Economics 210c/236a
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LECTURE 3
The Effects of Monetary Changes: Statistical Identification

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I. Some Background on VARs

A Two-Variable VAR

Suppose the true model is:

$$
\begin{aligned}
x_{1t} &= \theta x_{2t} + b_{11}x_{1,t-1} + b_{12}x_{2,t-1} + \varepsilon_{1t}, \\
x_{2t} &= \gamma x_{1t} + b_{21}x_{1,t-1} + b_{22}x_{2,t-1} + \varepsilon_{2t},
\end{aligned}
$$

where ε_{1t} and ε_{2t} are uncorrelated with one another, with the contemporaneous and lagged values of the right-hand side variables, and over time.

Rewrite this as:

$$\begin{bmatrix} 1 & -\theta \\ -\gamma & 1 \end{bmatrix} \begin{matrix} x_{1t} \\ x_{2t} \end{matrix} = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \begin{matrix} x_{1,t-1} \\ x_{2,t-1} \end{matrix} + \begin{matrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{matrix},$$

or

$$CX_t = BX_{t-1} + E_t,$$

where

$$C \equiv \begin{bmatrix} 1 & -\theta \\ -\gamma & 1 \end{bmatrix}, \; X_t \equiv \begin{matrix} x_{1t} \\ x_{2t} \end{matrix}, \; B \equiv \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}, \; E_t \equiv \begin{matrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{matrix}.$$

This implies

$$X_t = C^{-1}(BX_{t-1} + E_t)$$

$$= \Pi X_{t-1} + U_t,$$

where $\Pi \equiv C^{-1}B$, $U_t \equiv C^{-1}E_t$.

The assumptions of the model imply that the elements of U_t are uncorrelated with X_{t-1}. We can therefore estimate the elements of Π by estimating each equation of $X_t = \Pi X_{t-1} + U_t$ by OLS.

Extending to K Variables and N Lags

The "true model" takes the form:

$$CX_t = \sum_{n=1}^{N} B^n X_{t-n} + E_t,$$

where C is K x K, X is K x 1, B is K x K, and E is K x 1.

This leads to:

$$X_t = \sum_{n=1}^{N} \Pi^n X_{t-n} + U_t,$$

where

$$\Pi^n \equiv C^{-1}B^n,\ U_t \equiv C^{-1}E_t.$$

An Obvious (at Least in Retrospect) Insight

Consider

$$X_t = C^{-1}(BX_{t-1} + E_t)$$

$$= \Pi X_{t-1} + U_t,$$

where $\Pi \equiv C^{-1}B$, $U_t \equiv C^{-1}E_t$.

The elements of *B* and *C* are not identified.

Thus, to make progress we need to make additional assumptions.

II. Christiano, Eichenbaum, and Evans: "The Effects of Monetary Policy Shocks: Evidence from the Flow of Funds"

Timing Assumptions

- The most common approach to identifying assumptions in VARs is to impose zero restrictions that give the matrix of contemporaneous effects, *C*, a recursive structure.
- Specifically, one chooses an ordering of the variables, 1, 2, …, *n*, and assumes that variable 1 is not affected by any of the other variables within the period and potentially affects all the others within the period; variable 2 is not affected by any variables other than variable 1 within the period and potentially affects all the others except variable 1; …; variable *n* is potentially affected by all the other variables within the period and does not affect any of the others.
- Such assumptions are known as *timing* or *ordering* assumptions, or *Cholesky identification*.

Simplified Version of Christiano, Eichenbaum, and Evans

- Two variables, one lag:

$$y_t = \qquad b_{11}y_{t-1} + b_{12}i_{t-1} + \varepsilon_{yt},$$

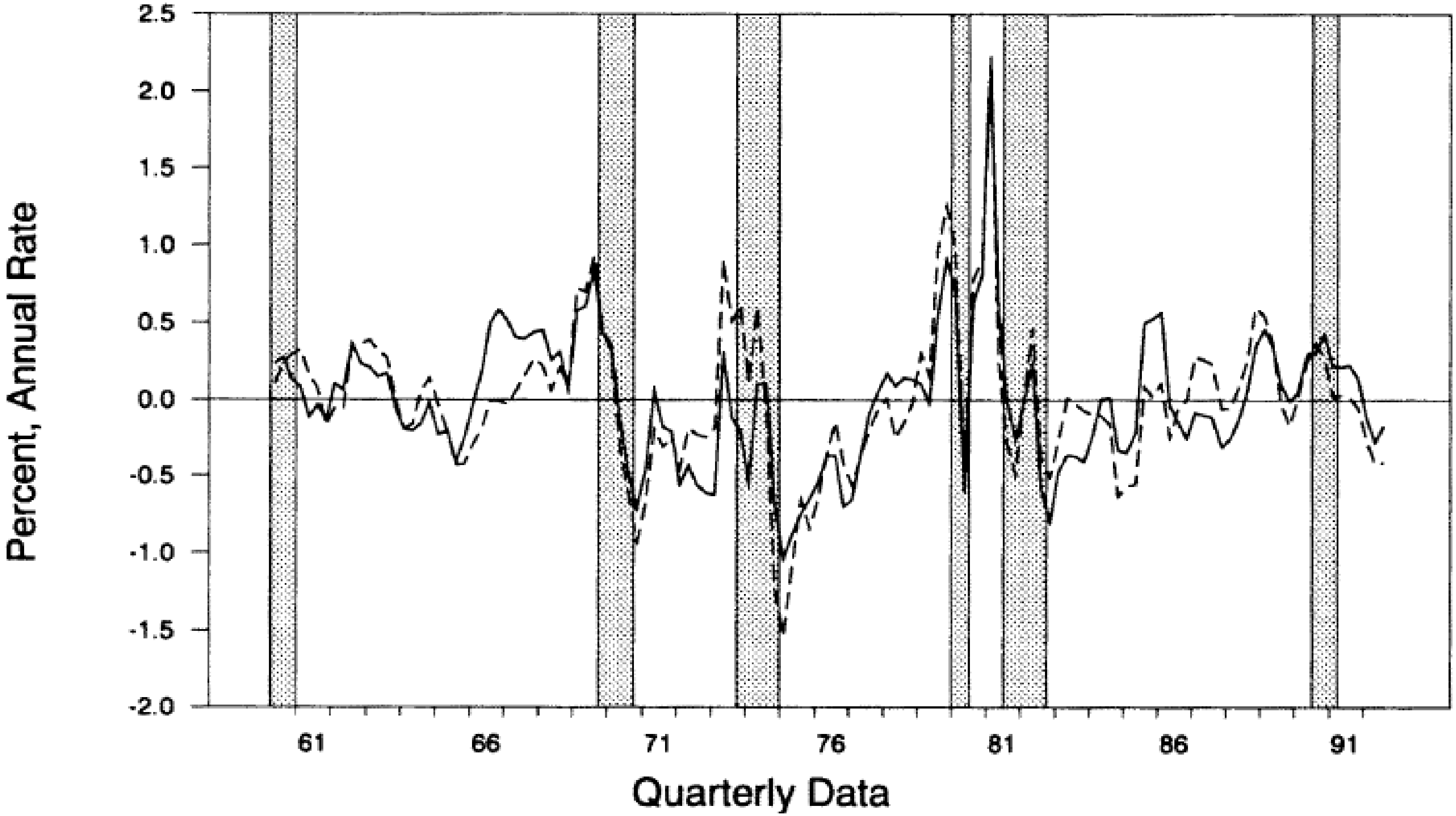
$$i_t = \gamma y_t + b_{21}y_{t-1} + b_{22}i_{t-1} + \varepsilon_{it}.$$

- The reduced form is:

$$y_t = b_{11}y_{t-1} + b_{12}i_{t-1} + \varepsilon_{yt},$$

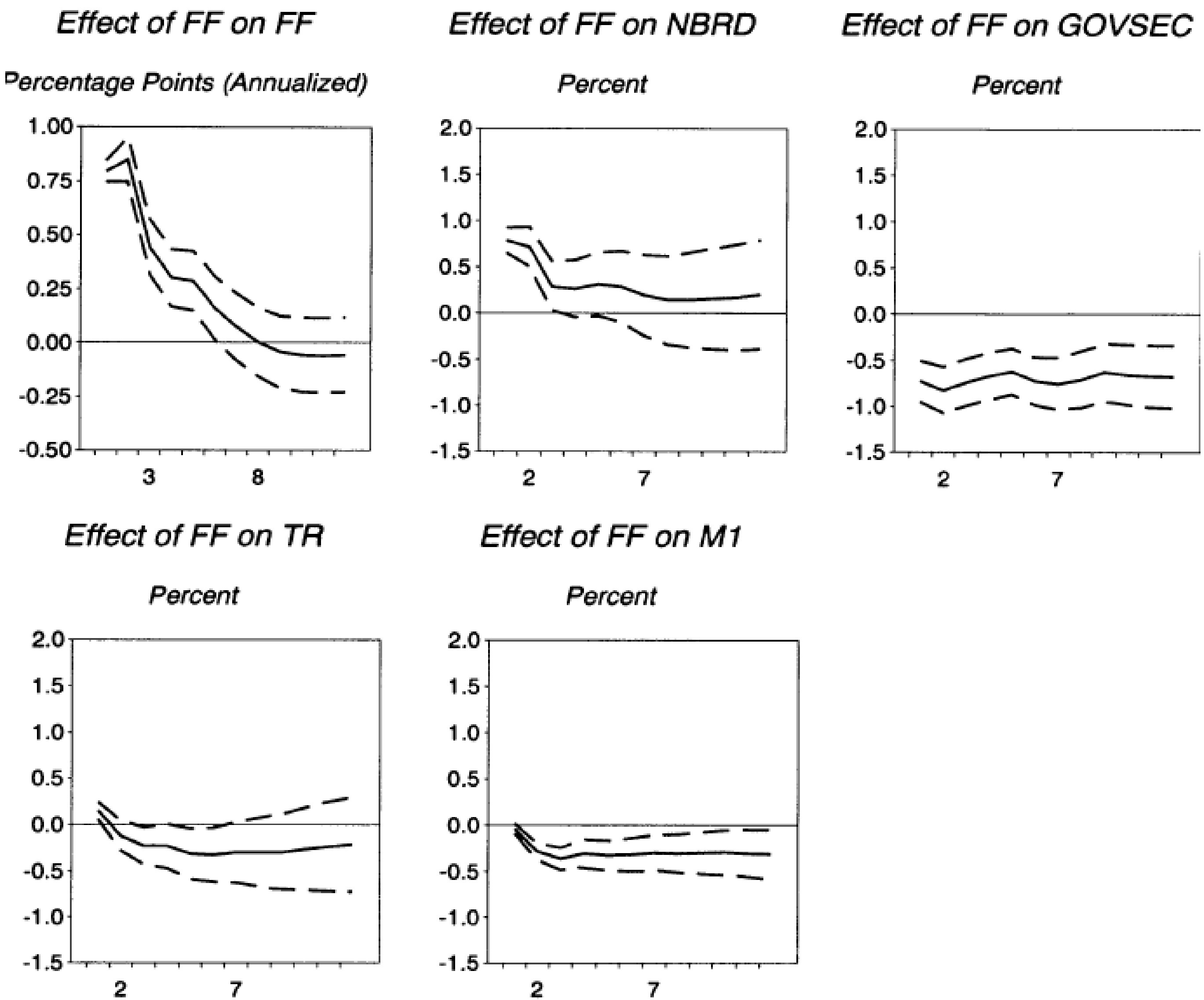
$$i_t = (b_{21} + \gamma b_{11})y_{t-1} + (b_{22} + \gamma b_{12})i_{t-1} + \left(\gamma\varepsilon_{yt} + \varepsilon_{it}\right).$$

FIGURE 1. — THREE QUARTER, CENTERED AVERAGE OF FF POLICY SHOCKS WITH AND WITHOUT COMMODITY PRICES



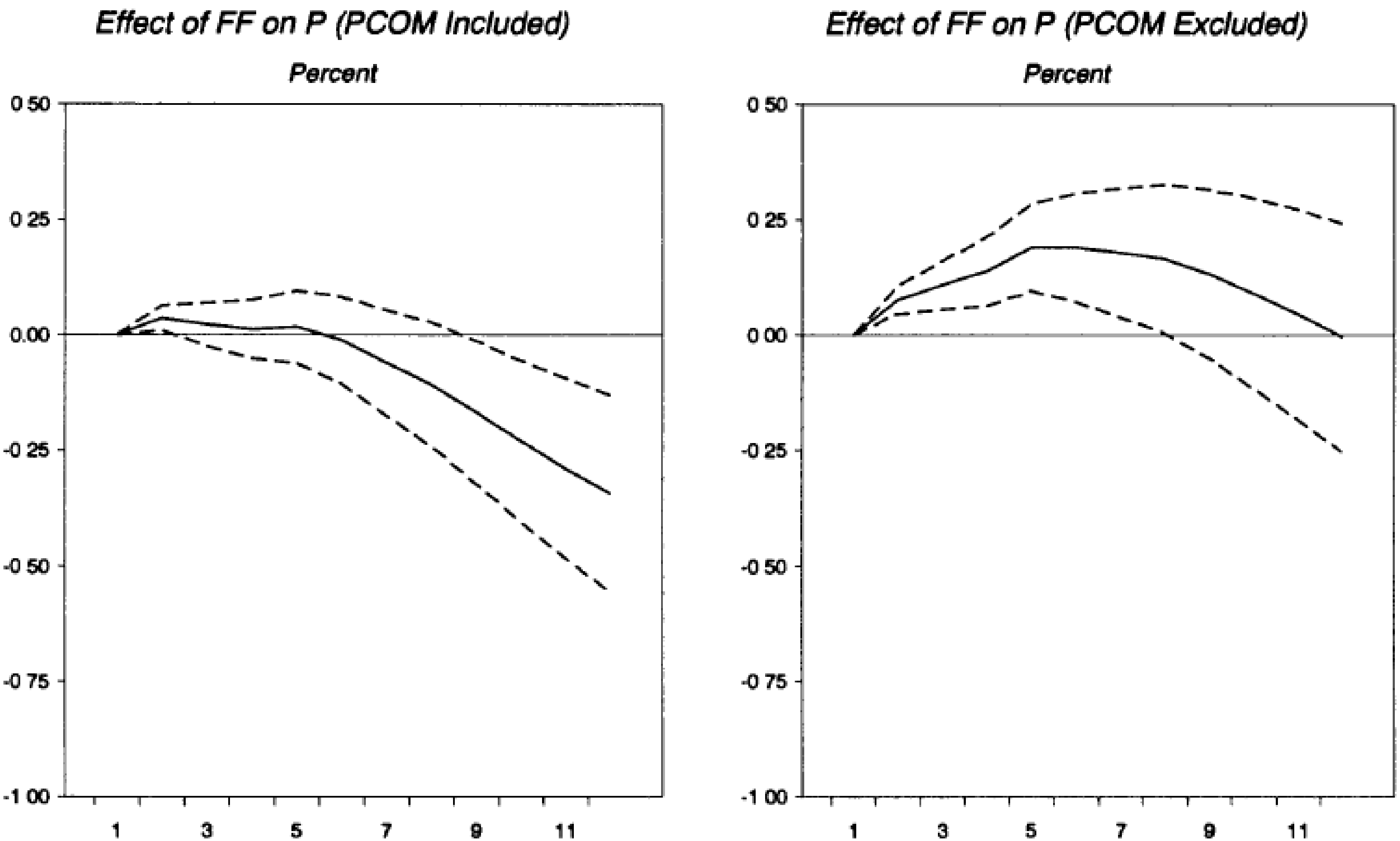
From: Christiano, Eichenbaum, and Evans

FIGURE 2. — EFFECT OF POLICY SHOCKS ON MONETARY VARIABLES



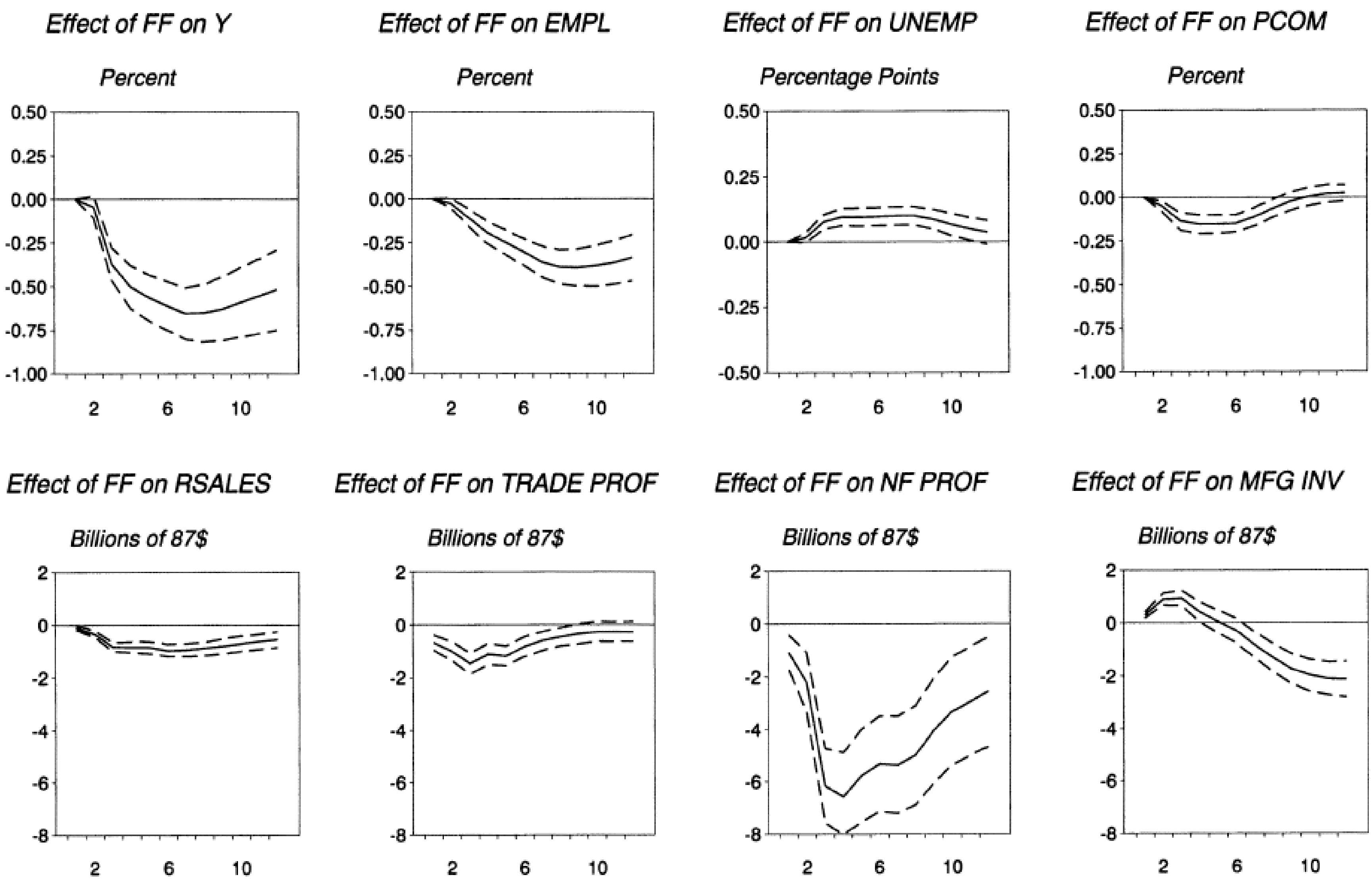
From: Christiano, Eichenbaum, and Evans

FIGURE 4. — EFFECT OF POLICY SHOCKS ON PRICE LEVEL



From: Christiano, Eichenbaum, and Evans

FIGURE 3. — EFFECT OF POLICY SHOCKS ON MACROECONOMIC VARIABLES



From: Christiano, Eichenbaum, and Evans

Two Other Ways of Estimating the Effects of Monetary Policy Shocks under CEE's Assumptions

Recall:

$$y_t = \qquad b_{11}y_{t-1} + b_{12}i_{t-1} + \varepsilon_{yt}, \tag{1}$$

$$i_t = \gamma y_t + b_{21}y_{t-1} + b_{22}i_{t-1} + \varepsilon_{it}. \tag{2}$$

1. Just estimate (1) and (2) directly!

2. First, estimate (2) by OLS, and find the residuals. Then, estimate $y_t = b_{12}\hat{\varepsilon}_{i,t-1} + \delta_t$ by OLS.

Given the assumptions, $\delta_t = b_{11}y_{t-1} + b_{12}\gamma y_{t-1} + b_{12}b_{21}y_{t-2} + b_{12}b_{22}i_{t-2} + \varepsilon_{yt}$ and is uncorrelated with $\varepsilon_{i,t-1}$. Thus, we will obtain an estimate of b_{12}.

Other Types of Restrictions to Make VARs Identified

- Zero restrictions other than ordering assumptions.
- Long-run restrictions.
- Imposing coefficient restrictions motivated by theory.
- …

III. Romer and Romer: "A New Measure of Monetary Shocks: Derivation and Implications"

Deriving Our New Measure

- Derive the change in the intended funds rate around FOMC meetings using narrative and other sources.
- Regress on Federal Reserve forecasts of inflation and output growth.
- Take residuals as new measure of monetary policy shocks.

Regression Summarizing Usual Fed Behavior

$$(1) \qquad \Delta ff_m = \alpha + \beta ffb_m + \sum_{i=-1}^{2} \gamma_i \widetilde{\Delta y}_{mi}$$

$$+ \sum_{i=-1}^{2} \lambda_i (\widetilde{\Delta y}_{mi} - \widetilde{\Delta y}_{m-1,i}) + \sum_{i=-1}^{2} \varphi_i \tilde{\pi}_{mi}$$

$$+ \sum_{i=-1}^{2} \theta_i (\tilde{\pi}_{mi} - \tilde{\pi}_{m-1,i}) + \rho \tilde{u}_{m0} + \varepsilon_m .$$

ff is the federal funds rate

y is output; *π* is inflation; u is the unemployment rate

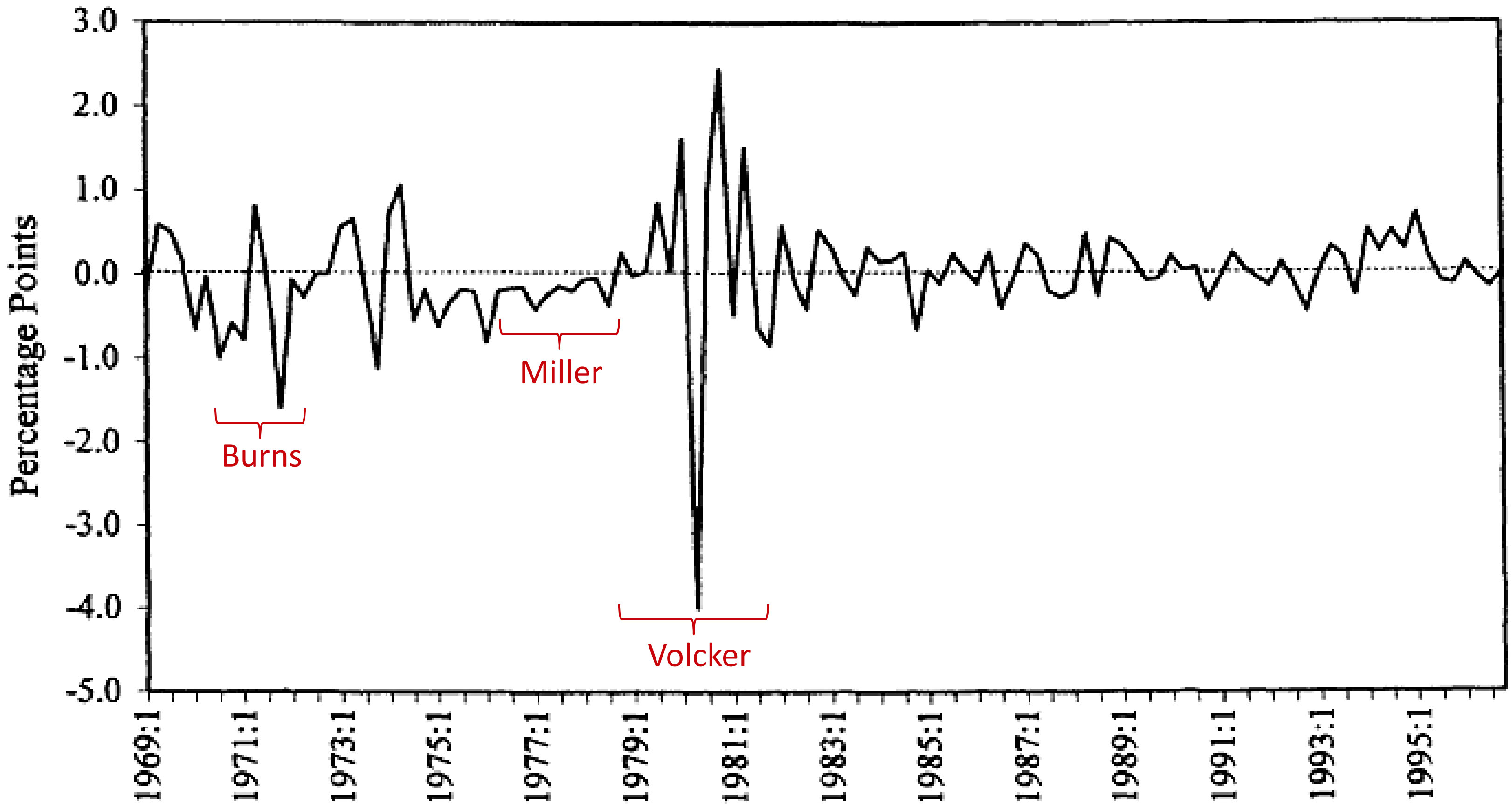
~ over a variable indicates a Greenbook forecast

From: Romer and Romer, "A New Measure of Monetary Shocks"

What kinds of thing are in the new shock series?

- Unusual movements in funds rate because the Fed was also targeting other measures.
- Mistakes based on a bad model of economy.
- Change in tastes.
- Political factors.
- Pursuit of other objectives.

a. New Measure of Monetary Policy Shocks



From: Romer and Romer, “A New Measure of Monetary Shocks”

Evaluation of the New Measure

- Key issue – is there useful information used in setting policy not contained in the Greenbook forecasts?

Digression: Kuttner's Alternative Measure of Monetary Shocks

- Get a measure of unexpected changes in the federal funds rate by (roughly) comparing the implied change indicated by fed funds futures and the actual change.

Table 2
Actual, expected and unexpected changes in the Fed funds target

Date		FOMC	Actual	Expected	Unexpected
1989	6/6		−25	−24	−1
	7/7	√	−25	−22	−3
	7/27		−25	−25	0
	10/18		−25	−25	0
	11/6		−25	−29	+4
	12/20	√	−25	−8	−17
1990	7/13		−25	−11	−14
	10/29		−25	+6	−31
	11/14	√	−25	−29	+4
	12/7		−25	+2	−27
	12/18	√	−25	−4	−21
1991	1/8		−25	−7	−18
	2/1		−50	−25	−25
	3/8		−25	−9	−16
	4/30		−25	−8	−17
	8/6		−25	−10	−15
	9/13		−25	−20	−5
	10/31		−25	−20	−5
	11/6	√	−25	−13	−12
	12/6		−25	−16	−9
	12/20		−50	−22	−28
1992	4/9		−25	−1	−24
	7/2	√	−50	−14	−36
	9/4		−25	−3	−22
1994	2/4	√	+25	+13	+12
	3/22	√	+25	+28	−3
	4/18		+25	+15	+10
	5/17	√	+50	+37	+13
	8/16	√	+50	+36	+14
	11/15	√	+75	+61	+14
1995	2/1	√	+50	+45	+5
	7/6	√	−25	−24	−1
	12/19	√	−25	−15	−10
1996	1/31	√	−25	−18	−7
1997	3/25	√	+25	+22	+3
1998	9/29	√	−25	−25	0
	10/15		−25	+1	−26
	11/17	√	−25	−19	−6
1999	6/30	√	+25	+29	−4
	8/24	√	+25	+23	+2
	11/16	√	+25	+16	+9
2000	2/2	√	+25	+30	−5

From: Kenneth Kuttner, “Monetary Policy Surprises.”

Single-Equation Regression for Output

$$(2) \quad \Delta y_t = a_0 + \sum_{k=1}^{11} a_k D_{kt} + \sum_{i=1}^{24} b_i \Delta y_{t-i} + \sum_{j=1}^{36} c_j S_{t-j} + e_t,$$

y is the log of industrial production
S is the new measure of monetary policy shocks
D's are monthly dummies

From: Romer and Romer, "A New Measure of Monetary Shocks"

Fitting this Specification into the Earlier Framework

Suppose the true model is:

$$y_t = a_1 y_{t-1} + b_1 i_{t-1} + \varepsilon_{yt}, \quad (1)$$

$$i_t = a_2 \tilde{y}_t + b_2 \tilde{\pi}_t + \varepsilon_{it}, \quad (2)$$

where $\tilde{y}$ and $\tilde{\pi}$ are the forecasts as of period t, and ε_{it} is uncorrelated with all the other things on the right-hand side of (1) and (2) $(y_{t-1}, i_{t-1}, \tilde{y}_t, \tilde{\pi}_t, \text{and } \varepsilon_{yt})$.

(2) implies:

$$i_{t-1} = a_2 \tilde{y}_{t-1} + b_2 \tilde{\pi}_{t-1} + \varepsilon_{i,t-1}.$$

Substituting this in to (1) gives us:

$$y_t = b_1 \varepsilon_{i,t-1} + \delta_t, \qquad \text{where } \delta_t = a_1 y_{t-1} + b_1 [a_2 \tilde{y}_{t-1} + b_2 \tilde{\pi}_{t-1}] + \varepsilon_{yt}.$$

Under the assumptions of the model, δ_t is uncorrelated with $\varepsilon_{i,t-1}$, and so we can estimate this equation by OLS and recover the effect of *i* on *y* (b_1).

Single-Equation Regression for Output

Using the New Measure of Monetary Shocks

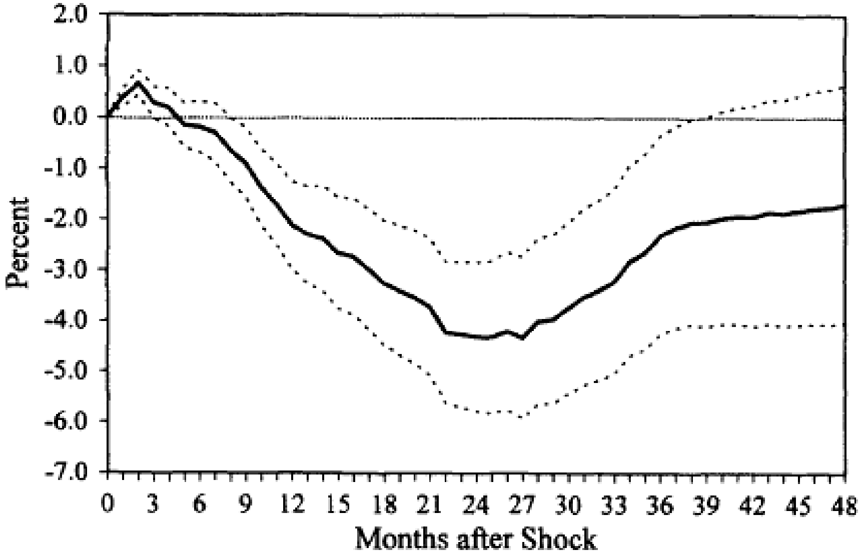


FIGURE 2. THE EFFECT OF MONETARY POLICY ON OUTPUT

Using the Change in the Actual Funds Rate

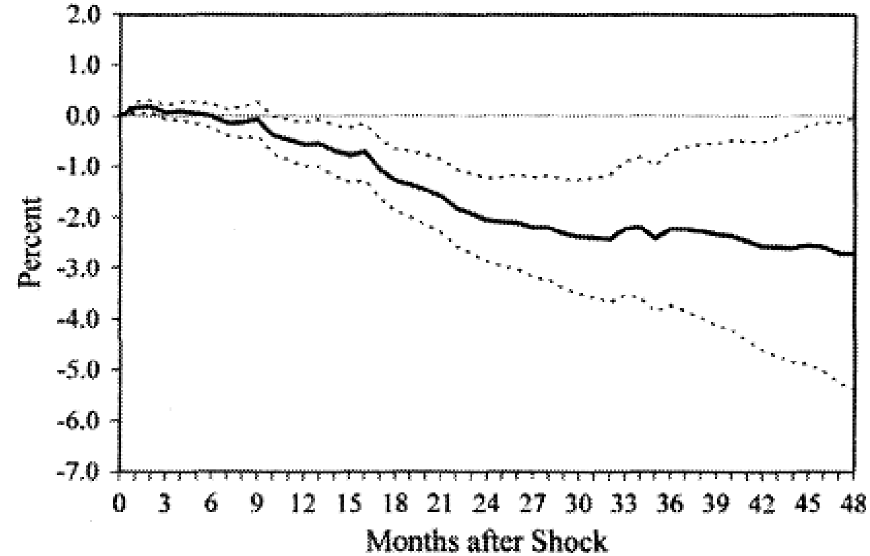


FIGURE 3. THE EFFECT OF BROADER MEASURES OF MONETARY POLICY ON OUTPUT

From: Romer and Romer, “A New Measure of Monetary Shocks”

Single-Equation Regression for Prices

Using the New Measure of Monetary Shocks

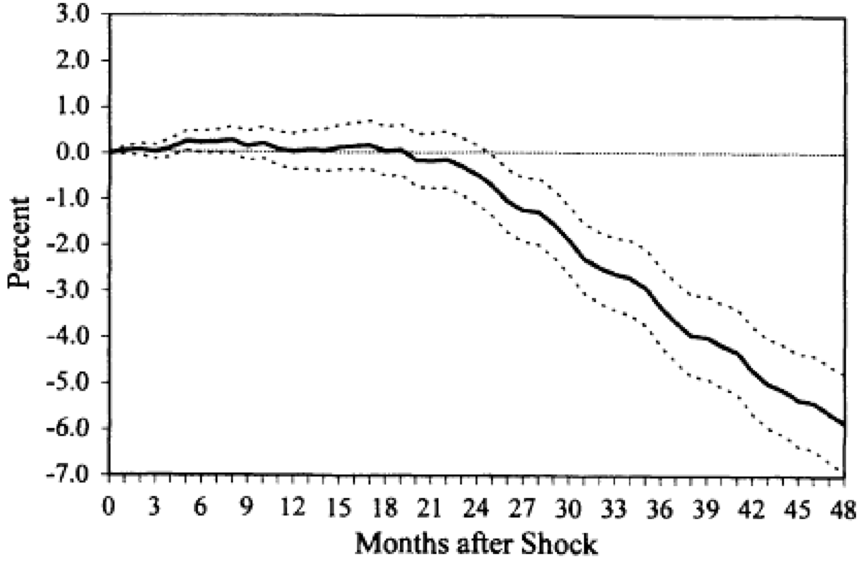


FIGURE 4. THE EFFECT OF MONETARY POLICY ON THE PRICE LEVEL

Using the Change in the Actual Funds Rate

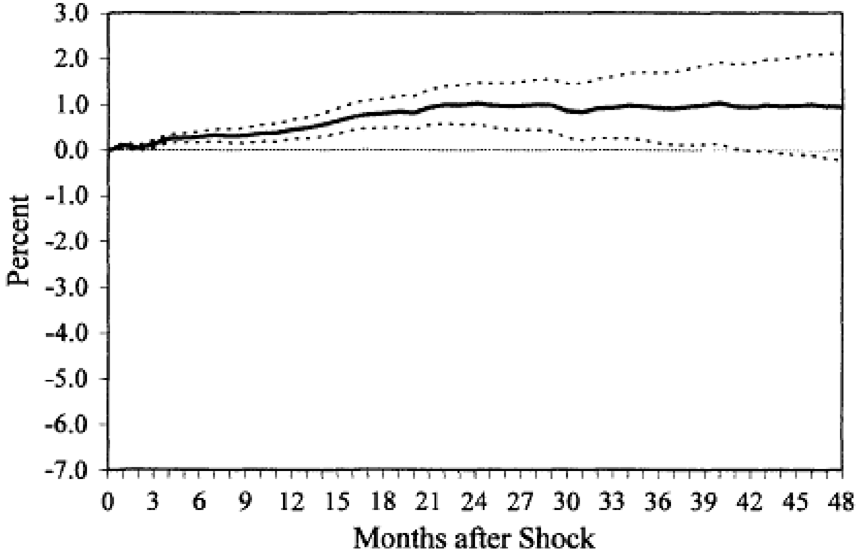


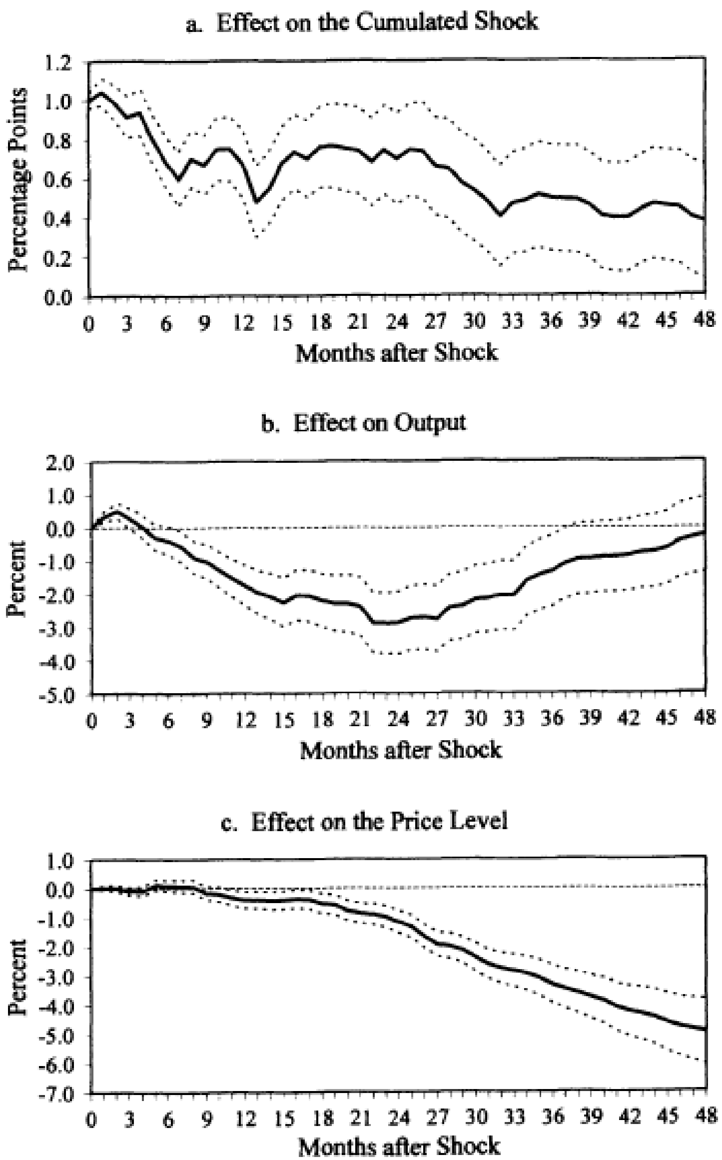
FIGURE 6. THE EFFECT OF BROADER MEASURES OF MONETARY POLICY ON THE PRICE LEVEL

From: Romer and Romer, “A New Measure of Monetary Shocks”

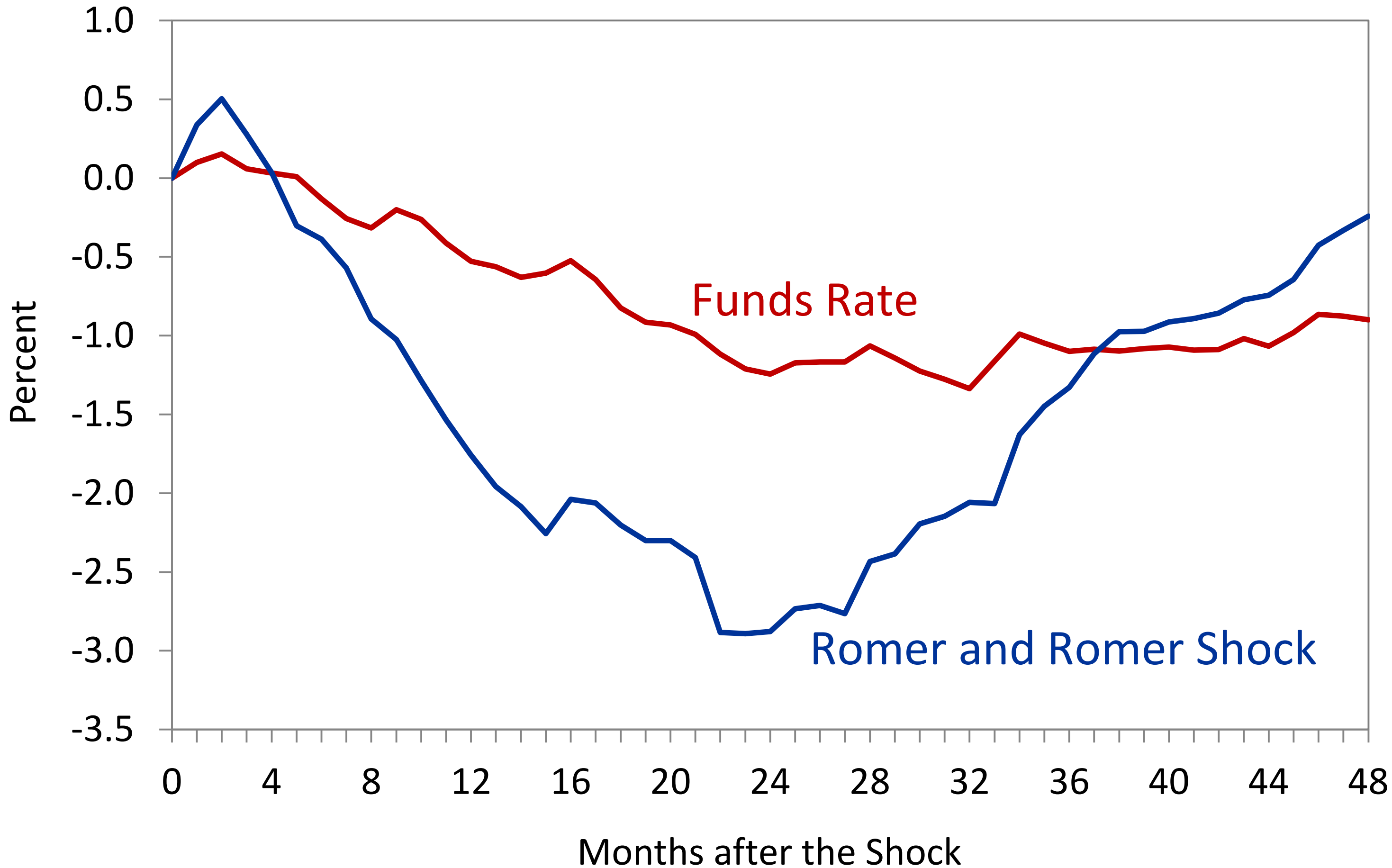
VAR Specification

- Three variables: log of IP, log of PPI for finished goods, measure of monetary policy.
- Monetary policy is assumed to respond to, but not to affect other variables contemporaneously.
- We include 3 years of lags, rather than 1 as Christiano, Eichenbaum, and Evans do.
- Cumulate shock to be like the level of the funds rate.

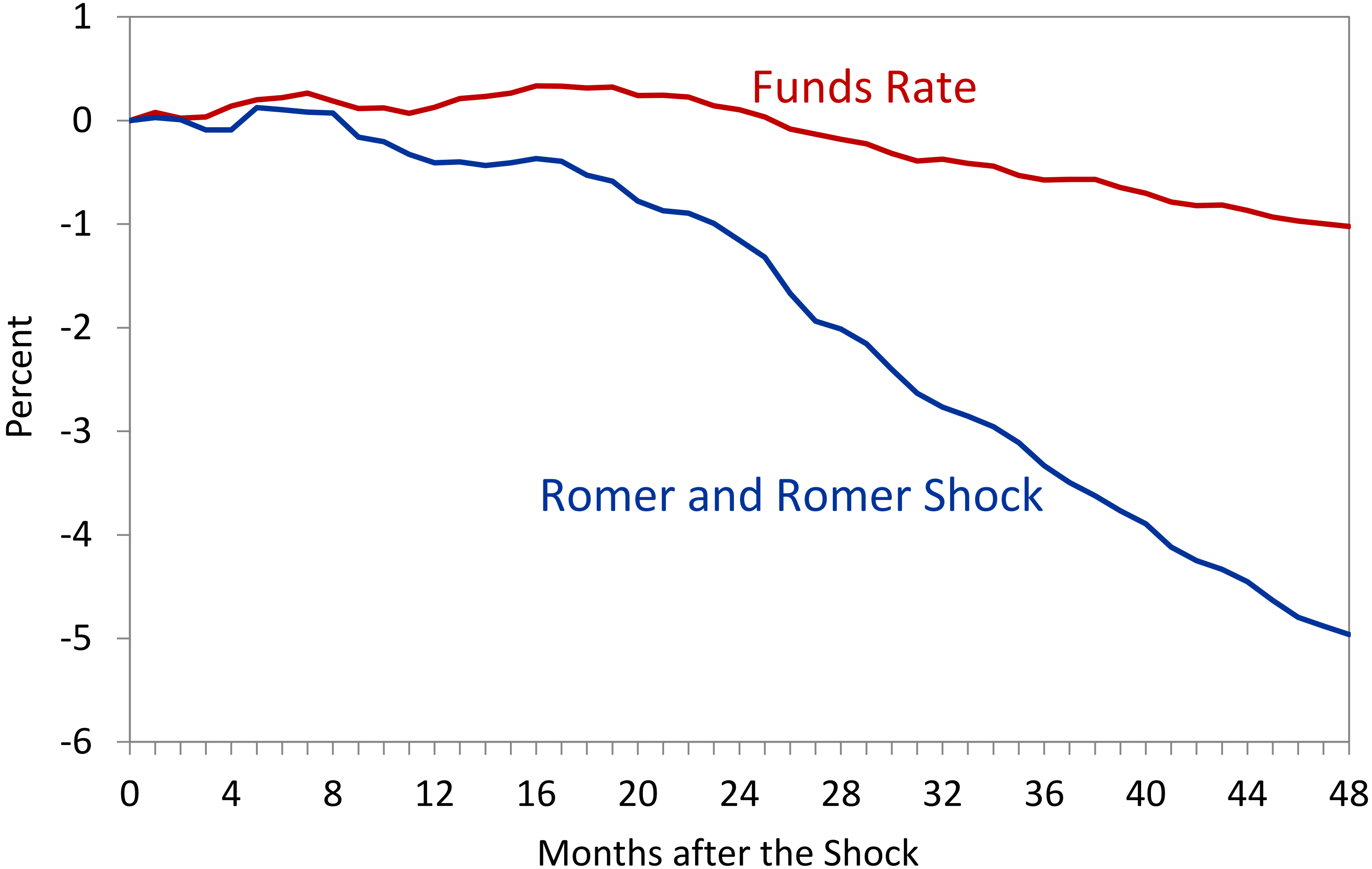
VAR Results


a. Effect on the Cumulated Shock
Percentage Points
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48
Months after Shock
b. Effect on Output
Percent
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48
Months after Shock
c. Effect on the Price Level
Percent
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48
Months after Shock

Comparison of VAR Results: Impulse Response Function for Output



Comparison of VAR Results: Impulse Response Function for Prices



Impulse Response Function of DFF to Shock

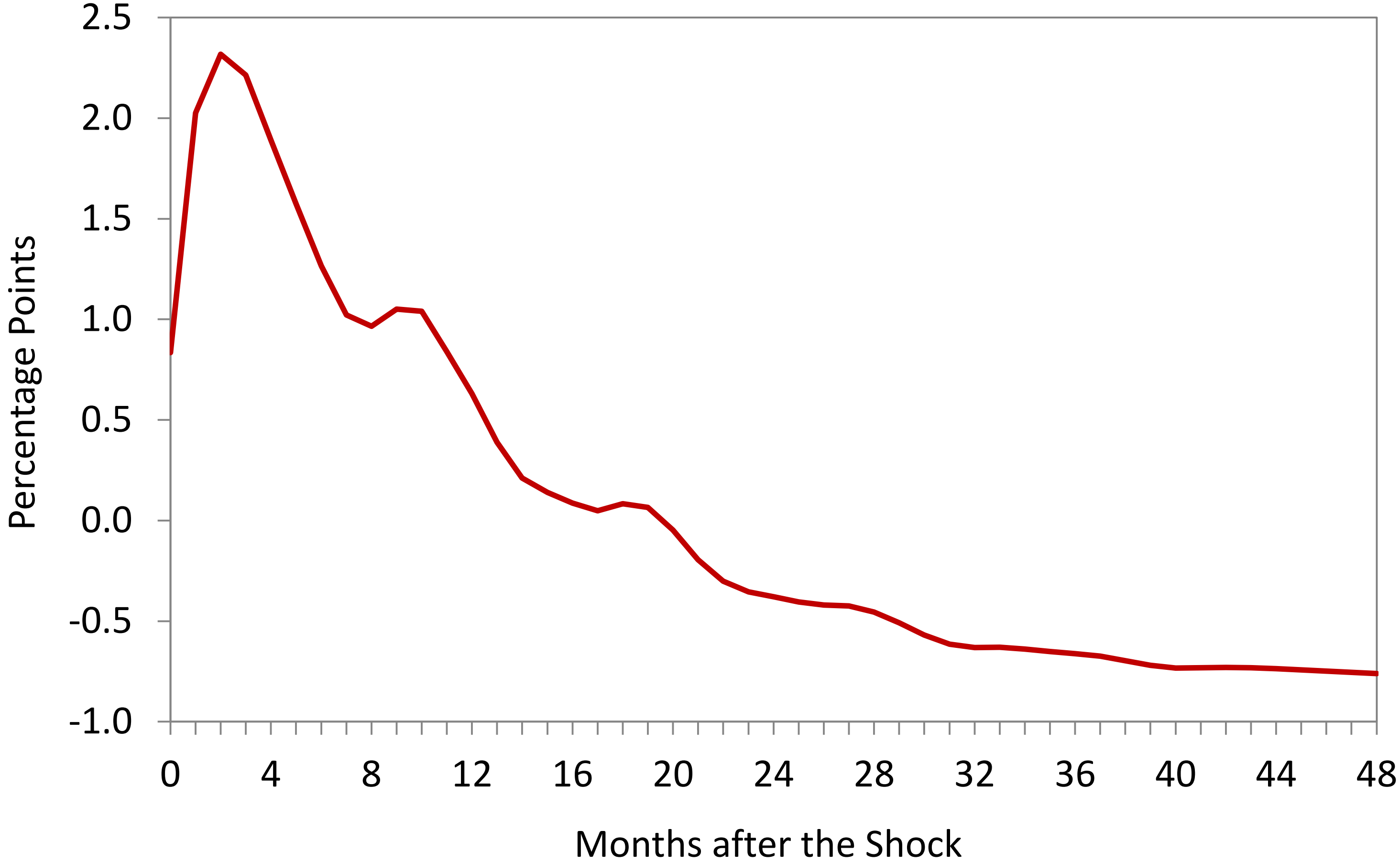
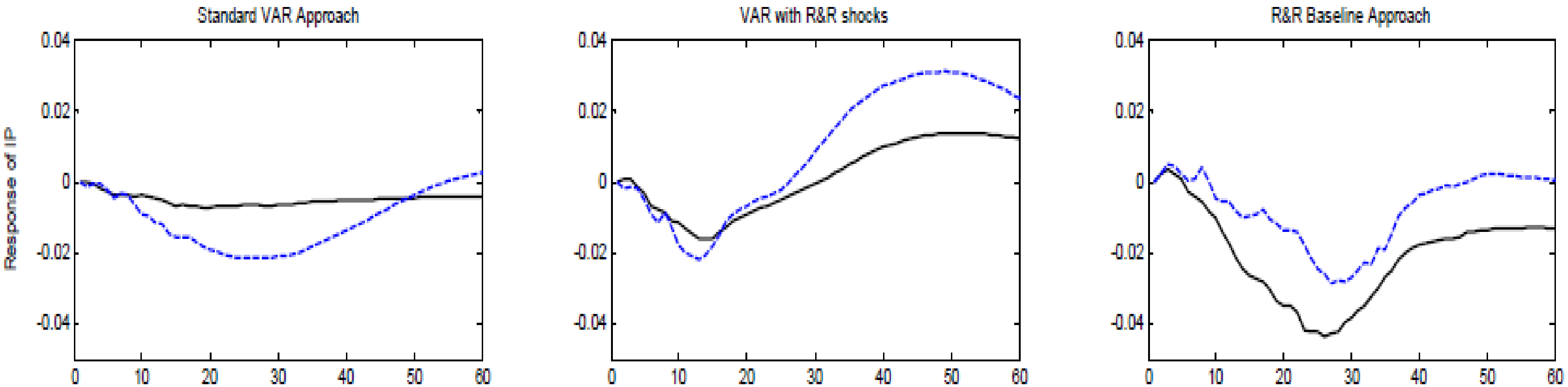


Figure 7: Impulse Responses to Monetary Policy Shocks Omitting the Early Volcker Period



Solid black line includes the early Volcker period, dashed blue line excludes it.

From: Coibion, "Are the Effects of Monetary Policy Shocks Big or Small?"

IV. Gertler and Karadi: "Monetary Policy Surprises, Credit Costs, and Economic Activity"

Key Features of Gertler and Karadi's Approach

- A different strategy for trying to isolate useful identifying variation in monetary policy: surprise changes in measures of monetary policy around the times of FOMC decisions.

- An IV approach to VARs: "external instruments."

Surprise Changes in Measures of Monetary Policy around the Times of FOMC Decisions

- The idea that changes in financial market variables in a very short window around an FOMC announcement are almost entirely responses to the announcement seems very reasonable.

- Concerns?
    - Potentially leaves out a lot of useful variation.
    - Is a surprise change in monetary policy necessarily the same as a pure monetary policy shock?

Background on External Instruments: A Naïve Approach to IV

- Suppose we want to estimate

$$y_t = \sum_{k=0}^{K} b_k i_{t-k} + e_t,$$

and that we have a variable z_t that we think is correlated with i_t and uncorrelated with the e's.

- It might be tempting to estimate the equation by IV, with instrument list z_t, z_{t-1}, …, z_{t-K}.
- Concerns:
  - We think i_{t-k} is affected by z_{t-k} and not the other z's. So, at the very least, this approach creates a lot of inefficiency.
  - Conjecture: This approach could magnify the bias caused by small misspecification.
  - How do we extend this to a VAR?

External Instruments in a Simple 2-Variable Model—Set-Up

- Suppose the true model is:

$$y_t = \theta i_t + b_{11} y_{t-1} + b_{12} i_{t-1} + \varepsilon_{yt},$$

$$i_t = \gamma y_t + b_{21} y_{t-1} + b_{22} i_{t-1} + \varepsilon_{it}.$$

- The reduced form is:

$$X_t = \Pi X_{t-1} + U_t,$$

(where: $X_t \equiv \begin{matrix} y_t \\ i_t \end{matrix}$, $\Pi \equiv C^{-1}B$, $\equiv \begin{bmatrix} 1 & -\theta \\ -\gamma & 1 \end{bmatrix}$, $B \equiv \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}$,
$U_t \equiv C^{-1}E_t$, $E_t \equiv \begin{matrix} \varepsilon_{yt} \\ \varepsilon_{it} \end{matrix}$).

External Instruments in a Simple 2-Variable Model—Using an Instrument

- Suppose we have a variable z_t that is correlated with ε_{it} and not systematically correlated with ε_{yt}.
- Let u_{yt} and u_{it} be the two elements of U_t—that is, the reduced form innovations in *y* and *i*.
- One can show that u_{yt} can be written in the form:
$$u_{yt} = \theta u_{it} + \varepsilon_{yt}.$$
- So, a regression of u_{yt} on u_{it}, using z_t as an instrument allows us to estimate θ.

External Instruments in a Simple 2-Variable Model—Using an Instrument (continued)

- Once we know θ, we can find γ.
- And once we know γ, we know all the elements of C (the matrix of contemporaneous coefficients).
- This allows us to go from estimates of Π (the reduced form relationship between (y_t,i_t) and (y_{t-1},i_{t-1}), which we can estimate by OLS) to estimates of B (the causal effect of (y_{t-1},i_{t-1}) on (y_t,i_t)), using $B = C\,\Pi$.
- Notice that we use only the variation in i associated with variation in z to estimate the contemporaneous impact of i on y, but all the variation in i to estimate the dynamics.

External Instruments—Complications

- We haven't discussed how to compute standard errors. (Addressed briefly in n. 13 of Gertler-Karadi.)
- Gertler and Karadi have multiple instruments, and they consider various candidate measures of *i*.
  - Instruments: surprise in the current federal funds futures rate; surprise in the 3-month ahead federal futures rate; surprises in in the 6-month, 9-month and 12-month ahead futures on 3-month Eurodollar deposits.
  - Candidate measures of *i*: the federal funds rate; the one-year government bond rate; the two-year government bond rate.

Where Is Our Ability to Estimate the Impulse Response Functions Coming from?

- “The monetary shocks … have a standard deviation of only about 5 basis points. This ‘power problem’ precludes … directly estimating their effect on future output” (Nakamura and Steinsson, 2018).
- The way Gertler and Karadi avoid this problem is by not directly estimating the effects of the shocks: they use the high frequency identification to find the contemporaneous effects, but the full variation to find the dynamics.
- Concern: what if the *b*’s aren’t structural parameters?

A Concrete Example of These Concerns

- Suppose the IV estimation of $u_{yt} = \theta u_{it} + \varepsilon_{yt}$ leads to an estimate of θ of zero.

- In that case, the external instruments approach is identical to the Christiano-Eichenbaum-Evans approach.

- But the possibility of $\theta \neq 0$ was not our only (or even our main) concern about CEE. Most notably, the possibility of forward-looking monetary policy was a larger one.

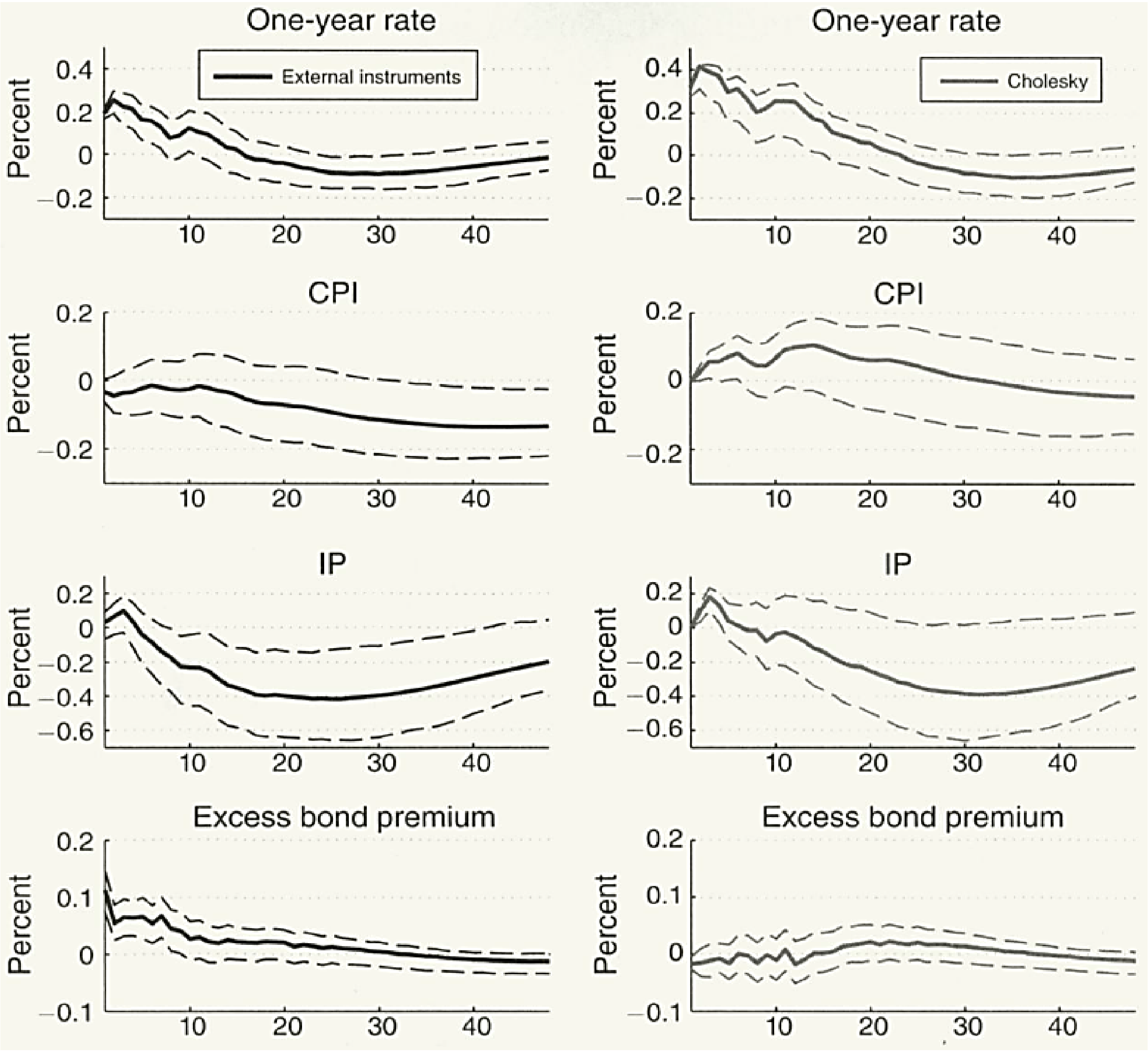
TABLE 3—EFFECTS OF HIGH-FREQUENCY INSTRUMENTS ON THE FIRST STAGE RESIDUALS OF THE FOUR VARIABLE VAR (*Monthly*, 1991–2012)

Variables	1 year (1)	1 year (2)	1 year (3)	1 year (4)	1 year (5)
FF1	0.890***				0.394
	(4.044)				(1.129)
FF4		1.151***		1.266***	1.243***
		(4.184)		(4.224)	(3.608)
ED2					1.440
					(1.244)
ED3					−4.443***
					(−2.635)
ED4			0.624**	−0.167	2.674**
			(2.039)	(−0.476)	(2.493)
Observations	258	258	258	258	258
R^2	0.066	0.078	0.025	0.079	0.110
F-statistic	16.36	17.50	4.159	11.00	8.347

From: Gertler and Karadi

Gertler and Karadi’s Baseline VAR

- Four variables: Log industrial production, log CPI, “Gilchrist-Zakrajšek excess bond premium,” 1-year government bond rate.
- Use one instrument: surprise in the 3-month ahead federal futures rate;
- Monthly data, 1979:7-2012:6.
- Only partially identified: the external IV approach allows Gertler and Karadi to identify the effects of monetary policy shocks (shocks to the 1-year rate), but not the effects of shocks to the other variables).



From: Gertler and Karadi

Gertler and Karadi's Extended VARs

- Add the mortgage spread, the commercial paper spread, and (one at a time): the federal funds rate, the 2-year, 5-year, or 10-year government bond rate, market-based measures of expected inflation, various private sector interest rates or spreads, ….