EVIDENCE FOR MONETARY NON-NEUTRALITY

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Central question in macroeconomics:

1. Monetary policy is a central macroeconomic policy tool
2. Answer helps distinguish between competing views of how the world works more generally (Why?)
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No consensus in many other countries

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(Often quite heated and antagonistic)
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Scientific question!!
   Conclusive empirical evidence should be able to settle this issue
   (for those willing to base opinion on evidence as opposed to ideology)
Why Don’t We Already Know?

Given central importance, how can we not already know?
Why Don’t We Already Know?

Given central importance, how can we not already know?

- Changes in monetary policy occur for a reason!!
- Purpose of central banks to conduct systematic policy that reacts to developments in economy
- Fed employs hundreds of PhD economists to pore over data
- Leaves little room for exogenous variation in policy needed to identify effects of policy
Fed lowered interest rates aggressively in fall of 2008

- Done in response to worsening financial crisis
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- Consider simple OLS regression:

\[ \Delta y_t = \alpha + \beta \Delta i_t + \epsilon_t \]
Fed lowered interest rates aggressively in fall of 2008

- Done in response to worsening financial crisis
- Consider simple OLS regression:

\[ \Delta y_t = \alpha + \beta \Delta i_t + \epsilon_t \]

- This regression will not identify effects of policy
- Financial crisis – event that induced Fed to act – is a confounding factor (in error term and correlated with \( \Delta i_t \))
When we ask prominent macroeconomists, most common answers are:\footnote{Of course, a significant fraction say something along the lines of “I know it in my bones that monetary policy has no effect on output.”}

- Friedman and Schwartz 63
- Volcker disinflation
- Mussa 86

Any mention of VARs and evident from other modern econometric methods is conspicuous by its absence.
TYPES OF EVIDENCE

- Evidence from Large Shocks
- Discontinuity-Based Evidence / High-Frequency Evidence
- Evidence from the Narrative Record
- Controlling for Confounding Factors
  - Structural Vector Autoregressions
  - Romer and Romer (2004)
Evidence from Large Shocks
Industrial Production in U.S. Great Depression

Source: Nakamura and Steinsson (2018)
Discontinuity-Based Evidence
MONETARY POLICY AND RELATIVE PRICES

- Strong evidence for effects of monetary policy on relative prices
- Important reason: Can be assessed using discontinuity-based identification
Change in U.S. - German real exchange rate. Source: Nakamura and Steinsson (2018)
Bretton Woods system of fixed exchange rates breaks down in Feb 73
- This is a pure high-frequency change in monetary policy

Sharp break in volatility of **real** exchange rate
Monetary Policy and Real Exchange Rate

- Bretton Woods system of fixed exchange rates breaks down in Feb 73
  - This is a pure high-frequency change in monetary policy
- Sharp break in volatility of real exchange rate
- Identifying assumption:
  - Nothing else changed discontinuously in Feb 73
- Imbalances had been building up gradually
  - More inflationary policy in US than in Germany, Japan, etc.
  - US running substantial current account deficit
  - Intense negotiations for months about future of system
  - Hard to see anything else that discontinuously changes in Feb 73
High-frequency evidence on real interest rates:
- Look at narrow time windows around FOMC announcements
- Measure real interest rate using yields on TIPS

Identifying assumption:
- Little else happens during narrow window (30-minutes)
- Changes must be due to what Fed did and announced

Nominal and real rates respond roughly one-for-one several years into term structure (see, e.g., Hansen-Stein 15, Nakamura-Steinsson 18)

We will return to this on Thursday
Advantages:

- Effect on relative prices can be estimated using discontinuity-based approaches
Evidence on Relative Prices

Advantages:

- Effect on relative prices can be estimated using discontinuity-based approaches

Disadvantages:

- No direct link to output
- Effects depend on how we interpret price changes (information, risk premia)
- Effect on output depends on various other parameters in the “real” model (e.g., IES)
Much weaker!

(e.g., Cochrane-Piazzesi 02, Angrist et al. 17)

- Output not observed at high frequency
- Monetary policy may affect output with “long and variable lags”
- Too many other shocks occur over several quarters
- Not enough statistical power to estimate effects on output using this method
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(e.g., Cochrane-Piazzesi 02, Angrist et al. 17)
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But, effect on relative prices is – arguably – the key empirical issue
- Relative prices affect output in all models
- Monetary and non-monetary models (e.g., NK versus RBC) differ sharply on whether monetary policy can affect relative prices
Evidence from the Narrative Record
Romer-Romer 89:

- Fed records can be used to identify natural experiments
- Specifically: “Episodes in which the Federal Reserve attempted to exert a contractionary influence on the economy in order to reduce inflation.”
- Six episodes (Romer-Romer 94 added a seventh)
- After each one, unemployment rises sharply
- Strong evidence for substantial real effects of monetary policy

(Paper also contains an interesting critical assessment of Friedman-Szhwartz 63)
Unemployment rate. Vertical lines are Romer-Romer 89 dates. Source: Nakamura and Steinsson (2018)
Process for selecting the shock dates is opaque
- High cost of replication
- Similar critique applies to many complex econometric methods

Few data points
- May happen to be correlated with other shocks
- Hoover-Perez 94 point out high correlation with oil shocks

Shocks predictable suggesting endogeneity
- Difficult to establish convincingly due to overfitting concerns
- Cumulative number of predictability regressions run hard to know
<table>
<thead>
<tr>
<th>Romer and Romer Dates</th>
<th>Oil Shock Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 1947</td>
<td>December 1947</td>
</tr>
<tr>
<td>June 1953</td>
<td></td>
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<tr>
<td>September 1955</td>
<td>June 1956</td>
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<td>February 1957</td>
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<td>December 1968</td>
<td>March 1969</td>
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<td>December 1970</td>
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<td>April 1974</td>
<td>January 1974</td>
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<tr>
<td>August 1978</td>
<td>March 1978</td>
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<tr>
<td>October 1979</td>
<td>September 1979</td>
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<tr>
<td>February 1981</td>
<td></td>
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<tr>
<td>January 1987</td>
<td></td>
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<tr>
<td>December 1988</td>
<td>December 1988</td>
</tr>
<tr>
<td>August 1990</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Romer-Romer dates are identified by Romer and Romer (1989) and Romer and Romer (1994). Oil-shock dates up to 1981 are taken from Hoover and Perez (1994), who refine the narrative identification of these shocks by Hamilton (1983). The last three oil shock dates are from Romer and Romer (1994).

Source: Nakamura and Steinsson (2018)
Controlling for Confounding Factors
Large class of linear rational expectations models can be written as follows:

\[ AY_{t+1} = BY_t + C\epsilon_{t+1} + D\eta_{t+1} \]

where

- \( Y_t \) is an \( n \times 1 \) vector
- \( E[\epsilon_{t+1}|l_t] = 0, E[\eta_{t+1}|l_t] = 0 \)
- \( \epsilon_{t+1} \) are exogenous shocks (\( m_1 \times 1 \) vector)
- \( \eta_{t+1} \) are prediction errors (\( m_2 \times 1 \) vector)
- Only some elements of \( Y_{t+1} \) have initial conditions
Example: New Keynesian Model

\[ \pi_t = E_t \pi_{t+1} + \kappa (y_t - y^n_t) \]
\[ y_t = E_t y_{t+1} - \sigma (i_t - E_t \pi_{t+1} - r^n_t) \]
\[ i_t = \phi_\pi \pi_t + \phi_y y_t + \nu_t \]
Example: New Keynesian Model

\[
\begin{align*}
\pi_t &= E_t \pi_{t+1} + \kappa (y_t - y^n_t) \\
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i_t &= \phi_\pi \pi_t + \phi_y y_t + \nu_t
\end{align*}
\]

Some manipulation yields:

\[
\begin{align*}
\pi_{t+1} &= \pi_t - \kappa y_t + \kappa y^n_t + \eta_{\pi,t+1} \\
y_{t+1} + \sigma \pi_{t+1} &= y_t + \sigma i_t - \sigma r^n_t + \eta_{y,t+1} + \sigma \eta_{\pi,t+1} \\
i_{t+1} - \phi_\pi \pi_{t+1} - \phi_y y_{t+1} &= \nu_{t+1}
\end{align*}
\]

where \( \eta_{\pi,t+1} = \pi_{t+1} - E_t \pi_{t+1} \) and \( \eta_{y,t+1} = y_{t+1} - E_t y_{t+1} \)
Example: New Keynesian Model

\[
\begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 \\
\sigma & 1 & 0 & 0 & 0 & 0 \\
-\phi_\pi & -\phi_y & 1 & 0 & 0 & -1 \\
0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 \\
\end{bmatrix}
\begin{bmatrix}
\pi_{t+1} \\
y_{t+1} \\
i_{t+1} \\
y^n_{t+1} \\
r^n_{t+1} \\
\nu_{t+1} \\
\end{bmatrix} =
\begin{bmatrix}
1 & -\kappa & 0 & \kappa & 0 & 0 \\
0 & 1 & \sigma & 0 & -\sigma & 0 \\
0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \rho_\pi & 0 & 0 \\
0 & 0 & 0 & 0 & \rho_y & 0 \\
0 & 0 & 0 & 0 & \rho_i & 0 \\
\end{bmatrix}
\begin{bmatrix}
\pi_t \\
y_t \\
i_t \\
y^n_t \\
r^n_t \\
\nu_t \\
\end{bmatrix} +
\begin{bmatrix}
0 & 0 & 0 \\
0 & 0 & 0 \\
0 & 0 & 0 \\
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1 \\
\end{bmatrix}
\begin{bmatrix}
\epsilon_{1,t+1} \\
\epsilon_{2,t+1} \\
\epsilon_{3,t+1} \\
\end{bmatrix} +
\begin{bmatrix}
1 & 0 \\
\sigma & 1 \\
0 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 0 \\
\end{bmatrix}
\begin{bmatrix}
\eta_{\pi,t+1} \\
\eta_{y,t+1} \\
\end{bmatrix}
\]

- Have assumed that \(y^n_t, r^n_t,\) and \(\nu_t\) are AR(1)
- System comes with only three initial conditions (for \(y^n_t, r^n_t,\) and \(\nu_t\)
SOLVING LINEAR RATIONAL EXPECTATIONS MODELS

- State space representation:
  \[ AY_{t+1} = BY_t + C\epsilon_{t+1} + D\eta_{t+1} \]

- Solution:
  \[ Y_t = GY_{t-1} + R\epsilon_t \]

- How to solve?
  - Blanchard-Kahn 80. See, e.g., Sims 00 or lecture notes by Den Haan

- Notice: Solution of a linear RE model is a VAR
Suppose we are interested in effect of \( \epsilon_{3,0} \) on \( y_t \) for \( t \geq 0 \)
(Recall that \( \epsilon_{3,0} \) is the innovation to the monetary shock)

Iterate forward the VAR starting at time 0:

\[
Y_t = G_t Y_{t-1} + G_{t-1}^- R\epsilon_0
\]

Suppose for simplicity that we start off in a steady state \( Y_{t-1} = 0 \):

\[
Y_t = G_{t-1}^- R\epsilon_0
\]

If we can estimate G and R, then we can calculate dynamic causal effect of all structural shocks
VAR Estimation: Empirical Challenges

\[ Y_t = GY_{t-1} + R\epsilon_t \]

1. Some variables in true VAR may be unobservable
   - In NK model example, \((y_t^n, r_t^n, \text{and } \nu_t)\) are unobservable
   - How about solving out for these variables?
   - This typically transforms a VAR(p) into a VARMA(\(\infty, \infty\)) in the remaining variables
   - Implicit assumption in VAR estimation that true VARMA(\(\infty, \infty\)) in observable variables can be approximated by a VAR(p)
     (Problem Set 3 will have you think more about this)
2. How do we get from reduced form errors to structural errors?

- Suppose you estimate a VAR (i.e., estimate $n$ OLS regressions)
- You will get:

$$Y_t = GY_{t-1} + u_t$$

where $u_t$ are reduced form errors with variance-covariance matrix $\Sigma$

- Unfortunately, $\Sigma$ not enough to identify $R$
- **Structural** VARs make additional assumptions to be able to identify $R$
  - Two ways of thinking about it: Identification of $R$ or identification of structural shocks $\epsilon_t$

- Example: Short-run restrictions (see Stock-Watson 01)
Dynamic Causal Inference

Objective:
- Causal effect of change in monetary policy at time $t$ on output / prices / etc. at time $t+j$

Two steps:
1. Identify shocks (exogenous variation in (say) monetary policy)
2. Estimate effects of shocks on output / prices / etc.

Important to consider these two steps separately
Common approach:
- Regress fed funds rate on output, inflation, etc. + a few lags of fed funds rate, output, inflation, etc.

\[ i_t = \alpha + \phi_y y_t + \phi_{\pi} \pi_t + [\text{four lags of } i_t, y_t, \pi_t] + \epsilon_t \]

- View residual as exogenous variation in monetary policy

- Equivalent to performing a Cholesky decomposition on reduced form errors from VAR, ordering fed funds rate last (See Stock-Watson 01)
SVARs: Identifying the Shocks

\[ i_t = \alpha + \phi_y y_t + \phi_\pi \pi_t + [\text{four lags of } i_t, y_t, \pi_t] + \epsilon_t \]

What can go wrong?
SVARs: Identifying the Shocks

\[ i_t = \alpha + \phi_y y_t + \phi_\pi \pi_t + \text{[four lags of } i_t, y_t, \pi_t] + \epsilon_t \]

What can go wrong?

1. Reverse causation:
   - Assumption begin made: Correlation between \( i_t \) and \((\pi_t, y_t)\) is due to \((\pi_t, y_t)\) influencing \( i_t \) but not the other way around
   - If \( i_t \) influences \((\pi_t, y_t)\) (contemporaneously), we have a “simultaneous equation problem” (\( \epsilon_t \) correlated with \((\pi_t, y_t)\))
   - Assumption being made: \( i_t \) is “fast-moving” variable, while \( \pi_t \) and \( y_t \) are slow moving. So \( i_t \) doesn’t affect \( \pi_t \) and \( y_t \) contemporaneously
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Often, the discussion of identification stops here and seems surprisingly innocuous. Where did the rabbit go into the hat?
SVARs: Identifying the Shocks

\[ i_t = \alpha + \phi_y y_t + \phi_\pi \pi_t + [\text{four lags of } i_t, y_t, \pi_t, \text{etc.}] + \epsilon_t \]

What can go wrong?

2. Omitted variables bias:
   - There may be other variables that affect \( i_t \) and also \( y_{t+j} \)
   - Fed bases policy on huge amount of data
     - Banking sector, stock market, foreign developments, commodity prices, terrorist attacks, temporary investment tax credit, Y2K, etc., etc.
   - Too many variables to include in regression!
   - Any information used by Fed and not sufficiently controlled for by included controls will result in endogenous variation in policy being viewed as exogenous shock to policy
Was 9/11 a Monetary Shock?

According to structural VARs: Yes!?!  
- Nothing had yet happened to controls in VAR  
- Drop in rates cannot be explained, therefore an exogenous shock  

In reality: Obviously not!  

Any unusual (from perspective of VAR) weakness in output growth after 9/11, perversely, attributed to exogenous easing of monetary policy  

Highly problematic
**NEWS SHOCKS AND VARs**

9/11 an example of a news shock

- Almost nothing happened to contemporaneous output
- But event contains news about future output
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Why not just include fast moving variables like stock/bond prices in interest rate equation to capture news?
News Shocks and VARs

- 9/11 an example of a news shock
  - Almost nothing happened to contemporaneous output
  - But event contains news about future output
- Why not just include fast moving variables like stock/bond prices in interest rate equation to capture news?
  - Only makes sense if these variables not affected by contemporary monetary policy
  - But that is clearly not the case
  - Post-treatment controls (endogenous or “bad” controls)
The identifying assumption in a monetary VAR often described as:
- Fed funds rate does not affect output, inflation, etc. contemporaneously

Seems like magic:
- You make one relatively innocuous assumption
- Violá: You can estimate dynamic causal effects of monetary policy
Identifying Assumptions in SVARs

- Timing assumption not only identifying assumption being made

- Timing assumption rules out reverse causality
  - Contemporaneous correlation assumed to go from output to interest rates
  - Not other way around

- Bigger concern: Omitted variables bias
  - Monetary policy and output may be reacting to some other shock
  - If not sufficiently proxied by included controls, this shock will cause omitted variables bias (e.g., 9/11)
Hopeless to control individually for everything in Feds information set

Alternative approach:
- Control for Fed’s own forecasts (Greenbook forecasts)

Key idea:
- Endogeneity of monetary policy comes from **one thing only**: What Fed thinks will happen to the economy
- Controlling for this is sufficient
Romer-Romer’s shock series addresses two problems:

1. Fed has imperfect control over fed funds rate
   - More of a problem before Greenspan era
   - Movements in FFR relative to FOMC target are endogenous
     (FFR rises relative to target in response to good news about future output)
   - Romer-Romer construct FFR target series
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     (FFR rises relative to target in response to good news about future output)
   - Romer-Romer construct FFR target series

2. Movements in FOMC’s FFR target are endogenous
   - “Anticipatory effects” important
     (e.g., Fed lowers rates in anticipation of economic weakness)
   - Use of Fed’s Greenbook forecasts control for such endogeneity
     (Greenbook typically prepared six days before meeting)
Romer-Romer’s specification:

\[
\Delta ff_m = \alpha + \beta ff_{bm} + \sum_{i=-1}^{2} \gamma_i \Delta \tilde{y}_{mi} + \sum_{i=-1}^{2} \lambda_i (\Delta \tilde{y}_{mi} - \Delta \tilde{y}_{m-1,i}) \\
+ \sum_{i=-1}^{2} \phi_i \tilde{\pi}_{mi} + \sum_{i=-1}^{2} \theta_i (\tilde{\pi}_{mi} - \tilde{\pi}_{m-1,i}) + \rho \tilde{u}_{m0} + \epsilon_m
\]

- \(\Delta ff_m\) change in intended FFR at meeting
- \(ff_{bm}\) level before meeting
- \(\tilde{y}, \tilde{\pi}, \tilde{u}\) forecasts of output, inflation, and unemployment
- Both forecasts and change in forecasts since last meeting included
Does this Make Sense?

- Residual $\epsilon_m$ considered exogenous monetary policy shock
- Does this make sense?
Residual $\epsilon_m$ considered exogenous monetary policy shock

Does this make sense?

Romer-Romer 04:

*It is important to note that the goal of this regression is not to estimate the Federal Reserve’s reaction function as well as possible. What we are trying to do is to purge the intended funds rate series of movements taken in response to useful information about future economic developments. Once we have accomplished this, it is desirable to leave in as much of the remaining variation as possible.*
Proposition 1: To measure the effects of monetary policy on output it is enough that the shock is orthogonal to output forecasts. The shock does not have to be orthogonal to price, exchange rate or other forecasts. It may be predictable from time t information; it does not have to be a shock to agent’s or the Fed’s entire information set.

(no proof provided)

All the shock has to do is remove the reverse causality from output forecasts.
Preferred specification for effects on output:

\[ \Delta f_{f_m} = \alpha + \sum_{i=-1}^{2} \gamma_i \Delta \tilde{y}_{mi} + \beta f_{f_{m-1}} + \delta \Delta f_{f_{m-1}} + \epsilon_{ym} \]

Preferred specification for effects on inflation:

\[ \Delta f_{f_m} = \alpha + \sum_{i=-1}^{2} \gamma_i \Delta \tilde{\pi}_{mi} + \beta f_{f_{m-1}} + \delta \Delta f_{f_{m-1}} + \epsilon_{\pi m} \]
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- Lagged FFR only included to make shocks serially uncorrelated, which simplifies interpretation
- No need to include other controls
- In fact, better not to, since this keeps more shocks
Fed does not roll dice

Every movement in intended fed funds rate is a response to something

Some are responses to something that directly affects outcome variable of interest
  These are endogenous

Reactions to anything else (exchange rate, political pressure, etc)
  * conditional on output forecast* count as a shock
What Are the Shocks?

1. Variation in Fed operating procedure important
   - E.g., emphasis on monetary quantities in 1979-1982

2. Variation in policy makers’ beliefs about workings of economy
   - In early 1970’s Fed believed inflation highly unresponsive to slack
     (Romer-Romer 02)

3. Variation in policy maker preferences/goals
   - E.g., time-varying distaste for inflation

4. Political influences
   - E.g., Arthur Burns set loose policy in 1977 to get re-appointed

5. Pursuit of other objectives
   - At some times, Fed concerned about exchange rate
Policy makers’ beliefs about the workings of the economy are another source of shocks. For example, in the early 1970s the prevailing framework at the Federal Reserve held that inflation was extremely unresponsive to economic slack (Romer and Romer, 2002). One would expect this belief to lead the Federal Reserve to set lower interest rates than it otherwise would have. And indeed, our shock series is generally negative in 1971 and 1972.

A third source of shocks are the Federal Reserve’s tastes and goals. A Federal Reserve that has a particular distaste for inflation, for example, is likely to set higher interest rates than it typically would. Our series shows obvious upward spikes in 1969, 1973–1974, and 1979–1982. These are three periods that we identified in previous work as times when the Federal Reserve decided that the current level of inflation was too high and that it was willing to endure output losses to reduce it (Romer and Romer, 1989). These policy shifts involved more than mere changes in tastes, and to a large extent reflected changes in the Federal Reserve’s understanding of the economy. Thus there is not a sharp distinction between shocks coming from the Federal Reserve’s beliefs and ones stemming from its tastes.

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Cochrane (2004) argues monetary shocks can be predictable.

Does this make sense?
Cochrane (2004) argues monetary shocks can be predictable. Does this make sense?

It does not in and of itself cause endogeneity concerns. It does complicate interpretation. Shocks can have effects both upon announcement and when they are implemented.

- Upon announcement: Yield curve will move
- Upon implementation: Short rates themselves move
Dynamic causal inference involves two steps:

1. Identifying exogenous variation in policy (the shocks)
2. Estimating an impulse response given the shocks

Three methods to construct impulse response:

1. Directly regress variable of interest on shock (Jorda 05)
2. Iterate forward VAR
3. Iterate forward univariate AR specification (Romer-Romer 04)
Simple approach: Regress variable of interest directly on shock: (perhaps including some pre-treatment controls)

\[ y_{t+j} - y_{t-1} = \alpha + \beta \nu_t + \Gamma X_{t-1} + \epsilon_t \]

- Variable of interest: \( y_{t+j} - y_{t-1} \)
- Monetary shock: \( \nu_t \)
- Pre-treatment controls: \( X_{t-1} \)

Separate regression for each horizon \( j \)
This imposes minimal structure (other than linearity)
Specification advocated by Jorda 05 (often called “local projection”)
Construct impulse response by iterating forward entire estimated VAR system

Embeds whole new set of strong identifying assumptions
- Not only interest rate equation that must be correctly specified
- Entire system must be correct representation of dynamics of all variables in the system
- i.e., whole model must be correctly specified (including number of shocks, number of lags, relevant variable observable)
- Recall earlier discussion of true VARMA(∞,∞) in observed variables being approximated by VAR(p)
- See discussion in Plagborg-Moller and Wolf 19
\[ \Delta y_t = a_0 + \sum_{k=1}^{11} a_k D_{kt} + \sum_{i=1}^{24} b_i \Delta y_{t-i} + \sum_{j=1}^{36} c_j S_{t-j} + \epsilon_t \]

- \( \Delta y_t \) monthly change in industrial production
- \( D_{kt} \) month dummies (they use seasonally unadjusted data)
- \( S_t \) monetary shocks
- Assume money doesn’t affect output contemporaneously
  (No contemporaneous monetary shock)
- Impulse response:
  - Effect on \( y_{t+1} \) is \( c_1 \)
  - Effect on \( y_{t+2} \) is \( c_1 + (c_2 + b_1 c_1) \)
Lagged Dependent Variables

\[ \Delta y_t = a_0 + \sum_{k=1}^{11} a_k D_{kt} + \sum_{i=1}^{24} b_i \Delta y_{t-i} + \sum_{j=1}^{36} c_j S_{t-j} + e_t \]

- Inclusion of lagged dependent variables may induce bias
- \(b_i\)s are estimated off of dynamics of output to all shocks
- If dynamics after monetary shocks are different, inclusion of lagged output terms will induce bias
Lagged Dependent Variables

\[ \Delta y_t = a_0 + \sum_{k=1}^{11} a_k D_{kt} + \sum_{i=1}^{24} b_i \Delta y_{t-i} + \sum_{j=1}^{36} c_j S_{t-j} + e_t \]

- Inclusion of lagged dependent variables may induce bias
- \( b_i \)'s are estimated off of dynamics of output to all shocks
- If dynamics after monetary shocks are different, inclusion of lagged output terms will induce bias
- Extreme example:
  - Two shocks: money and weather
  - Weather i.i.d. while money is persistent
  - Weather shocks induce negative autocorrelation in output
  - Estimated effects of monetary shocks will be affected by this
VAR Specification

Jorda Specification

Romer-Romer Specification

VAR Shocks

Romer-Romer Shocks

Black line: Industrial production. Blue line: Real interest rate

Nakamura-Steinsson (UC Berkeley)
VAR Specification

Jorda Specification

Romer-Romer Specification

VAR Shocks

Romer-Romer Shocks

Black line: CPI. Blue line: Nominal interest rate
High Frequency Identification
A substantial amount of monetary news is released at the end of each FOMC meeting.

Possible to use a “discontinuity” based identification approach.

Look at changes in interest rates during a narrow window around FOMC meeting.
  - One-day window or 30-minute window

Basic idea: Changes in interest rates at these times dominated by monetary announcement.
- Policy indicator: Change in fed funds rate target
- Variables of interest: Longer-term nominal rates
  (One-day windows, Sept 74 - Sept 79)
- Question: Can the Fed control *nominal* interest rates?
Table 3
The effect of funds rate target changes on market interest rates.\(^a\)

\[
\Delta R_t = b_1 + b_2 \Delta FF_t + u_t
\]

<table>
<thead>
<tr>
<th>(\Delta R_t)</th>
<th>(b_1)</th>
<th>(b_2)</th>
<th>(R^2)</th>
<th>(SER)</th>
<th>(DW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-month bill rate</td>
<td>0.016</td>
<td>0.554</td>
<td>0.47</td>
<td>0.13</td>
<td>1.89</td>
</tr>
<tr>
<td></td>
<td>(1.04)</td>
<td>(8.10)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-month bill rate</td>
<td>0.017</td>
<td>0.541</td>
<td>0.59</td>
<td>0.10</td>
<td>1.82</td>
</tr>
<tr>
<td></td>
<td>(1.44)</td>
<td>(10.25)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-month bill rate</td>
<td>0.024</td>
<td>0.500</td>
<td>0.56</td>
<td>0.10</td>
<td>1.94</td>
</tr>
<tr>
<td></td>
<td>(2.02)</td>
<td>(9.61)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-year bond rate</td>
<td>0.018</td>
<td>0.289</td>
<td>0.46</td>
<td>0.07</td>
<td>1.59</td>
</tr>
<tr>
<td></td>
<td>(2.16)</td>
<td>(7.87)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5-year bond rate</td>
<td>0.012</td>
<td>0.208</td>
<td>0.36</td>
<td>0.06</td>
<td>1.59</td>
</tr>
<tr>
<td></td>
<td>(1.66)</td>
<td>(6.43)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7-year bond rate</td>
<td>0.009</td>
<td>0.185</td>
<td>0.39</td>
<td>0.05</td>
<td>1.89</td>
</tr>
<tr>
<td></td>
<td>(1.47)</td>
<td>(6.78)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-year bond rate</td>
<td>0.012</td>
<td>0.131</td>
<td>0.32</td>
<td>0.04</td>
<td>1.94</td>
</tr>
<tr>
<td></td>
<td>(2.34)</td>
<td>(5.85)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-year bond rate</td>
<td>0.007</td>
<td>0.098</td>
<td>0.29</td>
<td>0.03</td>
<td>2.04</td>
</tr>
<tr>
<td></td>
<td>(1.73)</td>
<td>(5.46)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Includes 75 changes in the federal funds rate target from September 1974 through September 1979. Bill and bond rate changes are calculated over the day of the target changes. \(t\)-statistics are in parentheses.

\(^b\)Significant at the 1\% level, using a two-tailed test.

\(^c\)Significant at the 5\% level, using a two-tailed test.

Source: Cook and Hahn (1989).
100bp change in fed funds target moves 3M Tbill rate by only 55bp
Suggests that Fed can’t move nominal interest rates very effectively

Really?

What concern might arise with this approach?
100bp change in fed funds target moves 3M Tbill rate by only 55bp
Suggests that Fed can’t move nominal interest rates very effectively

Really?
What concern might arise with this approach?
Some changes in funds rate target might be anticipated
Policy indicator: Change in fed funds future for current month

Variables of interest: Longer-term nominal rates

(One-day window, June-89 - Feb-00)

Able to distinguish between anticipated and unanticipated movements in fed funds rate
Table 2
Actual, expected and unexpected changes in the Fed funds target

<table>
<thead>
<tr>
<th>Date</th>
<th>FOMC</th>
<th>Actual</th>
<th>Expected</th>
<th>Unexpected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>6/6</td>
<td>-25</td>
<td>-24</td>
<td>-1</td>
</tr>
<tr>
<td></td>
<td>7/7</td>
<td>-25</td>
<td>-22</td>
<td>-3</td>
</tr>
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<td>7/27</td>
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<td>0</td>
</tr>
<tr>
<td></td>
<td>10/18</td>
<td>-25</td>
<td>-25</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>11/6</td>
<td>-25</td>
<td>-29</td>
<td>+4</td>
</tr>
<tr>
<td></td>
<td>12/20</td>
<td>-25</td>
<td>-8</td>
<td>-17</td>
</tr>
<tr>
<td>1990</td>
<td>7/13</td>
<td>-25</td>
<td>-11</td>
<td>-14</td>
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<tr>
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<td>10/29</td>
<td>-25</td>
<td>+6</td>
<td>-31</td>
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<tr>
<td></td>
<td>11/14</td>
<td>-25</td>
<td>-29</td>
<td>+4</td>
</tr>
<tr>
<td></td>
<td>12/7</td>
<td>-25</td>
<td>+2</td>
<td>-27</td>
</tr>
<tr>
<td></td>
<td>12/18</td>
<td>-25</td>
<td>-4</td>
<td>-21</td>
</tr>
<tr>
<td>1991</td>
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<td>-18</td>
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<tr>
<td></td>
<td>2/1</td>
<td>-50</td>
<td>-25</td>
<td>-25</td>
</tr>
<tr>
<td></td>
<td>3/8</td>
<td>-25</td>
<td>-9</td>
<td>-16</td>
</tr>
<tr>
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<td>4/30</td>
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<td>-17</td>
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<td>9/13</td>
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<td>-5</td>
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<td></td>
<td>11/6</td>
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<td>-13</td>
<td>-12</td>
</tr>
<tr>
<td></td>
<td>12/6</td>
<td>-25</td>
<td>-16</td>
<td>-9</td>
</tr>
<tr>
<td></td>
<td>12/20</td>
<td>-50</td>
<td>-22</td>
<td>-28</td>
</tr>
<tr>
<td></td>
<td>7/2</td>
<td>-50</td>
<td>-14</td>
<td>-36</td>
</tr>
<tr>
<td></td>
<td>9/4</td>
<td>-25</td>
<td>-3</td>
<td>-22</td>
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<td>1994</td>
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<td>+25</td>
<td>+13</td>
<td>+12</td>
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<td></td>
<td>3/22</td>
<td>+25</td>
<td>+28</td>
<td>-3</td>
</tr>
<tr>
<td></td>
<td>4/18</td>
<td>+25</td>
<td>+15</td>
<td>+10</td>
</tr>
<tr>
<td></td>
<td>5/17</td>
<td>+50</td>
<td>+37</td>
<td>+13</td>
</tr>
</tbody>
</table>

Source: Kuttner (2001)
More recently, the 15 October 1998 rate cut is the only action since 1996 to have contained a large element of surprise.

### 3.3. Results

Having used the futures rates to distinguish between anticipated and unanticipated changes in the funds rate target, the natural question to ask is whether the responses of bill and bond rates to the two components differ or indeed whether rates respond at all to predictable actions. This can be done within the Cook and Hahn-style analysis by regressing the change in the interest rate on the two components of the target rate change:

$$
D R_t = a + b_1 D^* re_t + b_2 D^* ru_t + e_t; \tag{8}
$$

where again represents in turn the yields on 3-, 6- and 12-month bills, 2-, 5- and 10-year notes, and 30-year bonds.

The regression results appear in Table 3. As expected, the coefficients on the expected and surprise components are very different: the response to the unanticipated piece is large and highly significant, while the response to the anticipated piece is small, and statistically insignificant. For each maturity, a Wald test of the $b_1 = b_2$ restriction rejects the hypothesis of equal responses at the 0.05 level or better.

### Table 3

The 1-day response of interest rates to the Fed funds surprises$^a$

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

$^a$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.

Source: Kuttner (2001). Responses in basis points to 100 basis point change.
The coefficients describing interest rates' reaction to target rate changes in the post-1989 period are uniformly smaller and less significant than those for the 1975–1979 sample. The estimated responses of 3- and 6-month bill rates are 27 and 22 basis points, respectively, compared with 55 and 54 basis points in Cook and Hahn. The results are weaker at the long end of the yield curve as well, with essentially no response by the 30-year yield. By contrast, Cook and Hahn reported a statistically significant 10 basis point response for the 20-year bond, the longest-maturity Treasury bond at the time. In a regression pooling the post-1989 and Cook–Hahn data, the hypothesis of equal coefficients in the two subsamples can be rejected at 0.05 level for the 3- and 6-month bills.

One possible explanation for the lack of statistical significance is simply the smaller number of observations. This cannot explain the smaller magnitude of the response, however. Another possibility is that traders were not aware of the policy actions. This is implausible, however, as Fed actions have generally become more transparent since the period studied by Cook and Hahn. A more likely explanation is that target rate changes have been more widely anticipated in recent years. Bond yields set in forward-looking markets should

Table 1

The 1-day response of interest rates to changes in the Fed funds target

<table>
<thead>
<tr>
<th>Maturity</th>
<th>Intercept</th>
<th>Response</th>
<th>$R^2$</th>
<th>SE</th>
<th>DW</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 month</td>
<td>−3.6 (2.3)</td>
<td>26.8 (5.4)</td>
<td>0.42</td>
<td>9.8</td>
<td>2.04</td>
</tr>
<tr>
<td>6 month</td>
<td>−5.2 (3.6)</td>
<td>21.9 (4.6)</td>
<td>0.37</td>
<td>9.0</td>
<td>2.04</td>
</tr>
<tr>
<td>12 month</td>
<td>−5.1 (3.3)</td>
<td>19.8 (4.1)</td>
<td>0.29</td>
<td>9.5</td>
<td>2.07</td>
</tr>
<tr>
<td>2 year</td>
<td>−5.2 (3.4)</td>
<td>18.2 (3.7)</td>
<td>0.26</td>
<td>9.6</td>
<td>2.28</td>
</tr>
<tr>
<td>5 year</td>
<td>−4.5 (2.9)</td>
<td>10.4 (2.1)</td>
<td>0.10</td>
<td>9.8</td>
<td>2.40</td>
</tr>
<tr>
<td>10 year</td>
<td>−4.0 (2.9)</td>
<td>4.3 (1.0)</td>
<td>0.02</td>
<td>8.5</td>
<td>2.50</td>
</tr>
<tr>
<td>30 year</td>
<td>−3.6 (3.2)</td>
<td>0.1 (0.0)</td>
<td>0.00</td>
<td>6.9</td>
<td>2.47</td>
</tr>
</tbody>
</table>

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.

Source: Kuttner (2001). Responses in basis points to 100 basis point change.
Crucial to distinguish between anticipated and unanticipated movements in fed funds rate

Increasingly important in an era of greater monetary policy transparency
(where markets anticipate much of the monetary policy action)
FOMC Meeting on January 28, 2004:

- No change in Fed Funds Rate, fully anticipated
- Unexpected change in Fed Funds Rate: -1 bp
- Kuttner’s monetary shock indicator implies essentially no shock
FOMC Meeting on January 28, 2004:

- No change in Fed Funds Rate, fully anticipated
- Unexpected change in Fed Funds Rate: -1 bp
- Kuttner’s monetary shock indicator implies essentially no shock
- However, FOMC statement dropped the phrase:
  “policy accommodation can be maintained for a considerable period”
- Two- and five-year yields jumped 20-25 bp
  (largest movements around an FOMC announcement for years)
January 28, 2004 FOMC meeting example of forward guidance

Forward guidance: Statements by central bank meant to manage market expectations about what it is going to do in the future.
January 28, 2004 FOMC meeting example of forward guidance

Forward guidance: Statements by central bank meant to manage market expectations about what it is going to do in the future

Has become a major part of how monetary policy is conducted (especially at zero lower bound)

Implies that unexpected changes in fed funds rate are poor indicator for size monetary shock

- In past 15 years, Fed has usually managed expectations to the point that there is no surprise about action at meeting
- Main news about adjustments to language in post-meeting statement containing information about future moves
Consider changes in 5 fed funds and eurodollar futures:

- Fed Funds future for current month (scaled)
- Fed Funds future for month of next FOMC meeting (scaled)
- 3-month Eurodollar futures at horizons of 2Q, 3Q, 4Q

These span first year of term structure
Consider changes in 5 fed funds and eurodollar futures:

- Fed Funds future for current month (scaled)
- Fed Funds future for month of next FOMC meeting (scaled)
- 3-month Eurodollar futures at horizons of 2Q, 3Q, 4Q

These span first year of term structure

They then ask: Are effects of monetary policy announcements adequately characterized by a single factor? (i.e., unexpected changes in current fed funds rate)
GSS 05 perform principle component analysis on the 5 fed funds and eurodollar futures.

Two factors needed to characterize effect of FOMC announcements:

- Target factor (unexpected changes in current fed funds rate)
- Path factor (changes in future rates orthogonal to changes in current rate)
GSS 05 perform principle component analysis on the 5 fed funds and eurodollar futures.

Two factors needed to characterize effect of FOMC announcements:
- Target factor (unexpected changes in current fed funds rate)
- Path factor (changes in future rates orthogonal to changes in current rate)

Bulk of response of longer-term rates is to path factor.
Table 5. Response of Asset Prices to Target and Path Factors

<table>
<thead>
<tr>
<th></th>
<th>One Factor</th>
<th>Two Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Constant (std. err.)</td>
<td>Target Factor (std. err.)</td>
</tr>
<tr>
<td><strong>MP Surprise</strong></td>
<td>$-0.021^{***}$ (0.003)</td>
<td>$1.000^{***}$ (0.047)</td>
</tr>
<tr>
<td><strong>One-Year-Ahead Eurodollar Future</strong></td>
<td>$-0.018^{***}$ (0.006)</td>
<td>$0.555^{***}$ (0.076)</td>
</tr>
<tr>
<td><strong>S&amp;P 500</strong></td>
<td>$-0.008$ (0.041)</td>
<td>$-4.283^{***}$ (1.083)</td>
</tr>
<tr>
<td><strong>Two-Year Note</strong></td>
<td>$-0.011^{**}$ (0.005)</td>
<td>$0.485^{***}$ (0.080)</td>
</tr>
<tr>
<td><strong>Five-Year Note</strong></td>
<td>$-0.006$ (0.005)</td>
<td>$0.279^{***}$ (0.078)</td>
</tr>
<tr>
<td><strong>Ten-Year Note</strong></td>
<td>$-0.004$ (0.004)</td>
<td>$0.130^{**}$ (0.059)</td>
</tr>
<tr>
<td><strong>Five-Year Forward Rate Five Years Ahead</strong></td>
<td>$0.001$ (0.003)</td>
<td>$-0.098^{**}$ (0.049)</td>
</tr>
</tbody>
</table>

Note: Sample is all monetary policy announcements from July 1991–December 2004 (January 1990–December 2004 for S&P 500). Target factor and path factor are defined in the main text. Heteroskedasticity-consistent standard errors reported in parentheses. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively. See text for details.

Table 4. Ten Largest Observations of the Path Factor

<table>
<thead>
<tr>
<th>Date</th>
<th>$Z_1$ (Target Factor)</th>
<th>$Z_2$ (Path Factor)</th>
<th>Statement</th>
<th>Financial Market Commentary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan. 28, 2004</td>
<td>-1.1</td>
<td>42.7</td>
<td>√</td>
<td>Statement drops commitment to keep policy unchanged for “a considerable period,” bringing forward expectations of future tightenings</td>
</tr>
<tr>
<td>Jul. 6, 1995</td>
<td>-8.7</td>
<td>-38.4</td>
<td>√</td>
<td>First easing after long (seventeen-month) series of tightenings raises expectations of further easings; statement notes that inflationary pressures have receded</td>
</tr>
<tr>
<td>Aug. 13, 2002</td>
<td>8.1</td>
<td>-37.2</td>
<td>√</td>
<td>Statement announces balance of risks has shifted from neutral to economic weakness</td>
</tr>
<tr>
<td>May 18, 1999</td>
<td>0.5</td>
<td>32.8</td>
<td>√</td>
<td>Statement announces change in policy bias going forward from neutral to tightening</td>
</tr>
<tr>
<td>May 6, 2003</td>
<td>5.2</td>
<td>-27.0</td>
<td>√</td>
<td>Statement announces balance of risks now dominated by risk of “an unwelcome substantial fall in inflation”</td>
</tr>
<tr>
<td>Dec. 20, 1994</td>
<td>-15.1</td>
<td>26.6</td>
<td></td>
<td>Surprise that FOMC not tightening considering recent comments by Blinder on “overshooting”; some fear Fed may have to tighten more in 1995 as a result</td>
</tr>
<tr>
<td>Oct. 5, 1999</td>
<td>-2.7</td>
<td>25.8</td>
<td>√</td>
<td>Statement announces change in policy bias going forward from neutral to tightening</td>
</tr>
<tr>
<td>Oct. 28, 2003</td>
<td>3.9</td>
<td>-24.4</td>
<td>√</td>
<td>Statement leaves the “considerable period” commitment unchanged, pushing back expectations of future tightenings</td>
</tr>
<tr>
<td>Jan. 3, 2001</td>
<td>-32.3</td>
<td>22.8</td>
<td>√</td>
<td>Large surprise intermeeting ease reportedly causes financial markets to mark down probability of a recession; Fed is perceived as being “ahead of the curve” and as needing to ease less down the road as a result</td>
</tr>
<tr>
<td>Oct. 15, 1998</td>
<td>-24.0</td>
<td>-22.6</td>
<td>√</td>
<td>First intermeeting move since 1994 and statement pointing to “unsettled conditions in financial markets... restraining aggregate demand” increases expectations of further easings</td>
</tr>
</tbody>
</table>

Source: Gurkaynak-Sack-Swanson (2005)
1. If there are other shocks during window:
   - Policy indicator will be contaminated by these shocks because Fed may respond (now or in the future)
   - These same shocks may directly affect future variables
   - No longer estimating a causal effect of monetary shocks

2. If entire response of interest rates doesn’t occur in narrow window:
   - Estimate of monetary shock biased because shock size biased
   - Might be over-reaction or under-reaction

Key Question: How long should the window be?
Figure 1. Intraday Trading in Federal Funds Futures Contracts

(a) June 25, 2003 (July 2003 Contract)

(b) April 9, 1992 (April 1992 Contract)

(c) September 4, 1992 (September 1992 Contract)

Source: Gurkaynak-Sack-Swanson (2005)
The Power Problem

- HFI arguably the cleanest way to identify monetary shocks
  ... but shocks are small and sample short
- Regressions on future output very imprecise
  (Cochrane-Piazzesi 02, Angrist-Jorda-Kuersteiner 17)
- Angrist-Jorda-Kuersteiner 17
  - Policy indicator: unexpected fed funds target changes
  - Window: one-day (although slightly unusual methods)
  - Outcome variable: inflation, industrial production
  - Allow for different effects of increases and decreases
4.1 Other Empirical Comparisons

In an influential study of the effects of monetary policy shocks on the yield curve and macro variables, Cochrane and Piazzesi (2002) reported estimates of policy effects on the yield curve similar to ours. On the other hand, their results show little effect of policy changes on prices, while suggesting employment increases after a rate increase. The yield curve effects reported here are stronger than the VAR-based responses reported in Christiano, Eichenbaum, and Evans (1996, 1999).

Faust, Swanson, and Wright (2004) used policy-induced changes in federal funds futures prices to quantify policy shocks. Their VAR-based estimates of the effect of a positive 25 basis point surprise show price decreases similar to those reported here. The corresponding estimated effects on output line up less well, however, with a mixture of positive and negative effects. In contemporaneous work related to ours, Tenreyro and Thwaites (2013) identified monetary policy effects using the events isolated by Romer and Romer (2004), highlighting differences in policy effectiveness in expansions and recessions. They find that Romer shocks appear to be more effective in the former than the latter.

As a theoretical matter, macro models with nominal rigidities, information asymmetries, menu costs, or lending constraints typically imply asymmetric responses to monetary policy interventions. For example, Cover (1992) and DeLong and Summers (1988) argue that contractionary monetary policy affects real variables more than expansionary policy. Using international data, Karras (1996) find strong evidence of asymmetry in the effects of monetary policy on output using European data. These papers are consistent with Keynes’ (1936) observations on the role of sticky wages in business cycles (see Ravn and Sola 2004 for a recent review of the relevant history of thought in this context).

Why are effects on output and inflation so imprecise?

- Shocks are small: High frequency method leaves out lots of shocks (perhaps vast majority)
  - All news about monetary policy on non-FOMC days not captured
- Sample period is short (only back to late 1980’s)
- Outcomes are noisy
  - Many other shocks affect output and inflation over a 1 year horizon
Potential solution:

- Focus on outcome variables that move **contemporaneously**
  - e.g., real yields and forwards (from TIPS)
  - (Hanson-Stein 15, Nakamura-Steinsson 18)
- Essentially a discontinuity based identification strategy
Policy indicator: Policy news shock

- First principle component of change in GSS 05’s 5 interest rate futures over narrow window around scheduled FOMC announcements
- Similar to GSS 05 path factor, but simpler (no 2nd factor)

Variables of interest: Nominal and real yields and forward rates

(30-minute window, 2000-2014)
<table>
<thead>
<tr>
<th></th>
<th>Nominal</th>
<th>Real</th>
<th>Inflation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2Y Treasury Yield</td>
<td>1.10</td>
<td>1.06</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>(0.33)</td>
<td>(0.24)</td>
<td>(0.18)</td>
</tr>
<tr>
<td>5Y Treasury Yield</td>
<td>0.73</td>
<td>0.64</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>(0.20)</td>
<td>(0.15)</td>
<td>(0.11)</td>
</tr>
<tr>
<td>10Y Treasury Yield</td>
<td>0.38</td>
<td>0.44</td>
<td>-0.06</td>
</tr>
<tr>
<td></td>
<td>(0.17)</td>
<td>(0.13)</td>
<td>(0.08)</td>
</tr>
<tr>
<td>2Y Treasury Inst. Forward Rate</td>
<td>1.14</td>
<td>0.99</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>(0.46)</td>
<td>(0.29)</td>
<td>(0.23)</td>
</tr>
<tr>
<td>3Y Treasury Inst. Forward Rate</td>
<td>0.82</td>
<td>0.88</td>
<td>-0.06</td>
</tr>
<tr>
<td></td>
<td>(0.43)</td>
<td>(0.32)</td>
<td>(0.15)</td>
</tr>
<tr>
<td>5Y Treasury Inst. Forward Rate</td>
<td>0.26</td>
<td>0.47</td>
<td>-0.21</td>
</tr>
<tr>
<td></td>
<td>(0.19)</td>
<td>(0.17)</td>
<td>(0.08)</td>
</tr>
<tr>
<td>10Y Treasury Inst. Forward Rate</td>
<td>-0.08</td>
<td>0.12</td>
<td>-0.20</td>
</tr>
<tr>
<td></td>
<td>(0.18)</td>
<td>(0.12)</td>
<td>(0.09)</td>
</tr>
</tbody>
</table>

Main take-away:

- Nominal and real rates move one-for-one several years out into term structure
- Response of break-even inflation is delayed and small

Challenges:

- Background noise
- Risk Premia
- Fed information effects