Lecture: Macroeconomic Shocks

222061-1617: Time Series Econometrics

Spring 2023

Jacek Suda[1]

[1] Based on notes by A. Zervou

Outline

Outline:

1. Intro/Setting
2. Identification
3. Impulse Response Functions

Questions

What are the causal effects of changes in:

- government spending, taxes
- monetary policy
- technology (TFP), preferences

on output, consumption, investment, prices, interest rates?

In order to find causal effects, we encounter identification, which turns correlations into causation.

History

- Until end of 1970's macro models with plethora of variables, studying effects of fiscal and monetary shocks.
- 80's revolution of VAR's and TFP shocks.

Steps

- Identify shocks
- Uncover causal effects
- Study impulse response functions.

Example

- By how much will GDP increase if government spending or taxes increase?
- Estimate with OLS and get estimates of $\beta_{y\tau}, \beta_{yg}$:

$$y_t = \beta_{y\tau}\tau_t + \beta_{yg}g_t + \varepsilon_{y,t},$$

τ: net taxes, g: government spending, y: GDP

- Possibly expect $\beta_{y\tau} < 0, \beta_{yg} > 0$.

Example

- But what if government spending and/or taxes are affected by GDP?
- Then g, τ correlate with $\varepsilon_{y,t}$
- We need to estimate a system of equations, as the following:

$$\begin{aligned}
\tau_t &= \beta_{\tau g} g_t + \beta_{\tau y} y_t + \varepsilon_{\tau,t}, \\
g_t &= \beta_{g\tau} \tau_t + \beta_{gy} y_t + \varepsilon_{g,t}, \\
y_t &= \beta_{y\tau} \tau_t + \beta_{yg} g_t + \varepsilon_{y,t}
\end{aligned}$$

- Identify the εs and then identify the βs: thus uncover causal effects
- That's the way macroeconomists deal with identification.

Shocks defined

- Shocks are primitive exogenous forces, uncorrelated with each other that are economically meaningful
- Closely related to structural disturbances
- Often confused with reduced form disturbances, or with instruments
- Depending on identification technique, it could be that a shock is an instrument or a reduced form shock
- The definition should be clear.

Example

$$
\begin{aligned}
\tau_t &= \beta_{\tau g} g_t + \beta_{\tau y} y_t + \varepsilon_{\tau,t}, \\
g_t &= \beta_{g\tau} \tau_t + \beta_{gy} y_t + \varepsilon_{g,t}, \\
y_t &= \beta_{y\tau} \tau_t + \beta_{yg} g_t + \varepsilon_{y,t}
\end{aligned}
$$

- Want to identify the ε's
- We assume that are uncorrelated
- Here, let each one shock affecting only one equation (*In stata, the B matrix is diagonal*)
- $\varepsilon_{\tau,t}$: tax shock, e.g., legislation resulting from a change in political power
- $\varepsilon_{g,t}$: Government spending shock, e.g., sudden outbreak of war raising military spending
- $\varepsilon_{y,t}$: Output shock, e.g., technological progress
- The above setting is not dynamic

Example

$$
\begin{aligned}
\tau_t &= \beta_{\tau g} g_t + \beta_{\tau y} y_t + \varepsilon_{\tau,t}, \\
g_t &= \beta_{g\tau} \tau_t + \beta_{gy} y_t + \varepsilon_{g,t}, \\
y_t &= \beta_{y\tau} \tau_t + \beta_{yg} g_t + \varepsilon_{y,t}
\end{aligned}
$$

- Want to identify the ε's
- We assume that are uncorrelated
- Here, let each one shock affecting only one equation (*In stata, the B matrix is diagonal*)
- Note: It could be structural shock affecting many equations, still uncorrelated with other structural shocks, e.g., a geopolitical shock affects fiscal and monetary policy (*In stata, the B matrix is not diagonal*)

Outline Identification

Outline:

1. Short Run Restrictions
2. Long Run Restrictions
3. Exogenous Series/High Frequency
4. External Instrument

General Dynamic Setting

- Three-equations general setting: $Y_t = [Y_{1,t}\ Y_{2,t}\ Y_{3,t}]'$.

$$Y_t = B_0 Y_t + B_1 Y_{t-1} + \Omega \varepsilon_t,$$

  where ε_t are structural shocks, uncorrelated
- B_0 is the contemporaneous effects matrix

$$B_0 = \begin{bmatrix} b_{0,11} & b_{0,12} & b_{0,13} \\ b_{0,21} & b_{0,22} & b_{0,23} \\ b_{0,31} & b_{0,32} & b_{0,33} \end{bmatrix}$$

- In the previous static example, $b_{0,11} = b_{0,22} = b_{0,33} = 0$, B_1 has all zeros and Ω is identity
- Note: Ω is identity, if ε is allowed to have variance different than one; if εs have one variance (as in stata), then Ω is diagonal

General Dynamic Setting: Reduced Form

- Rewrite model:

$$
\begin{aligned}
(I - B_0)Y_t &= B_1 Y_{t-1} + \Omega\, \varepsilon_t, \\
Y_t &= (I - B_0)^{-1} B_1 Y_{t-1} + (I - B_0)^{-1}\Omega\, \varepsilon_t, \\
Y_t &= \Gamma_1 Y_{t-1} + H\, \varepsilon_t, \\
Y_t &= \Gamma_1 Y_{t-1} + \eta_t,
\end{aligned}
$$

- $\eta_t \equiv (I - B_0)^{-1}\Omega\varepsilon_t$: reduced form shocks
- Call $H \equiv (I - B_0)^{-1}\Omega$.

General Dynamic Setting: Reduced Form

- $\eta_t = (I - B_0)^{-1}\Omega\varepsilon_t = H\varepsilon_t$: reduced form shocks
- Assume Ω identity (each shock enters only one equation, i.e., (*in stata, the B matrix is diagonal*) and structural shocks have unit effect: diagonal elements of H equal one.
- Then reduced form shocks:

$$\begin{aligned} \eta_{1,t} &= b_{0,12}\ \eta_{2,t} + b_{0,13}\ \eta_{3,t} + \varepsilon_{1,t}, \\ \eta_{2,t} &= b_{0,21}\ \eta_{1,t} + b_{0,23}\ \eta_{3,t} + \varepsilon_{2,t}, \\ \eta_{3,t} &= b_{0,31}\ \eta_{1,t} + b_{0,32}\ \eta_{2,t} + \varepsilon_{3,t} \end{aligned}$$

- $\eta_{1,t}$ depends on $\eta_{2,t}$, $\eta_{3,t}$ and so on
- The system cannot be identified without further restrictions.

Identification with Short Run Restrictions

Cholesky: Case 1
General Dynamic Setting

- Cholesky decomposition: H is lower triangular.
- With current ordering of B_0 matrix, $b_{0,12} = b_{0,13} = b_{0,23} = 0$, so $\eta_{1,t} = \varepsilon_{1,t}$
- Common Interpretation: Policy variable does not respond contemporaneously to economic conditions
- We put the policy variable first
- We often do that with fiscal policy, e.g., government spending does not respond contemporaneously to taxes or output; taxes do not respond contemporaneously to output
- Fiscal policy takes time to implement.

In gov't example

Structural Form:

$$\begin{aligned} g_t &= \beta_{g\tau}\tau_t + \beta_{gy}y_t + \varepsilon_{g,t}, \\ \tau_t &= \beta_{\tau g}g_t + \beta_{\tau y}y_t + \varepsilon_{\tau,t}, \\ y_t &= \beta_{y\tau}\tau_t + \beta_{yg}g_t + \varepsilon_{y,t}. \end{aligned}$$

Reduced Form:

$$\begin{aligned} g_t &= \eta_{g,t}, \\ \tau_t &= \eta_{\tau,t}, \\ y_t &= \eta_{y,t}. \end{aligned}$$

Reduced form shocks:

$$\begin{aligned} \eta_{g,t} &= \beta_{g\tau}\ \eta_{\tau,t} + \beta_{gy}\ \eta_{y,t} + \varepsilon_{g,t}, \\ \eta_{\tau,t} &= \beta_{\tau g}\ \eta_{g,t} + \beta_{\tau y}\ \eta_{y,t} + \varepsilon_{\tau,t}, \\ \eta_{y,t} &= \beta_{yg}\ \eta_{g,t} + \beta_{y\tau}\ \eta_{\tau,t} + \varepsilon_{y,t}. \end{aligned}$$

In gov't example

$$
\begin{aligned}
g_t &= \beta_{g\tau}\tau_t + \beta_{gy}y_t + \varepsilon_{g,t}, \\
\tau_t &= \beta_{\tau g}g_t + \beta_{\tau y}y_t + \varepsilon_{\tau,t}, \\
y_t &= \beta_{y\tau}\tau_t + \beta_{yg}g_t + \varepsilon_{y,t}.
\end{aligned}
$$

- E.g., government spending does not respond contemporaneously to taxes or output.
- Running the reduced form for g_t, get the reduced form innovation $\eta_{g,t}$.
- Get the reduced form innovation $\eta_{g,t}$ and let $\eta_{g,t} = \varepsilon_{g,t}$.
- We assume $\beta_{0,g\tau} = \beta_{0,gy} = 0$

- Reduced form shocks:

$$
\begin{aligned}
\eta_{g,t} &= \beta_{g\tau}\ \eta_{\tau,t} + \beta_{gy}\ \eta_{y,t} + \varepsilon_{g,t}, \\
\eta_{\tau,t} &= \beta_{\tau g}\ \eta_{g,t} + \beta_{\tau y}\ \eta_{y,t} + \varepsilon_{\tau,t}, \\
\eta_{y,t} &= \beta_{yg}\ \eta_{g,t} + \beta_{y\tau}\ \eta_{\tau,t} + \varepsilon_{y,t}.
\end{aligned}
$$

In gov't example

$$
\begin{aligned}
g_t &= \varepsilon_{g,t}, \\
\tau_t &= \beta_{\tau g} g_t + \beta_{\tau y} y_t + \varepsilon_{\tau,t}, \\
y_t &= \beta_{y\tau} \tau_t + \beta_{yg} g_t + \varepsilon_{y,t}.
\end{aligned}
$$

- E.g., government spending does not respond contemporaneously to taxes or output.
- Running the reduced form for g_t, get the reduced form innovation $\eta_{g,t}$.
- Get the reduced form innovation $\eta_{g,t}$ and let $\eta_{g,t} = \varepsilon_{g,t}$.
- We assume $\beta_{g\tau} = \beta_{gy} = 0$
- This identified $\varepsilon_{g,t}$ is like an instrument for $\eta_{g,t}$ in the rest of the η equations.
- Reduced form shocks:

$$
\begin{aligned}
\eta_{g,t} &= \varepsilon_{g,t}, \\
\eta_{\tau,t} &= \beta_{\tau g}\ \eta_{g,t} + \beta_{\tau y}\ \eta_{y,t} + \varepsilon_{\tau,t}, \\
\eta_{y,t} &= \beta_{yg}\ \eta_{g,t} + \beta_{y\tau}\ \eta_{\tau,t} + \varepsilon_{y,t}.
\end{aligned}
$$

In gov't example

$$
\begin{aligned}
g_t &= \varepsilon_{g,t}, \\
\tau_t &= \beta_{\tau g} g_t + \beta_{\tau y} y_t + \varepsilon_{\tau,t}, \\
y_t &= \beta_{y\tau} \tau_t + \beta_{yg} g_t + \varepsilon_{y,t}.
\end{aligned}
$$

- Then we also need to assume that output does not affect tax policy contemporaneously
- Running the reduced form for τ_t, get the reduced form innovation $\eta_{\tau,t}$
- Get the reduced form innovation $\eta_{\tau,t}$ and let $\eta_{\tau,t} = \beta_{\tau g}\ \varepsilon_{g,t} + \varepsilon_{\tau,t}$
- We assume $\beta_{\tau y} = 0$. Note: it could be that we have a number from other studies, as did Blanchard and Perotti (2002), setting $\beta_{\tau y} = 2.08$ for cyclical sensitivity of taxes

- Reduced form shocks:

$$
\begin{aligned}
\eta_{g,t} &= \varepsilon_{g,t}, \\
\eta_{\tau,t} &= \beta_{\tau g}\ \varepsilon_{g,t} + \beta_{\tau y}\ \eta_{y,t} + \varepsilon_{\tau,t}, \\
\eta_{y,t} &= \beta_{yg}\ \varepsilon_{g,t} + \beta_{y\tau}\ \eta_{\tau,t} + \varepsilon_{y,t}.
\end{aligned}
$$

In gov't example

$$
\begin{aligned}
g_t &= \varepsilon_{g,t}, \\
\tau_t &= \beta_{\tau g} g_t + \varepsilon_{\tau,t}, \\
y_t &= \beta_{y\tau}\tau_t + \beta_{yg} g_t + \varepsilon_{y,t}.
\end{aligned}
$$

- Then we also need to assume that output does not affect tax policy contemporaneously
- Running the reduced form for τ_t, get the reduced form innovation $\eta_{\tau,t}$
- Get the reduced form innovation $\eta_{\tau,t}$ and let $\eta_{\tau,t} = \beta_{\tau g}\ \varepsilon_{g,t} + \varepsilon_{\tau,t}$
- We assume $\beta_{\tau y} = 0$
- Now run the second reduced form equation and get both an estimate for $\beta_{\tau g}$ and $\varepsilon_{\tau,t}$
- Reduced form shocks:

$$
\begin{aligned}
\eta_{g,t} &= \varepsilon_{g,t}, \\
\eta_{\tau,t} &= \beta_{\tau g}\ \eta_{g,t} + \varepsilon_{\tau,t} \\
\eta_{y,t} &= \beta_{yg}\ \eta_{g,t} + \beta_{y\tau}\ \eta_{\tau,t} + \varepsilon_{y,t}.
\end{aligned}
$$

In gov't example

$$
\begin{aligned}
g_t &= \varepsilon_{g,t}, \\
\tau_t &= \beta_{\tau g} g_t + \varepsilon_{\tau,t}, \\
y_t &= \beta_{y\tau}\tau_t + \beta_{yg} g_t + \varepsilon_{y,t}
\end{aligned}
$$

- Running the reduced form for y_t, get the reduced form innovation $\eta_{y,t}$
- Now run the third reduced form equation and get an estimate for β_{yg}, $\beta_{y\tau}$ and $\varepsilon_{y,t}$
- Reduced form shocks:

$$
\begin{aligned}
\eta_{g,t} &= \varepsilon_{g,t}, \\
\eta_{\tau,t} &= \beta_{\tau g}\ \eta_{g,t} + \varepsilon_{\tau,t} \\
\eta_{y,t} &= \beta_{yg}\ \eta_{g,t} + \beta_{y\tau}\ \eta_{\tau,t} + \varepsilon_{y,t}.
\end{aligned}
$$

- Recursive estimation

Cholesky: Case 2

- Cholesky decomposition: H is lower triangular.
- BUT, change ordering
- Common Interpretation: Endogenous variables do not respond contemporaneously to policy
- We put the policy variable last
- E.g., identify monetary policy shocks as shocks to federal funds rates, by assuming that federal funds rates changes do not affect contemporaneously output.

General Dynamic Setting

- Three-equations general setting: $Y_t = [Y_{2,t}\ Y_{3,t}\ Y_{1,t}]'$.

$$Y_t = B_0 Y_t + B_1 Y_{t-1} + \Omega \varepsilon_t,$$

where ε_t are structural shocks, uncorrelated.

- B_0 is the contemporaneous effects matrix

$$B_0 = \begin{bmatrix} b_{0,21} & b_{0,22} & b_{0,23} \\ b_{0,31} & b_{0,32} & b_{0,33} \\ b_{0,11} & b_{0,12} & b_{0,13} \end{bmatrix}$$

- Note: Ω is identity, if ε is allowed to have variance different than one; if εs have one variance (as in stata), then Ω is diagonal.

Example Cholesky: Case 2

Consider VAR for $\Delta y_t, \pi_t, i_t$ (output growth, inflation, and interest rate).

- Policy rule:

$$i_t = \beta_{31}\Delta y_t + \beta_{32}\pi_t + \varepsilon_{3t},$$

  where $\beta_{31}\delta y_t + \beta_{32}\pi_t$ is a reaction function and ε_{3t} is a policy shock.

- Inflation: *Policy variable affect inflation with a lag – that's an assumption allowing identification.*

$$\pi_t = \beta_{21}\Delta y_t + \gamma_{23} i_{t-1} + \varepsilon_{2t},$$

  with ε_{2t} being, for example, oil price shock.

- Output:

$$\Delta y_t = \gamma_{13} i_{t-1} + \varepsilon_{1t},$$

  with ε_{1t} denoting a productivity/supply shock.

- *Timing assumption: it may take a while to have change in i affecting output*

Example Cholesky: Case 2

VAR:

$$\begin{bmatrix} 1 & 0 & 0 \\ -\beta_{21} & 1 & 0 \\ -\beta_{31} & -\beta_{32} & 1 \end{bmatrix} \begin{bmatrix} \Delta y_t \\ \pi_t \\ i_t \end{bmatrix} = \begin{bmatrix} \gamma_{11} & \gamma_{12} & \gamma_{13} \\ \gamma_{21} & \gamma_{22} & \gamma_{23} \\ \gamma_{31} & \gamma_{32} & \gamma_{33} \end{bmatrix} \begin{bmatrix} \Delta y_{t-1} \\ \pi_{t-1} \\ i_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{bmatrix}.$$

- We put the policy variable last.
- See earlier Lectures on Sim's monetary policy example.

Identification with Long Run Restrictions

Long Run Restrictions

- Cholesky decomposition on long run variance.
- Make restrictions on long run relationships.
- E.g., in the long run, demand shocks have zero effects on macro variables.
- Restrictions on cumulative effects.
- See last Lecture

Factor Augmented VAR-FAVAR

FAVAR

- One limitation with VARs, apart from identification, is dimensionality
- It is hard to estimate VARs with many variables-many equations
- But there are questions that multiple dimensions are important, e.g., taking into account financial markets, or different price indexes
- Factor Augments VARs help in those cases
- Use common factors instead of single variables in VAR estimation
- Still requires Cholesky decomposition
- Bernanke, Boivin, Eliasz, QJE 2005.

Identification with Exogenous Series

High Frequency identification

- Use high-frequency data from financial instruments during key windows. e.g. news announcements around FOMC dates and the movement of federal funds futures to identify unexpected Fed policy actions
- This identification is based in part on timing, but because the timing is so high frequency (daily or higher), the assumptions are more plausible than those employed at the monthly or quarterly frequency

HF Example: Monetary Policy Effect

- Want to study the effect of monetary policy on asset returns
- Run regression of the monetary policy announcements on bond returns
- Let R be bond returns and $\tilde{r}$ changes to the federal funds rate target

$$\Delta R_t = \alpha + \beta_1 \Delta \tilde{r}_t + \omega_t$$

- Announcements of federal funds rate target treated as exogenous shocks
- If announcements of federal funds rate target are unexpected, then we can estimate the effect of asset returns to it
- Using high-frequency data we "solve" the endogeneity problem: asset returns response a day after announcement of target, does not affect announcement of target

HF Example: Monetary policy effects, early sample (Cook and Haan, JME 1989)

Table 3

The effect of funds rate target changes on market interest rates.[a]

$$\Delta R_t = b1 + b2\,\Delta RFF_t + u_t$$

ΔR_t	$b1$	$b2$	R^2	SER	DW
3-month bill rate	0.016 (1 04)	0.554 (8.10)[b]	0.47	0.13	1.89
6-month bill rate	0.017 (1.44)	0.541 (10.25)[b]	0.59	0.10	1.82
12-month bill rate	0.024 (2.02)[c]	0.500 (9.61)[b]	0.56	0.10	1.94
3-year bond rate	0.018 (2.16)[c]	0.289 (7.87)[b]	0.46	0 07	1.59
5-year bond rate	0.012 (1.66)	0.208 (6.43)[b]	0.36	0.06	1.59
7-year bond rate	0.009 (1.47)	0.185 (6 78)[b]	0.39	0 05	1.89
10-year bond rate	0.012 (2.34)[c]	0 131 (5.85)[b]	0.32	0.04	1.94
20-year bond rate	0.007 (1.73)	0.098 (5.46)[b]	0.29	0.03	2.04

Figure: Includes 75 changes in the federal funds rate target from Sep 1974 to Sep 1979. t-statistics in parentheses. b: Significant at the 1% level, using a two-tailed test, c: Significant at the 5% level, using a two-tailed test.

HF Example: Monetary policy effects, early sample (Cook and Haan, JME 1989)

- Sample of 1974 – 1979, when there were target "announcments"
- Finding: Target announcements important for bond markets
- Monetary policy is non-neutral, it affects the real economy
- 10 basis points increase in the federal funds rates target increases short-run bond returns by about 5 basis points
- 10 basis points increase in the federal funds rates target increases very long-run bond returns by about 1 basis points
- Effects large and significant
- Kuttner, JME 2001 revisited the issue.

HF example: Monetary policy effects, later sample (Kuttner, JME 2001)

Table 1
The 1-day response of interest rates to changes in the Fed funds target[a]

Maturity	Intercept	Response	R^2	SE	DW
3 month	– 3.6	26.8 instead of 55 in C-H	0.42	9.8	2.04
	(2.3)	(5.4)			
6 month	– 5.2	21.9	0.37	9.0	2.04
	(3.6)	(4.6)			
12 month	– 5.1	19.8	0.29	9.5	2.07
	(3.3)	(4.1)			
2 year	– 5.2	18.2	0.26	9.6	2.28
	(3.4)	(3.7)			
5 year	– 4.5	10.4	0.10	9.8	2.40
	(2.9)	(2.1)			
10 year	– 4.0	4.3	0.02	8.5	2.50
	(2.9)	(1.0)			
30 year	– 3.6	0.1 instead of 10 in C-H	0.00	6.9	2.47
	(3.2)	(0.0)			

[a] *Note*: The change in the target Fed funds rate is expressed in percent, and the interest rate changes are expressed in basis points. The sample contains 42 changes in the target Fed funds rate from 6 June 1989 through 2 February 2000. Parentheses contain t-statistics.

HF example: Monetary policy effects, later sample (Kuttner, JME 2001)

- Sample of 1989 – 2000
- Finding: Target announcements less important for bond market
- 10 basis points increase in the federal funds rates target increases short run bond returns by about 2.5 basis points. half than what Cook and Haan found
- 10 basis points increase in the federal funds rates target increases very long run bond returns by about 0.01 basis points, and not significantly different than zero
- Effects much smaller and often insignificant

HF Example: Monetary Policy Announcements in early vs later sample

- Finding: Target announcements in earlier sample important for bond market (and thus monetary policy is non-neutral, affects the economy)
- Finding: Target announcements in later sample not that important for bond market
- Is monetary policy neutral, non-effective, in later period?
- Or maybe monetary policy shocks are not well identified in later period?

HF Example: Monetary Policy Surprise Measure

- Identifying monetary policy shocks
- We want a measure of surprise/shock to the market: what the federal funds rate is after the target announcement minus what was expected to be before the announcement
- $$\tilde{r}_{t+1} - E_t \tilde{r}_{t+1},$$

  with $\tilde{r}_t$ the federal funds target rate, and E_t is time-t expectations
- In earlier sample, there was no prior information released and thus $E_t \tilde{r}_{t+1} = 0$ on average
- Using the actual target announcement as a proxy for the monetary policy shock was a good assumption
- In the later sample, this is not the case
- The Federal reserve releases information before the target announcement and thus $E_t \tilde{r}_{t+1} \neq 0$.

HF Example: Monetary Policy Surprise Measure Kuttner's (JME, 2001)

Kuttner's (JME, 2001) Surprise Measure: Measure of monetary policy surprise, $\Delta\tilde{r}_t^u$, unanticipated part:

$$\Delta\tilde{r}_t^u \equiv \frac{m}{m-t}(f_{s,t}^0 - f_{s,t-1}^0), \tag{1}$$

$f_{s,t}^0$ is the spot-month futures rate for the (effective) federal funds rate, m is the number of days in the specific month
-Take the difference of spot rate before and after the monetary policy action announcement
-If the announcement contains any news for the market, the spot rate will change
-Monetary policy shock measured by the markets' surprise.

HF example: Monetary policy effects, new measure, (Kuttner, JME 2001)

Table 3
The 1-day response of interest rates to the Fed funds surprises[a]

		Response to target change				
Maturity	Intercept	Anticipated	Unanticipated	R^2	SE	DW
3 month	– 0.7	4.4	79.1	0.70	7.1	1.82
	(0.5)	(0.8)	(8.4)			
6 month	– 2.5	0.6	71.6	0.69	6.3	2.06
	(2.2)	(0.1)	(8.5)			
12 month	– 2.2	– 2.3	71.6	0.64	6.9	2.10
	(1.8)	(0.5)	(7.8)			
2 year	– 2.8	– 0.4	61.4	0.52	7.8	2.25
	(2.0)	(0.1)	(6.0)			
5 year	– 2.4	– 5.8	48.1	0.33	8.6	2.37
	(1.6)	(0.9)	(4.3)			
10 year	– 2.4	– 7.4	31.5	0.19	7.8	2.37
	(1.8)	(1.3)	(3.1)			
30 year	– 2.5	– 8.2	19.4	0.13	6.5	2.46
	(2.2)	(1.7)	(2.3)			

[a] *Note*: Anticipated and unanticipated changes in the Fed funds target are computed from the Fed funds futures rates, as described in the text. Parentheses contain t-statistics. See also notes to Table 1.

HF example: Monetary policy effects, later sample (Kuttner, JME 2001): New Measure

- Sample of 1989 – 2000
- Finding: Unanticipated target announcements even more important for bonds market than what Cook and Haan found
- 10 basis points increase in the federal funds rates target surprise increases short run bond returns by about 7-8 basis points
- 10 basis points increase in the federal funds rates target surprise increases very long run bond returns by about 2 basis points
- Effects large and significant.

HF Example: New Measure

- Finding: Target announcements in earlier sample important for asset prices
- Finding: Target announcements in later sample not that important for asset prices
- Finding: Unanticipated target announcements in later sample important for asset prices
- Monetary policy is effective in later period too, but we need to take into account advances in Fed communication strategies that affect the shock identification
- Once we got well identified shocks, further one-equation studies of monetary policy followed.

HF Example: Monetary Policy Surprise and Stock Prices (Bernanke & Kuttner JoF, 2005)

Fixed Coefficients Approach Event Study:

$$R_t = \beta_0 + \beta_1 \Delta \tilde{r}_t^u + e_t, \tag{2}$$

R_t: daily returns on the S&P 500 index, $\Delta \tilde{r}_t^u$: federal funds rates futures market based surprise.

HF Example: Fixed Coefficients Approach Event Study (Jansen & Zervou 2018)

$$R_t = \beta_0 + \beta_1 \Delta \tilde{r}_t^u + e_t, \tag{3}$$

R_t: daily returns on the S&P 500 index, $\Delta \tilde{r}_t^u$: federal funds rates futures market based surprise.

- Split the sample: 1989-1993; 1989-2000; 1994-2000; 1994-2007; 2001-2007.

HF Example: Regression Results

	All	1989-1993	1989-2000	1994-2000	1994-2007	2001-2007
$\hat{\beta}_0$	0.211	0.209	0.285	0.336	0.211	0.130
$t_{\hat{\beta}_0}$	2.731	1.900	3.215	2.711	2.174	0.893
$\hat{\beta}_1$	-3.869	-4.450	-0.983	0.156	-3.773	-7.763
$t_{\hat{\beta}_1}$	-2.485	-3.228	-0.547	0.078	-2.125	-3.115
N	149	37	90	53	112	59

HF Example: Regression Results

- A percentage point surprise increase in ffr, decreases one-day stock price return by 3.869%
- Full sample results similar to Bernanke & Kuttner (JoF, 2005), who used again monetary surprises to see effects on stock prices
- Significant difference between the samples
- Investigate the time varying coefficient approach.

HF Identification

- High frequency identification has become a common way to identify monetary policy shocks
- Can study the effects of monetary policy on macro variables
- Event study approach, but can aggregate in e.g., quarterly frequency
- Limitation: futures' market opens in 1989.

Narrative Approach

Narrative Approach

- Use narrative approach by looking at historical documents to identify policy shocks
- Identify policy changes uncorrelated with the current state of the economy
- These shocks are uncorrelated with the other shocks
- Caution: Narratives alone do not provide exogeneity.

Narrative Approach: Fiscal shocks

- Fiscal shocks not main research focus 1980s-2000s; monetary policy shocks dominated until Great Recession
- Military spending: driven by military events rather than by macroeconomic events; put first in VARs
- How about anticipation effects?
- Narrative approach might overcome anticipation effects
- Ramey (QJE, 2011) computes "war dates", reading newspapers and computing a variable on "news" about military spending
- Treated an exogenous shock to policy and then studied the effects: can do single equation approach.

Narrative Approach: Fiscal shocks

- Narrative shocks find different results than SVARs on the topic
- Increase in government expenditures (demand shocks), increases output for both approaches ($Y = C + I + G + XN$)
- Increase in government expenditures (demand shocks), increases Consumption in VARs and decreases Consumption in Narrative approach
- Important issue: Consumption and Investment crowded out? Narrative approach finds yes
- Debate on fiscal multipliers, active research.

Narrative Approach: Monetary shocks

- Romer and Romer (1989) narrative approach
- Search meetings transcripts for "tight money shocks" dates
- Treated an exogenous shock to policy and then studied the effects: single equation approach
- But: they were possibly estimating reaction part of policy, not an exogenous shock
- E.g., if policy follows a Taylor-type of rule:

$$i_t = b_0 + b_1(\pi_t - \bar{\pi}) + b_2(y_t - \bar{y})$$

  then policy rate reacts to economic conditions.

Alternative way to identify exogenous monetary policy shock: high frequency data

Identification with Instrument

External Instrument

- We identify a "noisy" instrument of our shock with e.g., narrative evidence, high frequency information
- Then we can:
  - do "one-equation" approach IV, or
  - we can use the IV within the VAR, to reduce the number of restrictions we impose.
- So we could combine the external series approach and the VAR approach

Reminder: General Dynamic Setting

- Three-equations general setting: $Y_t = [Y_{1,t} \; Y_{2,t} \; Y_{3,t}]'$

$$Y_t = B_0 Y_t + B_1 Y_{t-1} + \Omega \varepsilon_t,$$

  where ε_t are structural shocks, uncorrelated
- B_0 is the contemporaneous effects matrix

$$B_0 = \begin{bmatrix} b_{0,11} & b_{0,12} & b_{0,13} \\ b_{0,21} & b_{0,22} & b_{0,23} \\ b_{0,31} & b_{0,32} & b_{0,33} \end{bmatrix}$$

- Note: Ω is identity, if ε is allowed to have variance different than one; if εs have one variance (as in stata), then Ω is diagonal.

Reminder: General Dynamic Setting: Reduced Form

- Rewrite model:

$$
\begin{aligned}
(I - B_0)Y_t &= B_1 Y_{t-1} + \Omega\, \varepsilon_t, \\
Y_t &= (I - B_0)^{-1} B_1 Y_{t-1} + (I - B_0)^{-1} \Omega\, \varepsilon_t, \\
Y_t &= \Gamma_1 Y_{t-1} + H\, \varepsilon_t, \\
Y_t &= \Gamma_1 Y_{t-1} + \eta_t,
\end{aligned}
$$

- $\eta_t \equiv (I - B_0)^{-1} \Omega \varepsilon_t$: reduced form shocks
- Call $H \equiv (I - B_0)^{-1} \Omega$.

Reminder: General Dynamic Setting: Reduced Form

- $\eta_t = (I - B_0)^{-1}\Omega\varepsilon_t = H\varepsilon_t$: reduced form shocks
- Assume Ω identity (each shock enters only one equation, i.e., (*in stata, the B matrix is diagonal*) and structural shocks have unit effect: diagonal elements of H equal one
- Then reduced form shocks:

$$
\begin{aligned}
\eta_{1,t} &= b_{0,12}\ \eta_{2,t} + b_{0,13}\ \eta_{3,t} + \varepsilon_{1,t}, \\
\eta_{2,t} &= b_{0,21}\ \eta_{1,t} + b_{0,23}\ \eta_{3,t} + \varepsilon_{2,t}, \\
\eta_{3,t} &= b_{0,31}\ \eta_{1,t} + b_{0,32}\ \eta_{2,t} + \varepsilon_{3,t}
\end{aligned}
$$

- $\eta_{1,t}$ depends on $\eta_{2,t}$, $\eta_{3,t}$ and so on
- The system cannot be identified without further restrictions.

External Instrument in our GD setting

Steps:

- Use "outside" the VAR info-external series Z_t (e.g., narrative evidence, high frequency information)
- Use Z_t as noisy measure of the true shock
- Conditions:

$$
\begin{aligned}
E[Z_t \ \varepsilon_{1,t}] &\neq 0, \\
E[Z_t \ \varepsilon_{i,t}] &= 0, \ i = 2, 3
\end{aligned}
$$

- Relevance condition: external instrument must be contemporaneously correlated with the structural policy shock. Important: first-stage F-statistic needs to be high (in empirical micro 18 and above!)
- Exogeneity condition: the external instrument must be contemporaneously uncorrelated with the other structural shocks.

External Instrument

Steps to identify $\varepsilon_{1,t}$:

- 1) Estimate the reduced form system to obtain estimates of the reduced form residuals η_t
- 2) Run two regressions: $\eta_{2,t}$ on $\eta_{1,t}$, and $\eta_{3,t}$ on $\eta_{1,t}$ using the external series Z_t as instrument. Get unbiased estimates of b_{21} and b_{31}. Define the residuals of these regressions to be $v_{2,t}$ and $v_{3,t}$
- 3) Regress $\eta_{1,t}$ on $\eta_{2,t}$ and $\eta_{3,t}$, using the $v_{2,t}$ and $v_{3,t}$ estimated in previous step, as the instruments. This yields unbiased estimates of b_{12} and b_{13}

External Instrument

Steps to identify $\varepsilon_{1,t}$:

- 1) Estimate the reduced form system to obtain estimates of the reduced form residuals η_t: $Y_t = \Gamma_1 Y_{t-1} + \eta_t$
- Reduced Form:

$$\begin{aligned} \eta_{1,t} &= b_{0,12}\ \eta_{2,t} + b_{0,13}\ \eta_{3,t} + \varepsilon_{1,t}, \\ \eta_{2,t} &= b_{0,21}\ \eta_{1,t} + b_{0,23}\ \eta_{3,t} + \varepsilon_{2,t}, \\ \eta_{3,t} &= b_{0,31}\ \eta_{1,t} + b_{0,32}\ \eta_{2,t} + \varepsilon_{3,t} \end{aligned}$$

  But we don't have $\varepsilon' s$ and dont want to make short run restrictions for bs (and thus get $\eta_{1,t} = \varepsilon_{1,t}$)

- Now ηs is my data; I want to find a good estimate of $b_{0,21}, b_{0,31}$; I see that η_1 also depends on η_2, η_3 through the first equation, so there is endogeneity, and cannot run equations 2 and 3
- Let Z be an instrument for ε_1, or actually, η_1.

External Instrument

Steps to identify $\varepsilon_{1,t}$:

- 2) Run two regressions: $\eta_{2,t}$ on $\eta_{1,t}$, and $\eta_{3,t}$ on $\eta_{1,t}$ using the external series Z_t as instrument:

$$\begin{aligned} \eta_{2,t} &= c_{0,21}\, Z_t + v_{2,t} \\ \eta_{3,t} &= c_{0,31}\, Z_t + v_{3,t} \end{aligned}$$

- $\hat{c}_{0,21}$, $\hat{c}_{0,31}$ are unbiased estimates of $b_{0,21}$ and $b_{0,31}$.

External Instrument

Steps to identify $\varepsilon_{1,t}$:

- 3) Regress $\eta_{1,t}$ on $\eta_{2,t}$ and $\eta_{3,t}$, using the $v_{2,t}$ and $v_{3,t}$ estimated in previous step, as the instruments:

$$\eta_{1,t} = c_{0,12}\hat{v}_{2,t} + c_{0,13}\hat{v}_{3,t} + j_{1,t}$$

- $v_{2,t}, v_{3,t}$ are orthogonal to Z, and thus to ε_1
- The regression yields $\hat{c}_{0,12}, \hat{c}_{0,13}$ as unbiased estimates of $b_{0,12}$ and $b_{0,13}$, and identifies ε_1 using j_1
- This way we identified a good number of parameters, without imposing restrictions.

IRF's

- If you use VAR for identification and is well specified, use VAR for IRF's
- BUT: If you do not use VAR for identification or if it is not well specified, then what?
- Use Jorda (2005) local projection method for estimating impulse responses.

Summary on Identification

- VAR Short Run Restrictions
- VAR Long Run Restrictions
- FAVAR
- External Series:
  - High Frequency data
  - Narrative approach
  - VAR with External Instrument: Proxy VAR
- Other ways we did not talk about:
  - Dynamic Stochastic General Equilibrium Models: we did two examples in macro
  - Sign restrictions in VARs

Next: We identify the shock, use Jorda methods to compute IRFs (not VAR).