



A Solution to the Price Puzzle on US Data

A Structural VAR Approach

Macroeconomics: Advanced Time-Series Analysis

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- 1 Introduction
- 2 Data and break points
- 3 Solving the price puzzle
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The price puzzle

- **Price puzzle** Sims, 1980: inflation increases following a contractionary monetary policy shock identified via a recursive SVAR
- At odds with standard macroeconomic theory:
 - higher interest rates should reduce demand
 - and lower inflation
- Two periods where the puzzle is particularly salient:
 - ① pre-Volcker era (before 1979)
 - ② post-2008 / post-2010 (ZLB, QE, forward guidance)

Main contributions

- **Baseline SVAR** (output gap, inflation, FFR):
 - strong price puzzle before 1979
 - re-emergence after 2010
 - consistent with early VAR evidence (Sims, 1980)
- **Information-based approaches:**
 - Sims, 1992 mitigates the price puzzle by adding commodity prices as an information proxy
 - Castelnuovo and Surico, 2010 explicitly includes Greenbook inflation expectations
 - expectations absorb anticipatory monetary policy reactions
- **Alternative identification strategies:**
 - sign-restricted SVARs (Uhlig, 2005)
 - narrative / external-instrument approach à la Romer and Romer, 2004
 - both confirm that the price puzzle reflects misidentification rather than transmission

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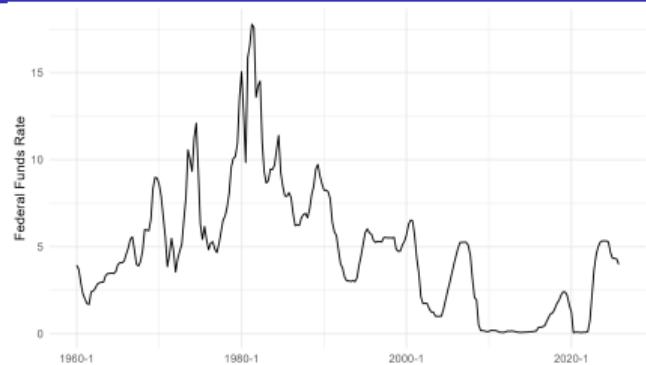
Data



Output gap (CBO)



Inflation (GDP deflator)



Federal funds rate (FRED)



Greenbook inflation forecasts

Break tests

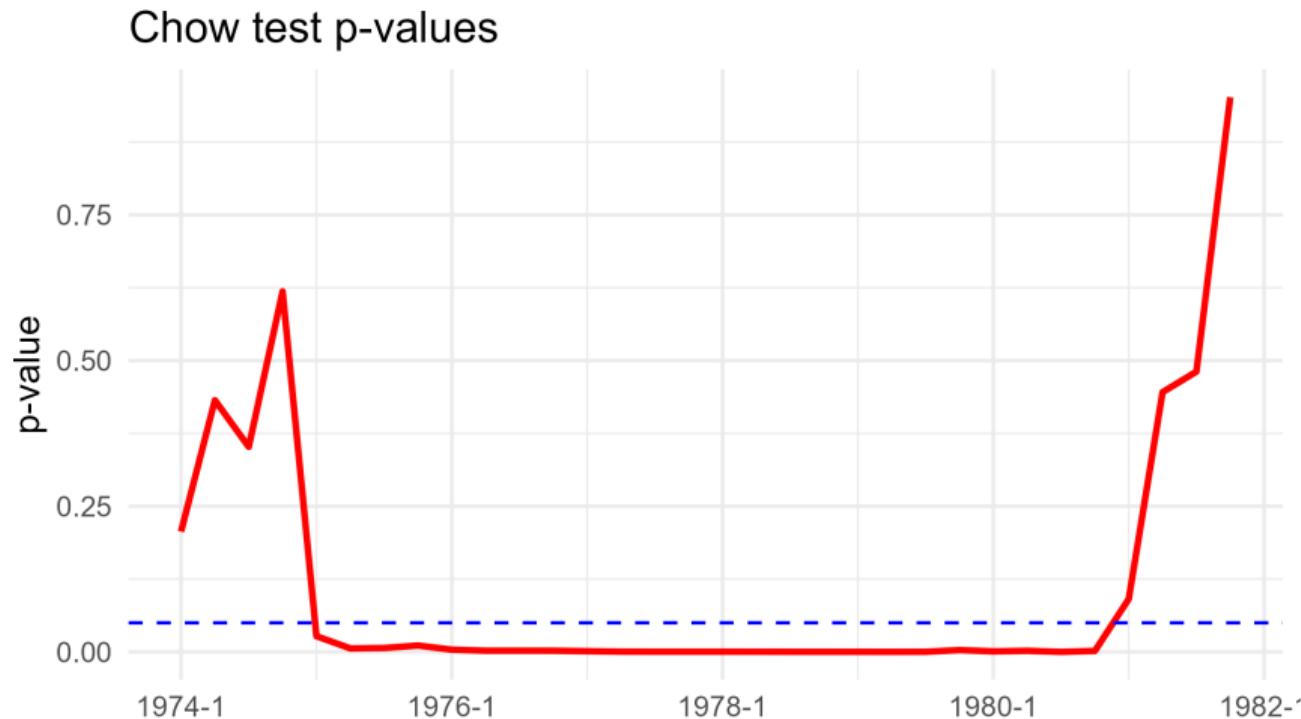


Figure: Chow test p-values for structural breaks

New Keynesian benchmark: model equations

(IS) Dynamic IS curve

$$x_t = \mathbb{E}_t x_{t+1} - \chi(i_t - \mathbb{E}_t \pi_{t+1}) + a_t$$

Shock processes (AR(1))

(NKPC) New Keynesian Phillips Curve

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa(x_t - c_t)$$

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

(MP) Monetary policy rule

$$i_t = \rho_R i_{t-1} + (1 - \rho_R) \left(\phi_\pi \mathbb{E}_t \pi_{t+1} + \phi_x (x_t - c_t) \right) + b_t$$

(Monetary) $b_t = \rho_b b_{t-1} + \varepsilon_t^b$

(Cost-push) $c_t = \rho_c c_{t-1} + \varepsilon_t^c$

NK IRFs vs SVAR IRFs

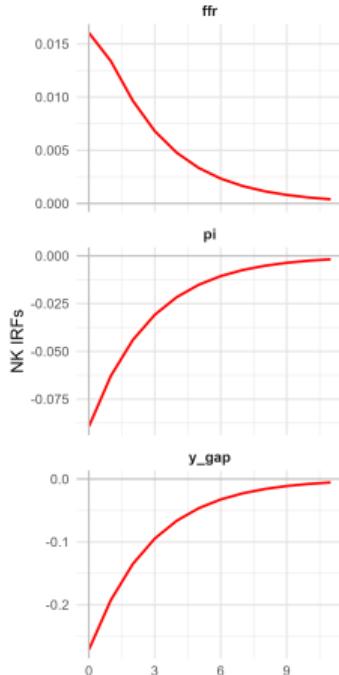


Figure: NK IRFs: monetary policy shock

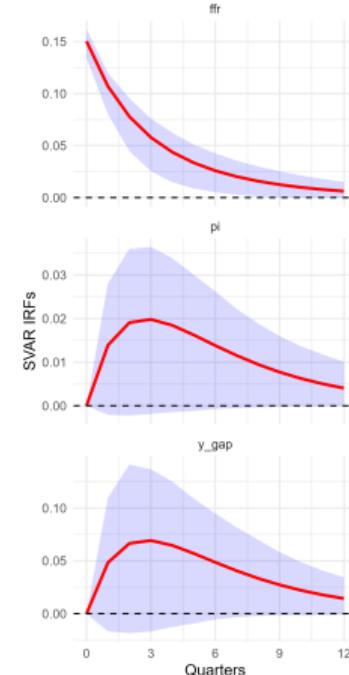


Figure: SVAR IRFs: artificial data

Interpretation

- **SVAR on simulated data:** Inflation displays a price puzzle, even though the data are generated by a standard NK model
- **Key insight:** The price puzzle is **not structural**.
- **Source of the puzzle:**
 - It arises from **identification and timing assumptions**, not from the underlying model
 - Monetary policy combines *policy reactions* and *policy shocks*
 - The endogenous policy reaction responds to expected inflation
 - Expectations are omitted from the VAR
- **Implication:** Remove the endogenous component and/or control for expected inflation.

SVAR evidence: real data

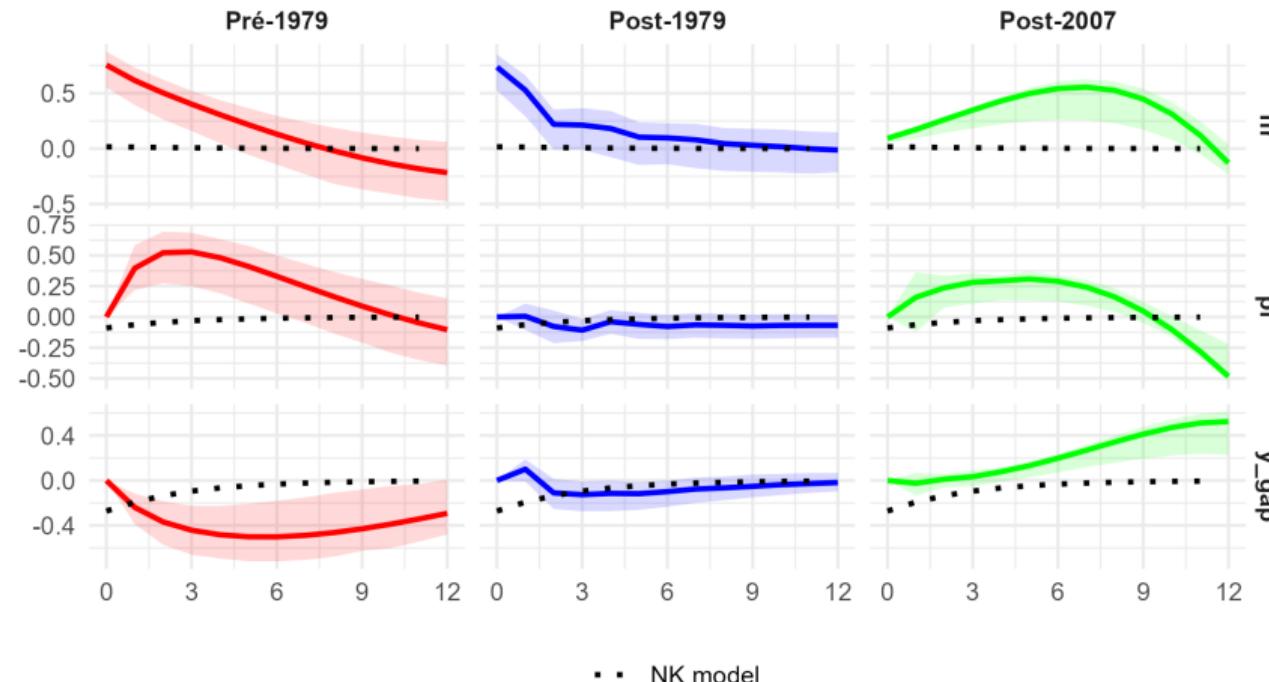


Figure: SVAR IRFs from real data

FEVD and shock misidentification

- The figure shows the **forecast error variance decomposition (FEVD)** of inflation.
- Inflation variability is mostly driven by **non-monetary shocks** (inflation and output gap) especially before 1979 and after 2008
- The monetary policy shock explains only a small share but reacts endogenously to expected inflation
- Recursive SVARs therefore **confound policy reactions with policy shocks**, generating a price puzzle

$$\text{FEVD}_{\pi,j}(h) = \frac{\sum_{k=0}^{h-1} (\text{IRF}_{\pi,j}(k))^2}{\sum_{m=1}^n \sum_{k=0}^{h-1} (\text{IRF}_{\pi,m}(k))^2}$$

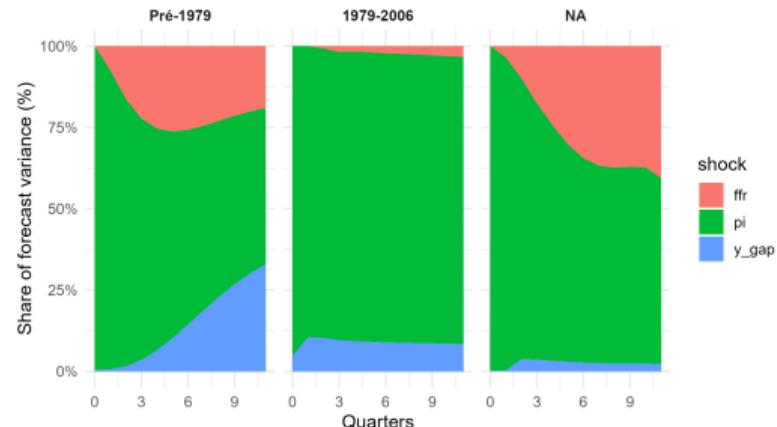


Figure: Inflation FEVD by shock

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Why does the puzzle vary across periods?

- Monetary policy regimes differ sharply across subsamples
- Before 1979:
 - weak anti-inflation credibility
 - policy reacts to expected inflation
 - recursive VARs confound reactions and shocks
- After Volcker:
 - stronger credibility and anchoring of expectations
 - cleaner identification of monetary shocks

Sign-restricted identification

- SVARs are **rotationally indeterminate**: many structural decompositions are consistent with the same reduced form
- Sign restrictions select rotations consistent with **economic theory**, rather than timing assumptions
- Monetary policy shock is identified by imposing:
 - $\text{IRF}_{\text{ffr}}(0) > 0$
 - $\text{IRF}_{y\text{-gap}}(1) < 0$
 - inflation left unrestricted.
- This removes anticipatory policy components that contaminate recursive (Cholesky) identification

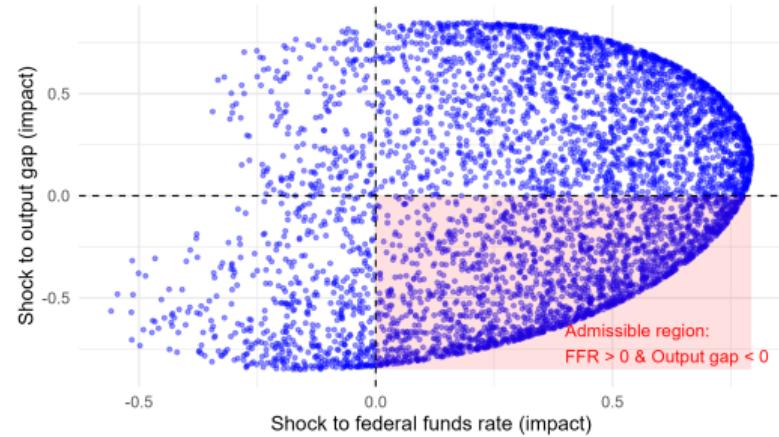


Figure: Admissible rotations under sign restrictions

Sign-restricted IRFs

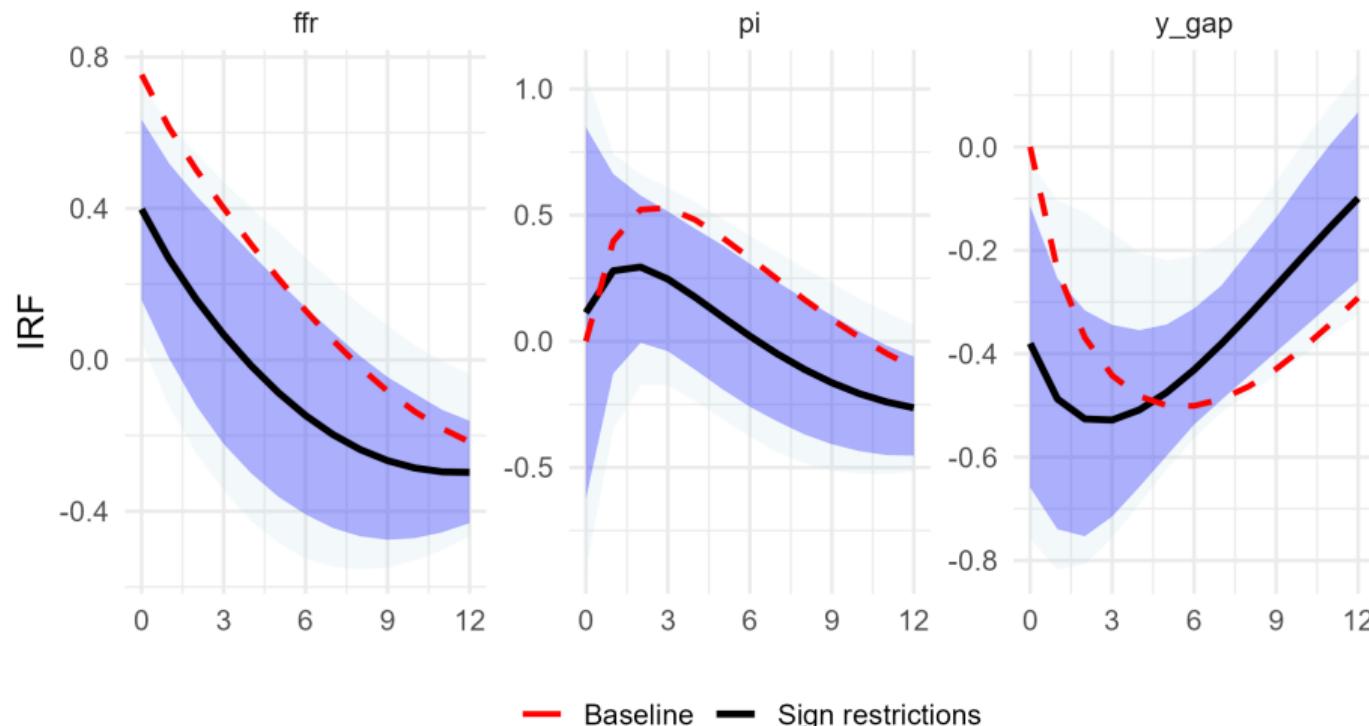


Figure: Sign-restricted impulse responses

Adding Greenbook expectations

- Include the Fed's internal inflation forecasts
- Greenbook forecasts reflect the Fed's internal information set
- Available before FOMC decisions
- Proxy for expected inflation used in policy decisions

CONFIDENTIAL -- FR										II - 4		June 22, 1966			
GROSS NATIONAL PRODUCT AND RELATED ITEMS (Expenditures and income figures are billions of dollars, seasonally adjusted annual rates)															
	1964	1965	1965			Projected			1966						
			II	III	IV	I	II	III	II	III	IV				
Gross National Product	628.7	676.3	668.8	681.5	697.2	713.9	725.0	739.0							
Final sales	623.9	668.1	662.4	673.9	687.1	705.8	715.0	731.0							
Personal consumption expenditures	398.9	428.7	424.5	432.5	441.0	451.8	456.4	465.7							
Durable goods	58.7	65.0	63.5	65.4	66.4	68.7	65.9	67.5							
Non durable goods	177.5	189.0	187.9	190.5	195.0	200.1	203.8	207.5							
Services	162.6	174.7	173.1	176.7	179.	185.0	186.7	190.7							
Gross private domestic investment	92.9	105.7	102.8	106.2	110.3	111.7	115.0	115.3							
Residential construction	27.5	27.6	28.0	27.7	27.2	28.2	27.7	27.0							
Business fixed investment	60.5	69.8	68.4	70.9	73.0	75.5	77.3	80.3							
Changes in business inventories	4.8	8.2	6.4	7.6	10.1	8.1	10.0	8.0							
Nonfarm	5.4	7.9	6.6	7.0	8.9	7.4	9.5	8.0							
Net exports	8.6	7.1	8.0	7.4	6.9	6.4	5.7	5.7							
Gov. purchases of goods and services	128.4	134.8	133.5	135.4	139.0	144.0	147.9	152.3							
Federal	65.3	66.6	65.7	66.5	69.2	72.5	74.7	77.9							
Defense	49.9	49.9	49.2	49.8	52.0	55.0	57.0	59.5							
Other	15.4	16.7	16.5	16.7	17.2	17.5	17.7	18.4							
State and local	63.1	68.2	67.8	68.9	69.8	71.5	73.2	74.4							
Gross National Product in constant (1958) dollars	577.6	609.6	603.5	613.0	624.6	633.5	650.0	642.4							
GNP Implicit deflator (1958=100)	108.9	110.9	110.8	111.2	111.7	112.1	113.5	114.5							
Personal income	495.0	530.7	524.7	536.0	546.0	557.1	566.0	580.0							
Wages and salaries	333.5	357.4	353.6	359.0	368.1	377.0	384.0	392.9							
Transfer payments	36.6	39.2	37.5	41.2	39.7	41.7	41.8	45.7							
Personal contributions for social insurance (deduction)	12.4	13.2	13.0	13.3	13.6	14.8	17.0	17.8							
Disposable personal income	435.8	465.3	458.5	471.2	480.3	488.7	494.6	506.9							
Personal saving	26.3	24.9	22.4	26.8	27.1	24.4	23.3	28.4							
Saving rate (per cent)	6.0	5.4	4.9	5.7	5.6	5.0	5.1	2.7							
Total labor force (millions)	77.0	78.4	78.1	78.5	79.0	79.4	79.7	80.1							
Armed forces	2.7	2.7	2.7	2.7	2.8	2.9	3.0	3.1							
Civilian labor force	74.2	75.6	75.6	75.8	76.2	76.5	76.7	77.0							
Employed	70.4	72.2	71.9	72.4	73.0	73.6	73.9	74.3							
Unemployed	3.9	3.5	3.6	3.4	3.2	2.9	2.8	2.7							
Unemployment rate (per cent)	5.2	4.6	4.7	4.5	4.2	3.8	3.7	3.5							

Figure: Excerpt from a Greenbook inflation forecast

IRFs with Greenbook expectations

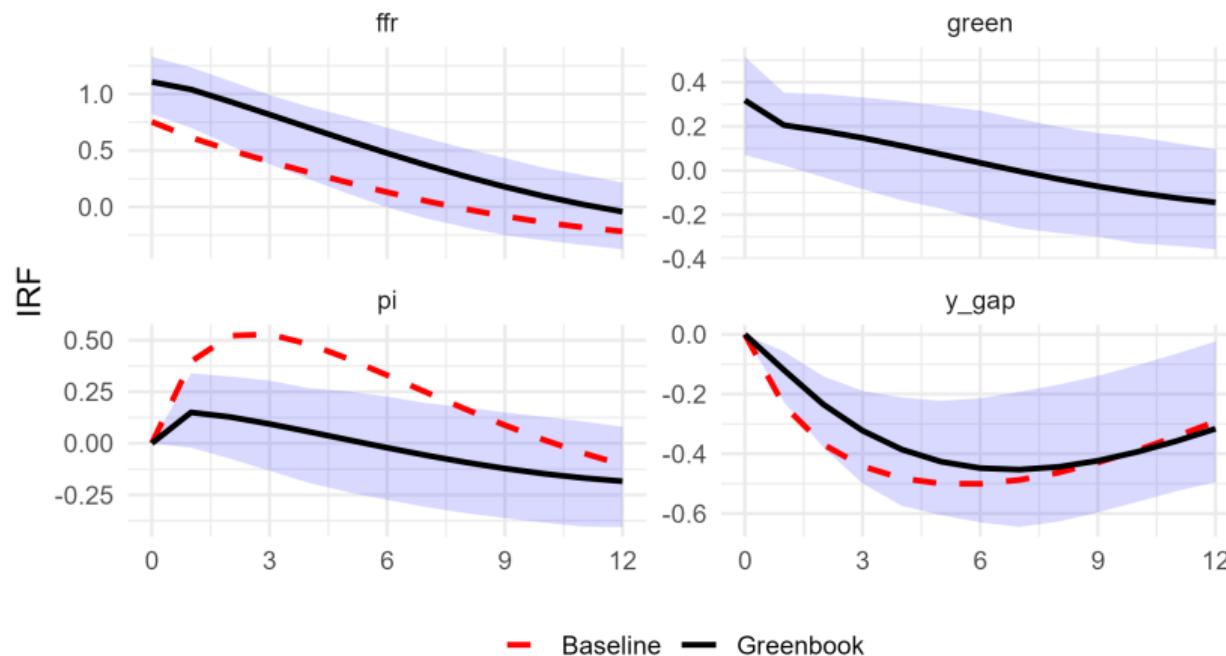


Figure: Impulse responses with Greenbook expectations

Combining both approaches

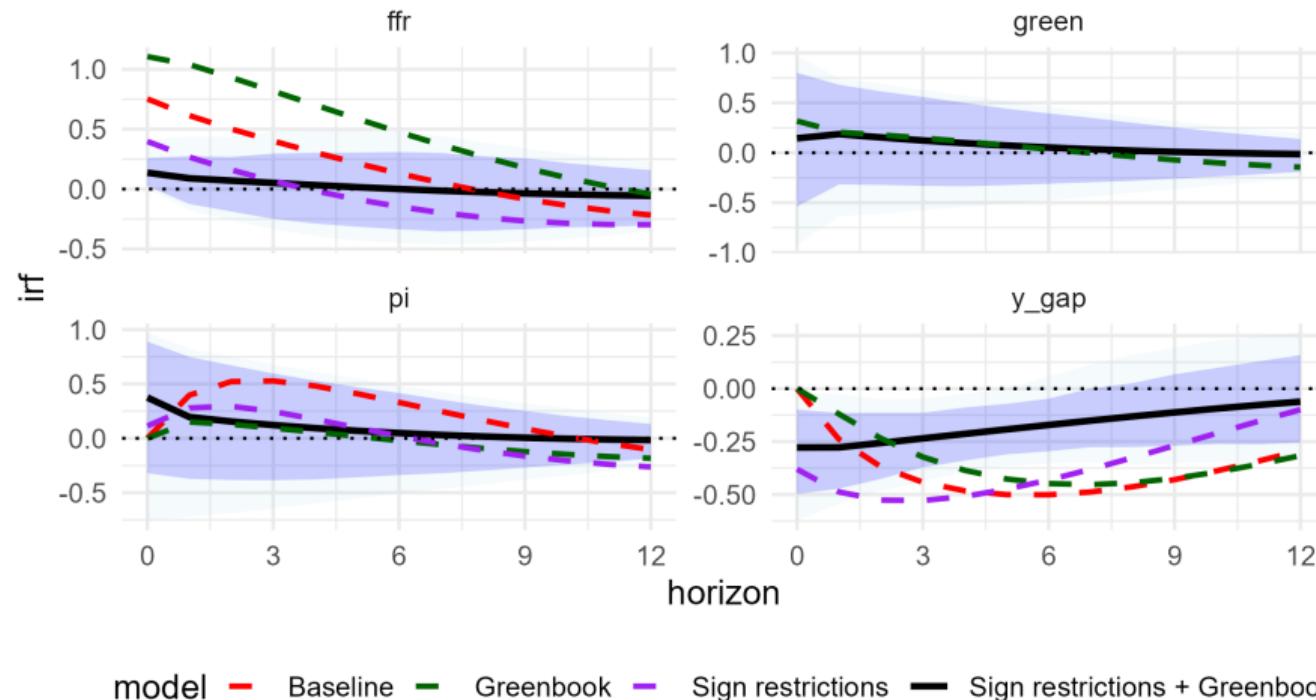


Figure: Baseline vs Sign Restrictions vs Greenbook vs Both

Why do few monetary shocks remain?

- **With Greenbook expectations included:**
 - most movements in the policy rate reflect expected inflation
 - little residual variation remains to be interpreted as an exogenous shock
- **Adding sign restrictions:**
 - drastically narrows the set of admissible rotations
 - only a few shocks behave like textbook monetary tightenings
- **Interpretation:**
 - monetary policy is largely systematic and forward-looking
 - truly discretionary monetary shocks are rare

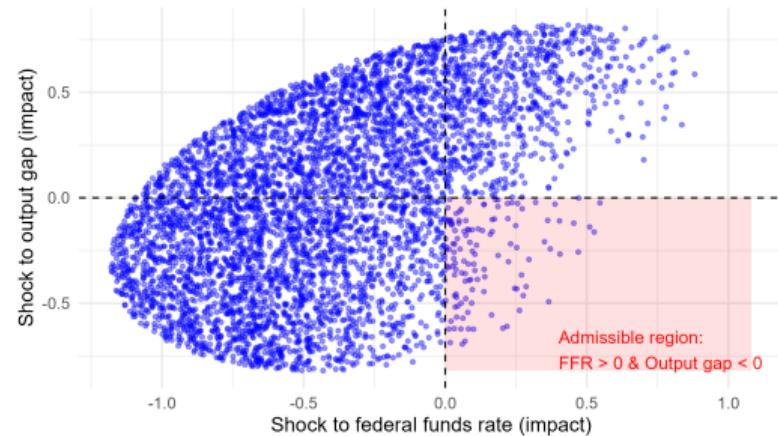


Figure: Admissible monetary shocks in the 4-VAR

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Conclusion

- The price puzzle reflects an **identification failure**, not a failure of theory
- Monetary policy is forward-looking and reacts to information absent from simple VARs
- Identification is **regime-dependent**:
 - recursive SVARs work better under stable, active and credible interest-rate rules
 - they fail at the ZLB and during unconventional policy regimes
- Echoing Sims:
 - VARs must evolve with policy regimes
 - and may struggle to capture rational expectations without explicit information variables

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References I

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