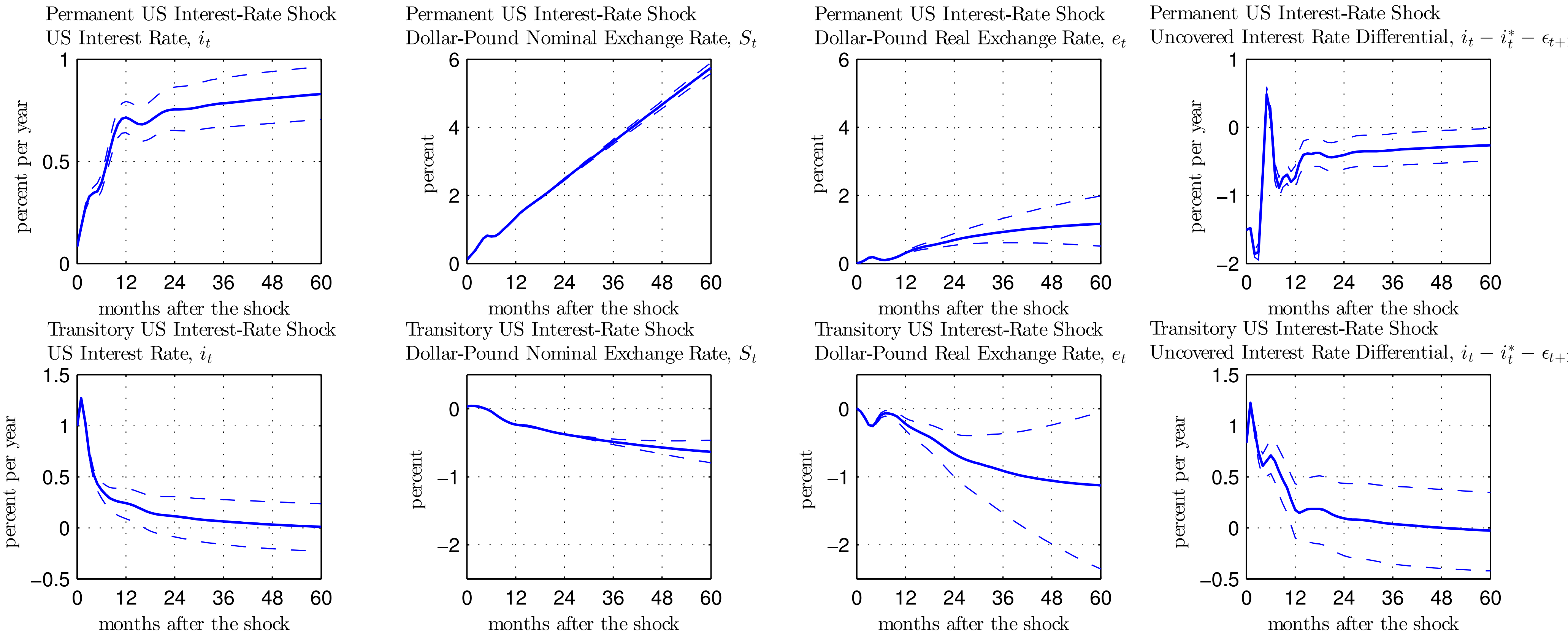
Parameter	Distribution	Mean.	Std. Dev.
Main diagonal elements of B_1	Normal	0.95	0.5
All other elements of B_i, $i = 1, \ldots, L$	Normal	0	0.25
C_{21}, C_{31}, C_{55}	Normal	-1	1
$-C_{12}, -C_{22}$	Gamma	1	1
All other estimated elements of C	Normal	0	1
ρ_{ii}, $i = 1, 2, 3, 5$	Beta	0.3	0.2
ρ_{44}	Beta	0.7	0.2
ψ_{ii}, $i = 1, \ldots, 5$	Gamma	1	1
R_{ii}	Uniform $\left[0, \frac{\text{var}(o_t)}{10}\right]$	$\frac{\text{var}(o_t)}{10\times 2}$	$\frac{\text{var}(o_t)}{10\times\sqrt{12}}$
Mean of o_t	Normal	mean(o_t)	$\sqrt{\frac{\text{var}(o_t)}{T}}$

Notes. The lag length, L, is assumed to be 6 months. The sample length, T, equals 513 months. The total number of parameters to be estimated is 193.

The Data

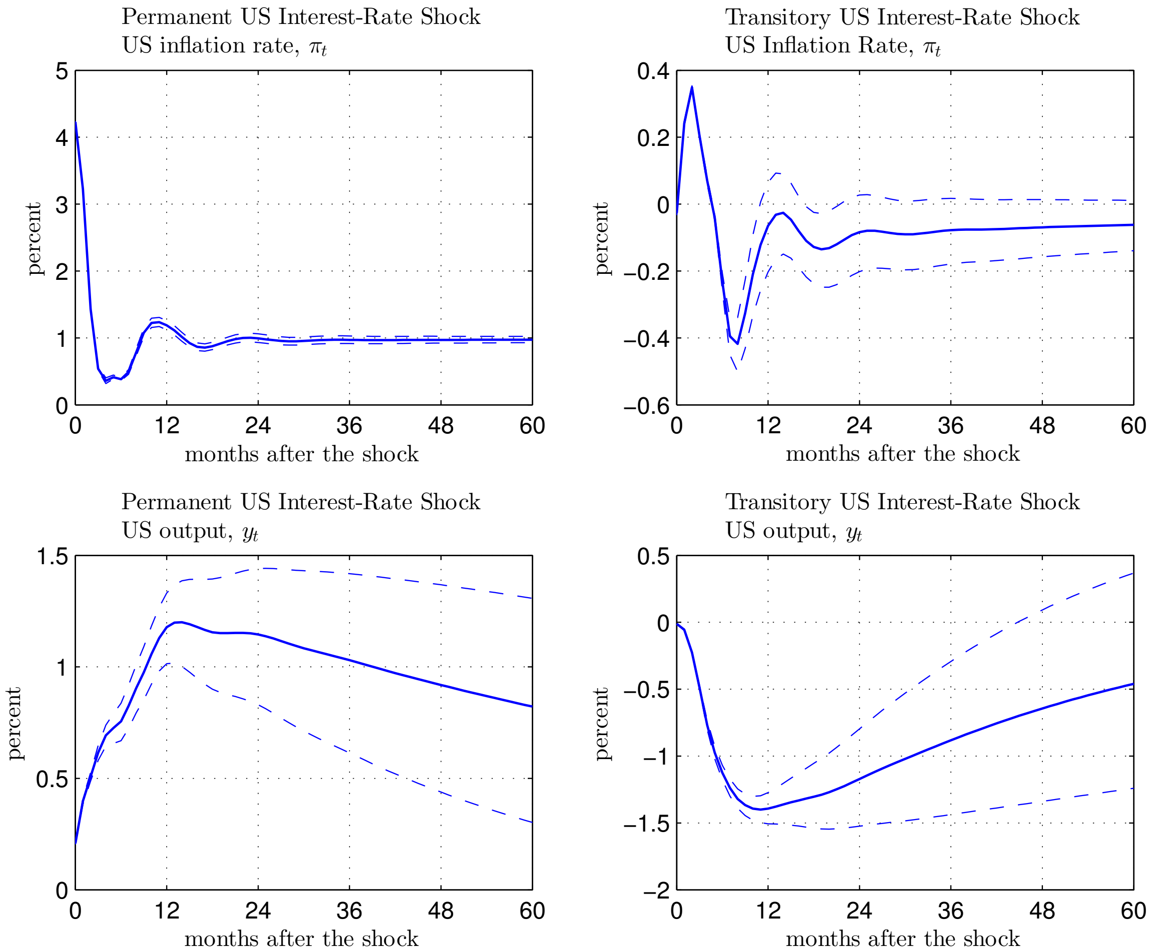
- Domestic country: U.S.; Foreign country: U.K. or Japan
- Monthly: 1974:1–2018:3.
- y_t = U.S. industrial production (Source: OECD MEI)
- P_t = U.S. CPI index (Source: OECD MEI)
- i_t = Federal Funds rate (Source: FRB)
- S_t = \$–£ or \$–¥ nominal exchange rate (Source: FRED)
- i^*_t = Official bank rate (Source: BOE) or Call rate (Source: BOJ)
- P^*_t = U.K. or JP CPI index (Source: OECD MEI)

Impulse Responses to Permanent and Transitory U.S. Monetary Shocks
Foreign country is the United Kingdom

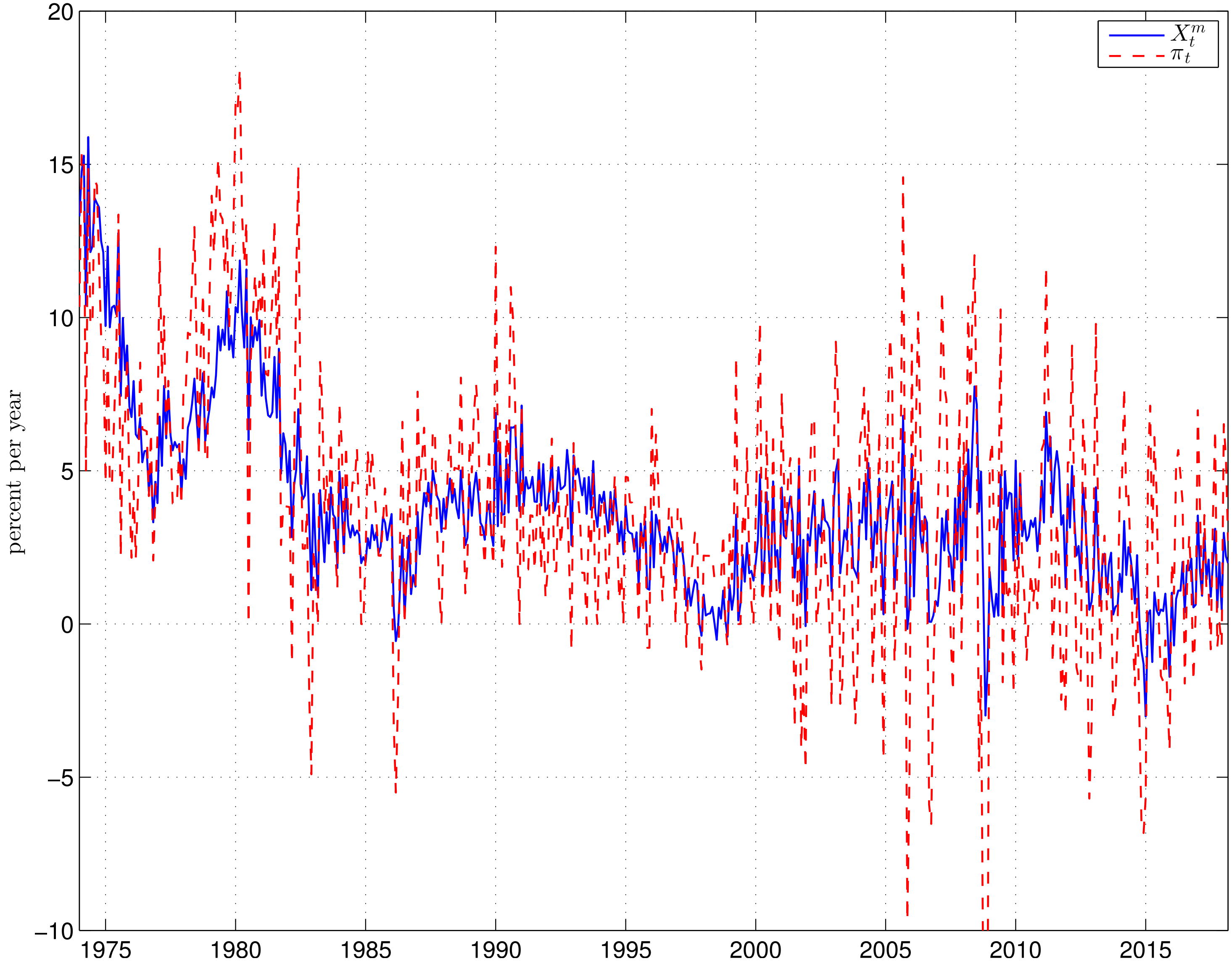


Solid lines: posterior mean estimates from MCMC chain of length 1 million.
Broken lines: asymmetric 95-percent Sims-Zha error bands.

Impulse Responses of U.S. Inflation and Output to Permanent and Transitory U.S. Monetary Shocks: United Kingdom

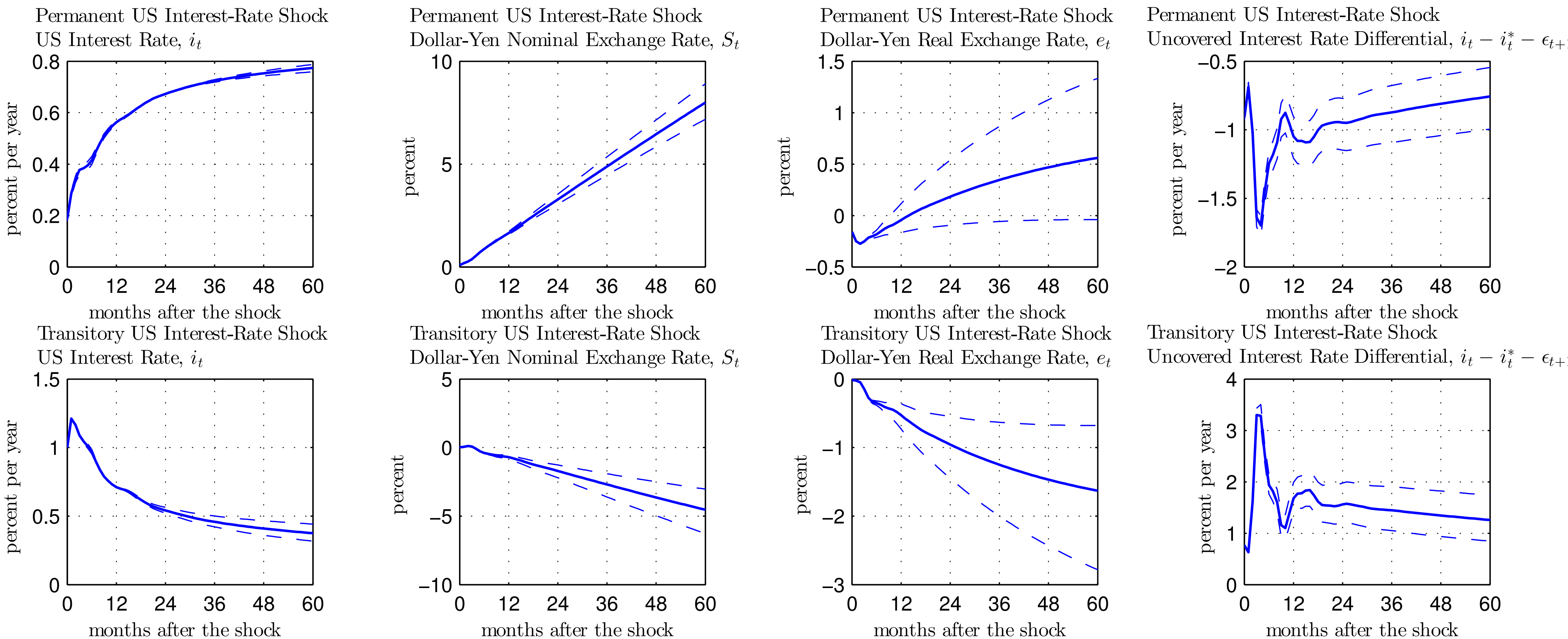


U.S. Inflation and Its Permanent Component: Empirical model with United Kingdom



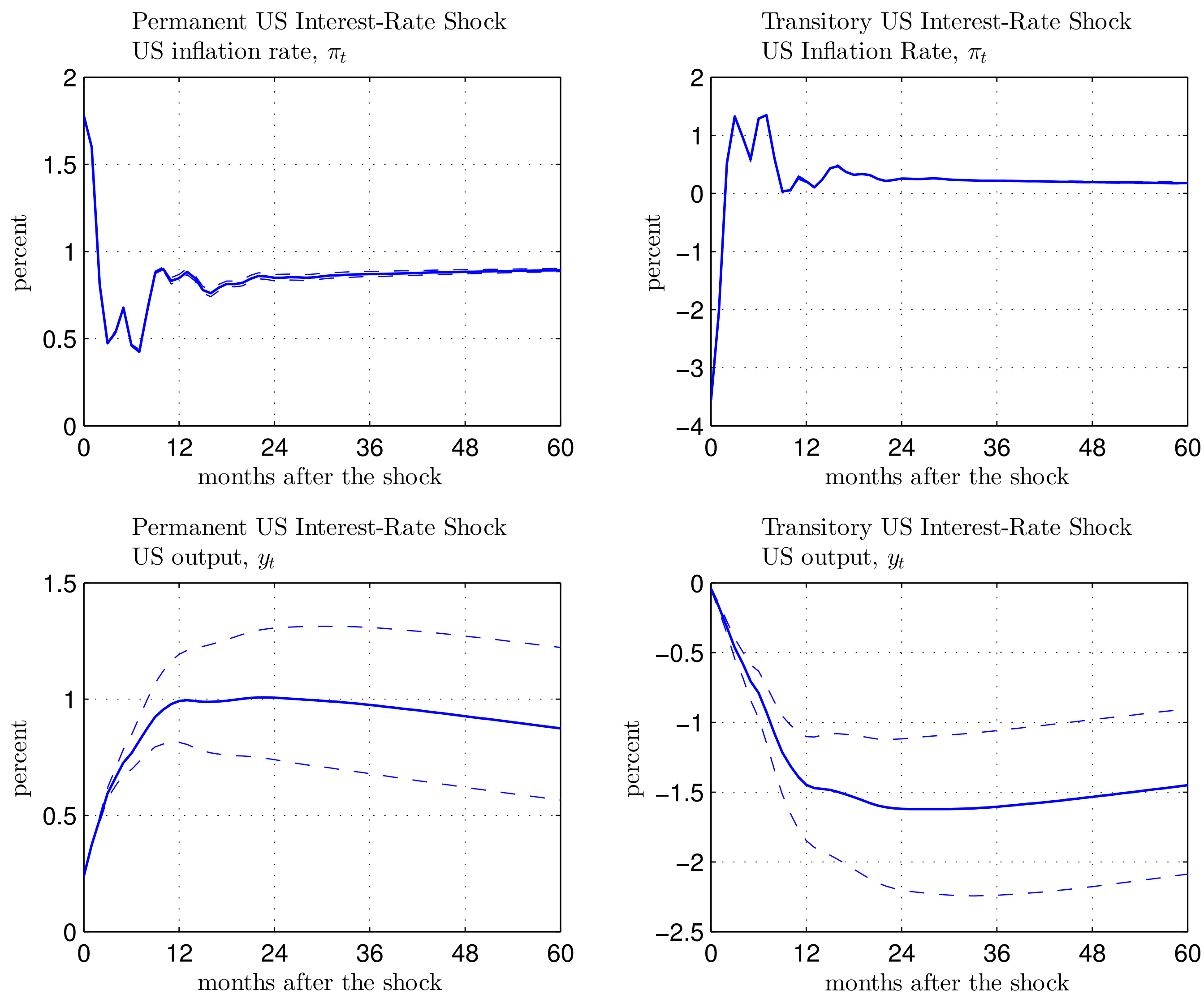
Results obtained when the foreign country is taken to be the United Kingdom continue to hold when the foreign country is assumed to be Japan.

Impulse Responses to Permanent and Transitory U.S. Monetary Shocks: Foreign country is Japan



Solid lines: posterior mean estimates from MCMC chain of length 1 million.
Broken lines: asymmetric 95-percent Sims-Zha error bands.

Impulse Responses of U.S. Inflation and Output to Permanent and Transitory U.S. Monetary Shocks: Foreign country is Japan



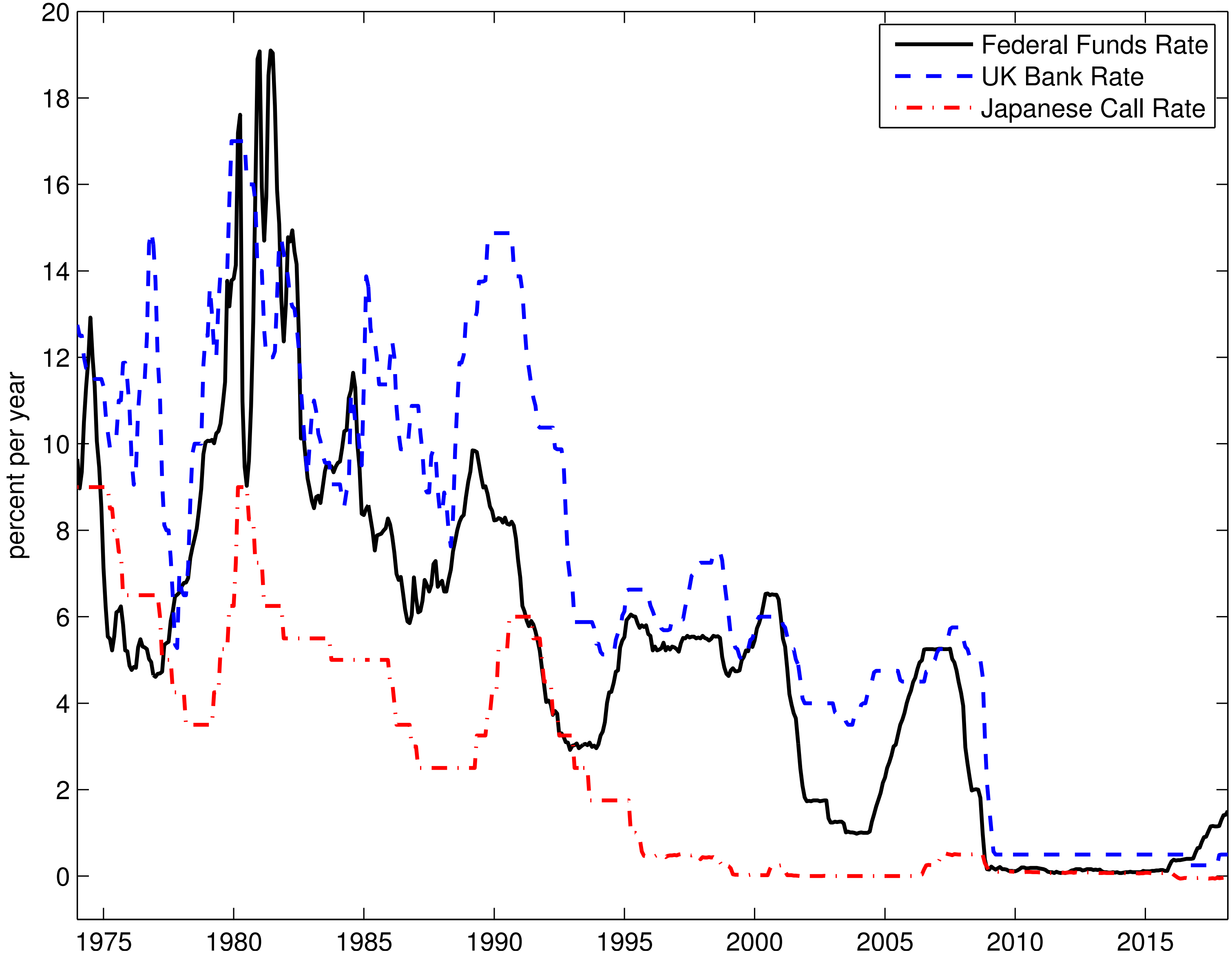
The Importance of Permanent Monetary Shocks for Exchange Rates

Forecast Error Variance Decomposition at Horizon 36 months

	A. United Kingdom						
	Δy_t	π_t	i_t	$\ln S_t$	$\ln e_t$	i_t^*	UID
Permanent M Shock, X_t^m	0.10	0.84	0.35	0.37	0.07	0.01	0.05
Transitory M Shock, z_t^m	0.08	0.01	0.06	0.00	0.01	0.01	0.01
Permanent NonM Shock, X_t	0.27	0.06	0.51	0.05	0.71	0.05	0.90
Transitory NonM Shock, z_t	0.50	0.03	0.00	0.00	0.20	0.00	0.00
Permanent Foreign M Shock, X_t^{m*}	0.05	0.05	0.08	0.58	0.00	0.94	0.04
	B. Japan						
	Δy_t	π_t	i_t	$\ln S_t$	$\ln e_t$	i_t^*	UID
Permanent M Shock, X_t^m	0.26	0.82	0.57	0.50	0.01	0.00	0.12
Transitory M Shock, z_t^m	0.04	0.07	0.08	0.01	0.01	0.00	0.03
Permanent NonM Shock, X_t	0.18	0.07	0.33	0.35	0.98	0.06	0.81
Transitory NonM Shock, z_t	0.44	0.04	0.01	0.02	0.00	0.00	0.01
Permanent Foreign M Shock, X_t^{m*}	0.08	0.01	0.02	0.12	0.00	0.93	0.03

Notes. Uncovered interest rate differential (UID)$= i_t - i_t^* - \epsilon_{t+1}$. Δy_t, U.S. output growth; π_t, U.S. inflation; i_t, the Federal Funds rate; $\ln S_t$, dollar-pound or dollar-yen nominal exchange rate; $\ln e_t$, the dollar-pound or dollar-yen real exchange rate; i_t^*, U.K. or Japanese nominal interest rate; $\epsilon_t \equiv \ln(S_t/S_{t-1})$, devaluation rate.

Cointegrated Monetary Policies?



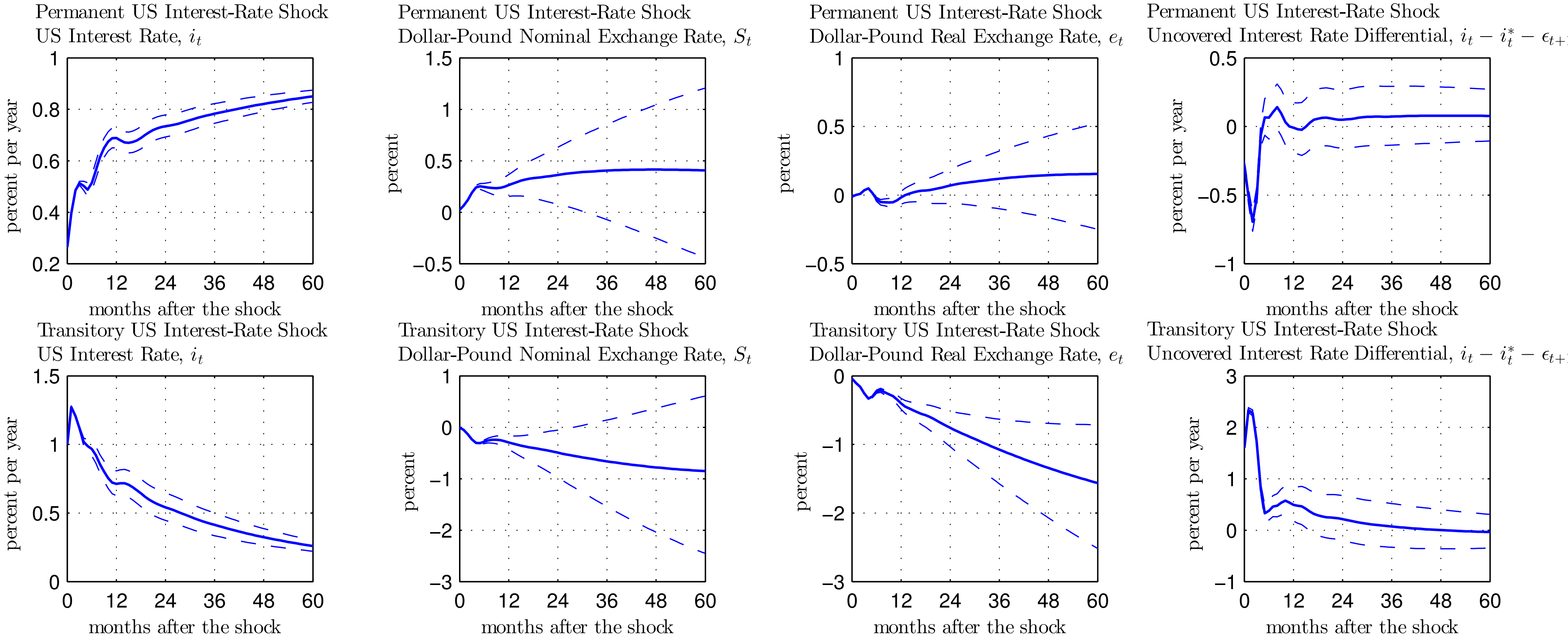
Model with only one permanent monetary shock

$$\begin{bmatrix} \Delta X^m_{t+1} \\ z^m_{t+1} \\ \Delta X_{t+1} \\ z_{t+1} \\ X^m_{t+1} - X^{m*}_{t+1} \end{bmatrix} = \rho \begin{bmatrix} \Delta X^m_t \\ z^m_t \\ \Delta X_t \\ z_t \\ X^m_t - X^{m*}_t \end{bmatrix} + \psi \begin{bmatrix} \nu^1_{t+1} \\ \nu^2_{t+1} \\ \nu^3_{t+1} \\ \nu^4_{t+1} \\ \nu^5_{t+1} \end{bmatrix}$$

The assumption that $X^m_t - X^{m*}_t$ is stationary induces stationarity in both the interest rate differential, $i_t - i^*_t$, and the devaluation rate, $\epsilon_t \equiv \ln(S_t/S_{t-1})$. $\rightarrow$ We can include ϵ_t as an observable.

$$o_t = \begin{bmatrix} \Delta y_t \\ r_t \\ \Delta i_t \\ \epsilon_t \\ i_t - i^*_t \end{bmatrix} + \mu_t$$

Impulse Responses to Permanent and Transitory U.S. Monetary Shocks Under Cointegrated U.S. and U.K. Monetary Policies



Solid lines: posterior mean estimates from MCMC chain of length 1 million.
Broken lines: asymmetric 95-percent Sims-Zha error bands.

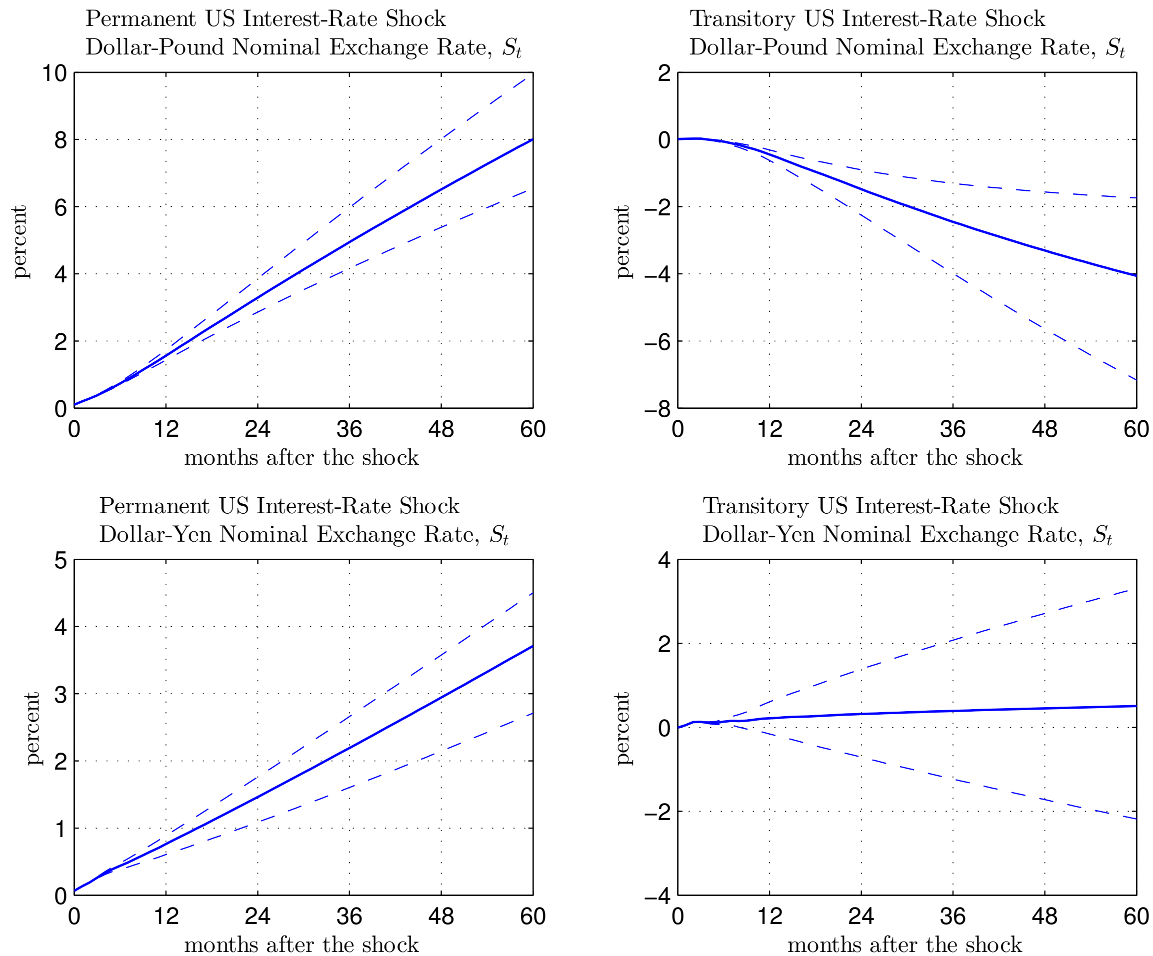
The Volcker Era

- Kim, Moon, and Velasco (JPE, 2017) argue that delayed overshooting is circumscribed to the Volcker Era. (Instantaneous overshooting is a feature of the post Volcker sample.)

- The present paper, by contrast, argues that once one allows for both transitory and permanent monetary shocks, the overshooting effect, instantaneous or delayed, disappears altogether.

- The next figure shows that our finding of no overshooting is robust to truncating the sample in December of 1987, the end of the Volcker era.

No Delayed Exchange Rate Overshooting During the Volcker Era



Baseline model estimated on the 1974:1-1987:12 sample.

Conclusions

The innovation of the present paper is to allow for permanent and transitory monetary shocks. Estimation on monthly post-Bretton-Woods data from the United States, the United Kingdom, and Japan shows that:

- permanent monetary shocks explain the majority of short-run movements in nominal exchange rates.

- there is no exchange-rate overshooting, either of the immediate or delayed type, in response to monetary shocks, suggesting that existing overshooting results may be the consequence of confounding permanent and transitory impulses.

- transitory tightenings cause deviations from uncovered interest-rate parity in favor of domestic assets, whereas permanent tightenings cause deviations in favor of foreign assets.

Extras

Forecast Error Variance Decomposition at Horizons between 12 and 48 months: United Kingdom

	Δy_t	π_t	i_t	$\ln S_t$	$\ln e_t$	i_t^*	uid
Permanent Monetary Shock, X_t^m							
Horizon 12 months	0.10	0.83	0.23	0.23	0.00	0.01	0.05
Horizon 24 months	0.10	0.83	0.31	0.36	0.03	0.01	0.05
Horizon 36 months	0.10	0.84	0.35	0.37	0.07	0.01	0.05
Horizon 48 months	0.10	0.85	0.37	0.36	0.10	0.00	0.05
Transitory Monetary Shock, z_t^m							
Horizon 12 months	0.08	0.01	0.23	0.00	0.00	0.01	0.01
Horizon 24 months	0.08	0.01	0.10	0.00	0.00	0.01	0.01
Horizon 36 months	0.08	0.01	0.06	0.00	0.01	0.01	0.01
Horizon 48 months	0.08	0.01	0.05	0.00	0.02	0.01	0.01
Permanent Nonmonetary Shock, X_t							
Horizon 12 months	0.26	0.07	0.47	0.50	0.98	0.06	0.93
Horizon 24 months	0.27	0.07	0.51	0.14	0.88	0.05	0.91
Horizon 36 months	0.27	0.06	0.51	0.05	0.71	0.05	0.90
Horizon 48 months	0.27	0.06	0.49	0.03	0.59	0.04	0.89
Transitory Nonmonetary Shock, z_t							
Horizon 12 months	0.52	0.05	0.00	0.00	0.01	0.00	0.00
Horizon 24 months	0.51	0.04	0.00	0.00	0.09	0.00	0.00
Horizon 36 months	0.50	0.03	0.00	0.00	0.20	0.00	0.00
Horizon 48 months	0.50	0.03	0.00	0.00	0.28	0.00	0.00
Permanent Foreign Monetary Shock, X_t^{m*}							
Horizon 12 months	0.03	0.04	0.06	0.26	0.00	0.92	0.01
Horizon 24 months	0.04	0.05	0.07	0.50	0.00	0.93	0.03
Horizon 36 months	0.05	0.05	0.08	0.58	0.00	0.94	0.04
Horizon 48 months	0.05	0.05	0.09	0.61	0.00	0.95	0.05

Note. uid$= i_t - i_t^* - \epsilon_{t+1}$.

Forecast Error Variance Decomposition at Horizons between 12 and 48 months: Japan

	Δy_t	π_t	i_t	$\ln S_t$	$\ln e_t$	i_t^*	uid
Permanent Monetary Shock, X_t^m							
Horizon 12 months	0.28	0.73	0.55	0.39	0.01	0.01	0.11
Horizon 24 months	0.26	0.80	0.58	0.54	0.01	0.00	0.12
Horizon 36 months	0.26	0.82	0.57	0.50	0.01	0.00	0.12
Horizon 48 months	0.26	0.83	0.56	0.48	0.02	0.00	0.12
Transitory Monetary Shock, z_t^m							
Horizon 12 months	0.04	0.15	0.26	0.01	0.00	0.01	0.03
Horizon 24 months	0.04	0.10	0.13	0.01	0.00	0.00	0.03
Horizon 36 months	0.04	0.07	0.08	0.01	0.01	0.00	0.03
Horizon 48 months	0.04	0.05	0.06	0.01	0.01	0.00	0.03
Permanent Nonmonetary Shock, X_t							
Horizon 12 months	0.13	0.03	0.12	0.51	0.99	0.12	0.84
Horizon 24 months	0.17	0.05	0.26	0.32	0.99	0.08	0.82
Horizon 36 months	0.18	0.07	0.33	0.35	0.98	0.06	0.81
Horizon 48 months	0.19	0.08	0.35	0.38	0.96	0.05	0.81
Transitory Nonmonetary Shock, z_t							
Horizon 12 months	0.48	0.08	0.00	0.01	0.00	0.01	0.01
Horizon 24 months	0.45	0.05	0.00	0.02	0.00	0.00	0.01
Horizon 36 months	0.44	0.04	0.01	0.02	0.00	0.00	0.01
Horizon 48 months	0.44	0.03	0.01	0.01	0.00	0.00	0.01
Permanent Foreign Monetary Shock, X_t^{m*}							
Horizon 12 months	0.08	0.01	0.06	0.07	0.00	0.85	0.01
Horizon 24 months	0.08	0.01	0.03	0.11	0.00	0.90	0.02
Horizon 36 months	0.08	0.01	0.02	0.12	0.00	0.93	0.03
Horizon 48 months	0.08	0.01	0.02	0.12	0.00	0.94	0.03

Note. uid= $i_t - i_t^* - \epsilon_{t+1}$.

The State Space Representation

Now including the constants, which were omitted earlier.

$$\widehat{Y}_t \equiv \begin{bmatrix} y_t - X_t - E(y_t - X_t) \\ \pi_t - X_t^m - E(\pi_t - X_t^m) \\ i_t - X_t^m - E(i_t - X_t^m) \\ \epsilon_t - X_t^m + X_t^{m*} - E(\epsilon_t - X_t^m + X_t^{m*}) \\ i_t^* - X_t^{m*} - E(i_t^* - X_t^{m*}) \end{bmatrix}; u_t \equiv \begin{bmatrix} \Delta X_t^m - E(\Delta X_t^m) \\ z_t^m \\ \Delta X_t - E(\Delta X_t) \\ z_t \\ \Delta X_t^{m*} - E(\Delta X_t^{m*}) \end{bmatrix}$$

$$\widehat{Y}_t = \sum_{i=1}^{L} B_i \widehat{Y}_{t-i} + C u_t$$

$$u_t = \rho u_{t-1} + \psi \nu_t$$

$$\xi_t \equiv \begin{bmatrix} \widehat{Y}_t' & \widehat{Y}_{t-1}' & \dots & \widehat{Y}_{t-L+1}' & u_t' \end{bmatrix}'$$

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

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

$V = 5$, number of variables included in the vector $\widehat{Y}_t$,
$S = 5$, number of shocks in the vector ν_t,
$L = 6$, number of lags.

$$B \equiv [B_1 \cdots B_L]; F = \begin{bmatrix} B & C\rho \\ \begin{bmatrix} I_{V(L-1)} & \emptyset_{V(L-1),V} \end{bmatrix} & \emptyset_{V(L-1),S} \\ \emptyset_{S,VL} & \rho \end{bmatrix}; P = \begin{bmatrix} C\psi \\ \emptyset_{V(L-1),S} \\ \psi \end{bmatrix}$$

$$A = \begin{bmatrix} E(\Delta X_t) & E(i_t - \pi_t) & E(\Delta X_t^m) & E(\Delta X_t^m - \Delta X_t^{m*}) & E(\Delta X_t^{m*}) \end{bmatrix}$$

$$H' = \begin{bmatrix} M_\xi & \emptyset_{V,V(L-2)} & M_u \end{bmatrix},$$

$$M_\xi = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & -1 \end{bmatrix}; M_u = \begin{bmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & -1 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}.$$

Prior for the elements of the matrix A: Normal, mean(o_t), standard deviation, $\sqrt{\frac{\text{var}(o_t)}{T}}$, where T denotes the sample length, 531 months.

Observation equations in model with only one permanent monetary shock

$$\Delta y_t = \widehat{y}_t - \widehat{y}_{t-1} + \Delta X_t$$

$$r_t = \widehat{i}_t - \widehat{\pi}_t$$

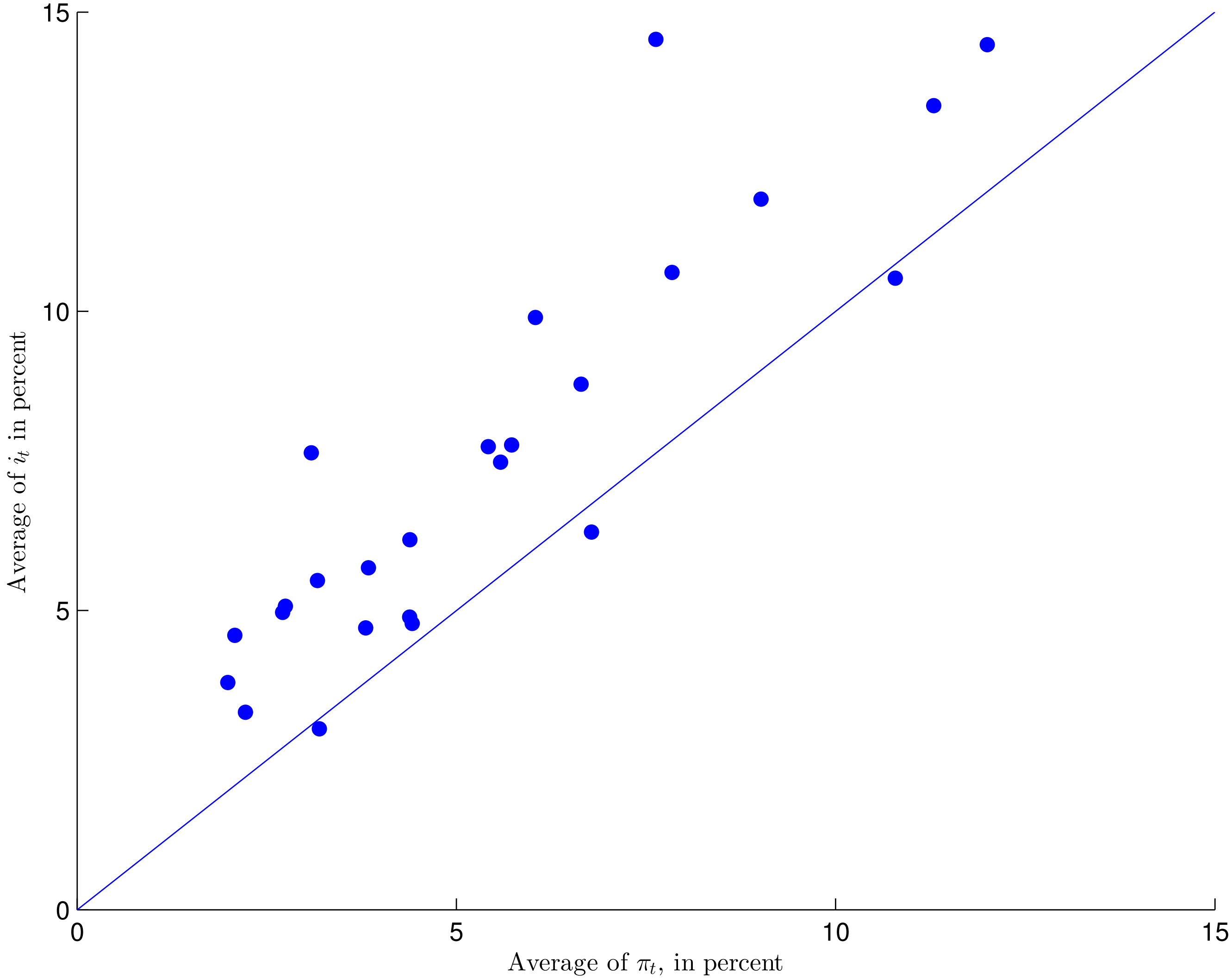
$$\Delta i_t = \widehat{i}_t - \widehat{i}_{t-1} + \Delta X_t^m$$

$$\epsilon_t = \widehat{\epsilon}_t + X_t^m - X_t^{m*}$$

$$i_t - i_t^* = \widehat{i}_t - \widehat{i}_t^* + X_t^m - X_t^{m*}.$$

Note that only the last two observation equations differ from their baseline counterparts.

Cross-Country Evidence on the Long-Run Fisher Effect
Long-Run Averages of Inflation and Nominal Interest Rates



25 OECD countries. Average sample period is 1989 to 2012.

Eichenbaum and Evans, QJE 1995

Three definitions of a monetary shock are considered:

1. Orthogonalized innovations to the log of the ratio of non-borrowed reserves to borrowed reserves ($NBRX$).

2. Orthogonalized innovations to the federal funds rate.

3. The Romer-Romer (1989) index of monetary contractions.

We will present their results for identification scheme 2, orthogonalized innovations to the federal funds rate, as all three schemes give qualitatively very similar results.

Sample

- Monthly data from 1974:1 to 1990:5.

- Five exchange rates (s_t): Yen, Deutsche Mark, Lira, French Franc, and UK Pound, where s_t denotes the log of the U.S. dollar price of one unit of foreign currency.

- The log of the real exchange rate is defined as $s_t^R = s_t + p_t^* - p_t$, where p_t^* and p_t denote the logs of the consumer price indices in the foreign country and the United States, respectively.

- VAR: 7 variables: log of U.S. industrial production (Y), log of U.S. consumer price index (P), log of foreign industrial production (Y^*), foreign interest rate (i^*), federal funds rate (i), log of non-borrowed-to-borrowed reserve ratio ($NBRX$), and the nominal (or real) exchange rate (s or s^R).

VAR Specification

- Ordering of the VAR: $[Y, P, Y^*, i^*, i, NBRX, s$ (or s^R)]
- Identification of monetary policy shock, Cholesky decomposition.
- VAR includes 6 lags.
- Monthly data from January 1974 to May 1990.
- Error bands of impulse responses: $\pm$1 standard deviation in width.

The next slide shows the impulse response to a U.S. monetary policy shock, specifically a tightening of 60 basis points. It is Figure 3 of Eichenbaum and Evans (QJE 1995).

Row 1: Impulse response of U.S. federal funds rate, i

Row 2: Impulse response of foreign interest rate, i^*

Row 3: Impulse response of real exchange rate, s^R

Row 4: Impulse response of log of nominal exchange rate, s

Row 5: Impulse response of uncovered interest rate differential, $i_t^* - i_t + s_{t+1} - s_t$

Columns are: Japan, Germany, Italy, France, and the United Kingdom

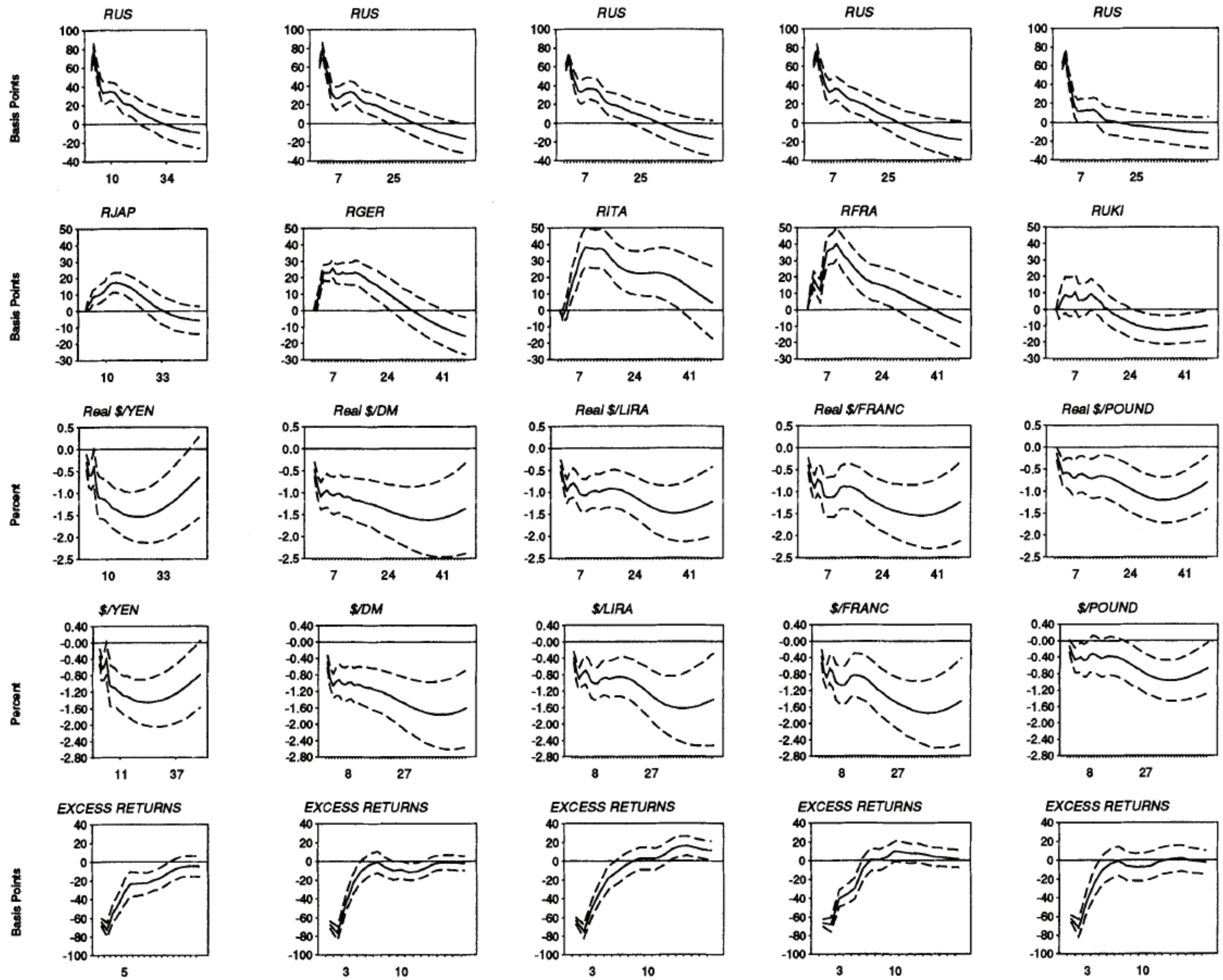


FIGURE III

Dynamic Response Functions: Orthogonalized Shock in Federal Funds Rate, Seven-Variable System

Column 1 displays the dynamic effect of an orthogonalized innovation in the Federal Funds rate on the Federal Funds rate (RUS), the Japanese interest rate (RJAP), the real U. S.–Japan exchange rate, the nominal U. S.–Japan exchange rate, and an uncovered interest parity condition. Columns 2 through 5 do the same for Germany, Italy, France, and the United Kingdom, respectively.

Main Findings of Eichenbaum and Evans (QJE, 1995)

1. A contractionary shock to U.S. monetary policy leads to persistent and **significant appreciation** in nominal and real U.S. exchange rates.

2. The maximal impact of a monetary shock on exchange rates does not occur contemporaneously but about **36 months** after the monetary policy shock. This finding supports a "broader view of overshooting," **delayed overshooting**.

3. A contractionary U.S. monetary policy shock induces a systematic and persistent **departure from uncovered interest parity** with "excess returns" in favor of U.S. assets.