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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Consensus within mainstream U.S. media that effects are large
No consensus in many other countries
Much controversy in academia
(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)
Given central importance, how can we not already know?
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- 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
Endogeneity of Monetary Policy

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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 \( \Delta i_t \))
What Is the Best Evidence We Have?

When we ask prominent macroeconomists, most common answers are:\(^1\)

- Friedman and Schwartz 63
- Volcker disinflation
- Mussa 86

Any mention of VARs and evidence from other modern econometric methods is conspicuous by its absence

\(^1\)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.”
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)
Changes in exchange rates and industrial production, 1929–1935

Figure 1

Changes in exchange rates and industrial production, 1929–1935

Source: Eichengreen and Sachs (1985)
Volcker Disinflation

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
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 tomorrow
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)
HIGH-FREQUENCY EVIDENCE ON OUTPUT?

- 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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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
Narrative Evidence – Romer-Romer 89

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-Schwartz 63)
Romer-Romer 89 Dates

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 A.1: Romer-Romer Dates and Oil-Shock Dates

<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></td>
<td>June 1953</td>
</tr>
<tr>
<td>September 1955</td>
<td>June 1956</td>
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<td></td>
<td>February 1957</td>
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<tr>
<td>December 1968</td>
<td>March 1969</td>
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<td></td>
<td>December 1970</td>
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<tr>
<td>April 1974</td>
<td>January 1974</td>
</tr>
<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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<td></td>
<td>February 1981</td>
</tr>
<tr>
<td></td>
<td>January 1987</td>
</tr>
<tr>
<td>December 1988</td>
<td>December 1988</td>
</tr>
<tr>
<td></td>
<td>August 1990</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:

(state space representation)

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

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
\[ \begin{align*}
\pi_t &= E_t \pi_{t+1} + \kappa (y_t - y^n_t) \\
y_t &= E_t y_{t+1} - \sigma (i_t - E_t \pi_{t+1} - r^n_t) \\
i_t &= \phi_\pi \pi_t + \phi_y y_t + \nu_t
\end{align*} \]
EXAMPLE: NEW KEYNESIAN MODEL

\[\pi_t = E_t\pi_{t+1} + \kappa(y_t - y_t^n)\]

\[y_t = E_t y_{t+1} - \sigma(i_t - E_t\pi_{t+1} - r_t^n)\]

\[i_t = \phi_\pi \pi_t + \phi_y y_t + \nu_t\]

Some manipulation yields:

\[\pi_{t+1} = \pi_t - \kappa y_t + \kappa y_t^n + \eta_{\pi,t+1}\]

\[y_{t+1} + \sigma \pi_{t+1} = y_t + \sigma i_t - \sigma r_t^n + \eta_y,t+1 + \sigma \eta_{\pi,t+1}\]

\[i_{t+1} - \phi_\pi \pi_{t+1} - \phi_y y_{t+1} = \nu_{t+1}\]

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**

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

- 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:

$$Y_t = G^t Y_{-1} + G^{t-1} R\epsilon_0$$

Suppose for simplicity that we start off in a steady state $Y_{-1} = 0$:

$$Y_t = G^{t-1} R\epsilon_0$$

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. 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)
2. Some variables in true VAR may be unobservable
   - In NK model example, \((y^n_t, r^n_t, \text{and } \nu_t)\) 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)
   - Appendix to Nakamura and Steinsson (2018, JEP) contains a problem set that is helpful for thinking through these issues

\[ Y_t = GY_{t-1} + R\epsilon_t \]
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” \( (\epsilon_t \text{ correlated with } (\pi_t, y_t)) \)
   - 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
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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  - 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?
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
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
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:

\[ \Delta ff_m = \alpha + \sum_{i=-1}^{2} \gamma_i \Delta \tilde{y}_{mi} + \beta ff_{m-1} + \delta \Delta ff_{m-1} + \epsilon^y_m \]

Preferred specification for effects on inflation:

\[ \Delta ff_m = \alpha + \sum_{i=-1}^{2} \gamma_i \Delta \tilde{\pi}_{mi} + \beta ff_{m-1} + \delta \Delta ff_{m-1} + \epsilon^\pi_m \]
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- Lagged FFR only included to make shocks serially uncorrelated, which simplifies interpretation
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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
What Do We Do with These Shocks?

- 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”)
VAR Impulse Responses

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

- \( \Delta y_t \) 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
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

Romer-Romer Specification

VAR Shocks

Romer-Romer Shocks

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

Jorda Specification

Romer-Romer Specification

VAR Shocks

Romer-Romer Shocks

Black line: CPI. Blue line: Nominal interest rate
HIGH FREQUENCY IDENTIFICATION AND THE INFORMATION EFFECT

Jon Steinsson

UC Berkeley

January 2020
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

Sample period: Sept 74 - Sept 79

Window length: 1 day

Question: Can the Fed control *nominal* interest rates?
Table 3
The effect of funds rate target changes on market interest rates.a

<table>
<thead>
<tr>
<th>ΔR_t</th>
<th>b1</th>
<th>b2</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)b</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)b</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)c</td>
<td>(9.61)b</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)c</td>
<td>(7.87)b</td>
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<td></td>
</tr>
<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>
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<tr>
<td></td>
<td>(1.66)</td>
<td>(6.43)b</td>
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<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>
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<tr>
<td></td>
<td>(1.47)</td>
<td>(6.78)b</td>
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<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)c</td>
<td>(5.85)b</td>
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<td></td>
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<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)b</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*aIncludes 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.

bSignificant at the 1% level, using a two-tailed test.

cSignificant 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
Fed funds target and 1 month Eurodollar rate in 2001. * indicates move at unscheduled meeting of FOMC
Policy indicator: Change in fed funds future for current month

Variables of interest: Longer-term nominal rates

Sample period: June-89 - Feb-00

Window length: 1-day

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></td>
<td>-25</td>
<td>-24</td>
</tr>
<tr>
<td></td>
<td>7/7</td>
<td></td>
<td>-25</td>
<td>-22</td>
</tr>
<tr>
<td></td>
<td>7/27</td>
<td></td>
<td>-25</td>
<td>-25</td>
</tr>
<tr>
<td></td>
<td>10/18</td>
<td></td>
<td>-25</td>
<td>-25</td>
</tr>
<tr>
<td></td>
<td>11/6</td>
<td></td>
<td>-25</td>
<td>-29</td>
</tr>
<tr>
<td></td>
<td>12/20</td>
<td></td>
<td>-25</td>
<td>-8</td>
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<tr>
<td>1990</td>
<td>7/13</td>
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<td>-25</td>
<td>-11</td>
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<td>10/29</td>
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<td>-25</td>
<td>+6</td>
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<td>11/14</td>
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<td>-29</td>
</tr>
<tr>
<td></td>
<td>12/7</td>
<td></td>
<td>-25</td>
<td>+2</td>
</tr>
<tr>
<td></td>
<td>12/18</td>
<td></td>
<td>-25</td>
<td>-4</td>
</tr>
<tr>
<td>1991</td>
<td>1/8</td>
<td></td>
<td>-25</td>
<td>-7</td>
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<td></td>
<td>2/1</td>
<td></td>
<td>-50</td>
<td>-25</td>
</tr>
<tr>
<td></td>
<td>3/8</td>
<td></td>
<td>-25</td>
<td>-9</td>
</tr>
<tr>
<td></td>
<td>4/30</td>
<td></td>
<td>-25</td>
<td>-8</td>
</tr>
<tr>
<td></td>
<td>8/6</td>
<td></td>
<td>-25</td>
<td>-10</td>
</tr>
<tr>
<td></td>
<td>9/13</td>
<td></td>
<td>-25</td>
<td>-20</td>
</tr>
<tr>
<td></td>
<td>10/31</td>
<td></td>
<td>-25</td>
<td>-20</td>
</tr>
<tr>
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<td>11/6</td>
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<td>-25</td>
<td>-13</td>
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<tr>
<td></td>
<td>12/6</td>
<td></td>
<td>-25</td>
<td>-16</td>
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<td>12/20</td>
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<td>-22</td>
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<td>7/2</td>
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<td>-14</td>
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<td>1994</td>
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<td>+25</td>
<td>+13</td>
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<td>+25</td>
<td>+13</td>
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<td>4/18</td>
<td></td>
<td>+25</td>
<td>+15</td>
</tr>
<tr>
<td></td>
<td>5/17</td>
<td></td>
<td>+50</td>
<td>+37</td>
</tr>
</tbody>
</table>

Source: Kuttner (2001)
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 target rate, with the first on 6 June 1989, and the last on 2 February 2000. The bill rate data are secondary market yields from the Federal Reserve H.15 release. The note and bond data are the yields of on-the-run Treasuries, obtained from Bloomberg.

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 targeta

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

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.

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)
Forward Guidance

- Early literature focused on change in current fed funds rate
- Central banks use statements to guide expectations about future policy
- Monetary policy shocks no longer unidimensional
- Actually potentially very high dimensional:
  - Some shocks affect short run but not long run
  - Others affect all horizons (level shock)
  - Yet others affect only long term rates (e.g. at ZLB)
- In standard models, these different types of shocks have very different effects!!
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

Has become a major part of how monetary policy is conducted over the past two decades

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>
<thead>
<tr>
<th></th>
<th>One Factor</th>
<th>Two Factors</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Constant (std. err.)</td>
<td>Target Factor (std. err.)</td>
<td>R²</td>
</tr>
<tr>
<td><strong>MP Surprise</strong></td>
<td>−0.021*** (0.003)</td>
<td>1.000*** (0.047)</td>
<td>.91</td>
</tr>
<tr>
<td><strong>One-Year-Ahead Eurodollar Future</strong></td>
<td>−0.018*** (0.006)</td>
<td>0.555*** (0.076)</td>
<td>.36</td>
</tr>
<tr>
<td><strong>S&amp;P 500</strong></td>
<td>−0.008 (0.041)</td>
<td>−4.283*** (1.083)</td>
<td>.37</td>
</tr>
<tr>
<td><strong>Two-Year Note</strong></td>
<td>−0.011** (0.005)</td>
<td>0.485*** (0.080)</td>
<td>.41</td>
</tr>
<tr>
<td><strong>Five-Year Note</strong></td>
<td>−0.006 (0.005)</td>
<td>0.279*** (0.078)</td>
<td>.19</td>
</tr>
<tr>
<td><strong>Ten-Year Note</strong></td>
<td>−0.004 (0.004)</td>
<td>0.130** (0.059)</td>
<td>.08</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>
<td>.06</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>Z₁ (Target Factor)</th>
<th>Z₂ (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)
THREATS TO IDENTIFICATION

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)
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
Figure 4. Estimated effects of target rate changes on macrovariables. These estimates use data from August 1989 through July 2007, and the propensity score mode labeled OP\(_F\) in Table 1. Dashed lines indicate 90% confidence bands.

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 Sola2004 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:

- Combine HFI with VAR
  - Gertler and Karadi (2015) do this
  - Called VAR with external instruments
    (Stock-Watson 12, Mertens-Ravn 13)

- How does this help?
  - Makes much stronger (VAR) assumptions about dynamics of the system
  - This yields tighter estimates of impulse responses
Primary interest: Effects of monetary policy on credit spreads
Primary interest: Effects of monetary policy on credit spreads

Cholesky timing assumptions not well suited for this

Must assume either:

- MP indicator ordered ahead of credit spread
  (i.e., MP doesn’t respond contemporaneously to credit spread)
- Credit spread ordered ahead of MP indicator
  (i.e., credit spread does not respond contemporaneously to MP)
Neither assumption palatable
- Both MP indicator and credit spreads “fast moving” variables
  - Hard to know which direction of causation explains contemporaneous correlation
Neither assumption palatable

Both MP indicator and credit spreads “fast moving” variables
  Hard to know which direction of causation explains contemporaneous correlation

Gertler-Karadi (2015):
  Shocks: “external instrument” identified using high frequency identification
  Impulse response: iterate a VAR
Estimate dynamics of system using a VAR:

\[ Y_t = \sum_{j=1}^{p} B_j Y_{t-j} + u_t \]

where \( B_j \) and \( u_t \) are estimated using OLS.
Estimate dynamics of system using a VAR:

$$Y_t = \sum_{j=1}^{p} B_j Y_{t-j} + u_t$$

where $B_j$ and $u_t$ are estimated using OLS.

Use HFI to get contemporaneous response of $Y_t$ to monetary shocks:
- Find a proxy $Z_t$ for monetary shocks
- Regress $u_t$ on $Z_t$

Iterate forward VAR dynamics to construct impulse response.
Data frequency: Monthly

Sample period for VAR: 1979:7-2012:6

Number of lags: 12

Simple VAR:

1. log industrial production
2. log CPI
3. 1Y nominal government yield (policy indicator)
4. Gilchrist-Zakrajsek 12 measure of credit spread

Baseline VAR: add additional indicators of credit costs and interest rates
• External instrument: Fed funds future 3 months ahead (FF4)
• Event window for instruments: 30 minutes
• Sample period for instruments: 1991:1-2012:6
We begin with the external instruments case. As noted earlier, we use the three-month ahead funds rate future surprise \( FF_4 \) to identify monetary policy shock. As a check to ensure that this instrument is valid, we report the \( F \)-statistic from the first-stage regression of the one-year bond rate residual on \( FF_4 \). We find an \( F \)-value of 21.55 and half. We also compute a robust \( F \)-statistic (which allows for heteroskedasticity) of 17.64. Both values are safely above the threshold suggested by Stock et al. (2002) to rule out a reasonable likelihood of a weak instruments problem.

As the top left panel shows, a one standard deviation surprise monetary tightening induces a roughly 25 basis point increase in the one-year government bond rate. Consistent with conventional theory, there is a significant decline in industrial production that reaches a trough roughly a year and a half after the shock. Similarly consistent with standard theory, there is a small decline in the consumer price index that is not statistically significant. Note that in contrast to the Cholesky identification, we do not impose zero restrictions on the contemporaneous responses of output and inflation. The identification of the monetary policy shock is entirely due to the external instrument.

The first-stage regression is incorporated in the reported confidence bands, because both stages of the estimation are included in the bootstrapping procedure. Thereby, we avoid any potential "generated regressor" problem.

\[
\begin{align*}
\text{First-stage regression:} \\
& F: 21.55; \text{Robust } F: 17.64; \text{ } R^2: 7.76 \text{ percent; Adjusted } R^2: 7.40 \text{ percent}
\end{align*}
\]

**Figure 1. One-Year Rate Shock with Excess Bond Premium**

Source: Gertler-Karadi (2015)
Cholesky VAR vs. HFI-VAR

Cholesky timing assumptions:

- Policy indicator ordered second to last (with GZ spread last)
  - Assumption: MP does not respond to GZ contemporaneously, but GZ does respond to MP

Price Puzzle:
CPI and IP move in the “wrong” direction
GZ falls in response to positive MP shock
Gertler-Karadi argue that these are signs of misspecification:
Low GZ is sign of strong economy

Identification based on HF external instruments:
Impulse responses much more reasonable
Cholesky VAR vs. HFI-VAR

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  - Gertler-Karadi argue that these are signs of misspecification:
    Low GZ is sign of strong economy

Identification based on HF external instruments:

- Impulse responses much more reasonable
THE POWER PROBLEM

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
Movements in real rates are the key empirical issue in monetary economics:

- Real rates affect output in all models (RBC and NK)
- Persistent movements in real rates is distinguishing feature of New Keynesian models
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

Sample period: 2000-2014

Window length: 30-minute window
### TABLE 1
Response of Interest Rates and Inflation to the Policy News Shock

<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
Much of literature uses 1-day or even 2-day event windows

Implicit assumption: No other shocks affect policy indicator over this event window
Much of literature uses 1-day or even 2-day event windows

Implicit assumption: No other shocks affect policy indicator over this event window

Perhaps OK when using target factor

Less likely to be OK when using longer term yields as policy indicator
  1 and 2 year yields vary substantially on non-FOMC days
  Presumably also vary for other reasons from FOMC announcement on FOMC days
Much of literature uses 1-day or even 2-day event windows

Implicit assumption: No other shocks affect policy indicator over this event window

Perhaps OK when using target factor

Less likely to be OK when using longer term yields as policy indicator
  - 1 and 2 year yields vary substantially on non-FOMC days
  - Presumably also vary for other reasons from FOMC announcement on FOMC days

How can we tell whether 1-day window OK?
Identification by Heteroskedasticity

Policy news shock ($\Delta i_t$) and other variables of interest ($\Delta s_t$) affected by monetary shock ($\epsilon_t$) and other shocks ($\eta_t$)

\[
\Delta i_t = \alpha_i + \epsilon_t + \eta_t
\]

\[
\Delta s_t = \alpha_s + \gamma \epsilon_t + \beta_s \eta_t
\]

Two regimes:
- “Treatment” sample: FOMC announcements (R1)
- “Control” sample: Other 30-minute/1-day windows (R2)

Identification assumption:

\[
\sigma_{\epsilon,R1} > \sigma_{\epsilon,R2} \quad \text{while} \quad \sigma_{\eta,R1} = \sigma_{\eta,R2}
\]
### TABLE 2
Allowing For Background Noise in Interest Rates

<table>
<thead>
<tr>
<th></th>
<th>10-Year Forward Nominal</th>
<th>Real</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Policy News Shock, 30-Minute Window:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OLS</td>
<td>-0.08</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>[-0.43, 0.28]</td>
<td>[-0.12, 0.36]</td>
</tr>
<tr>
<td>Rigobon</td>
<td>-0.12</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>[-0.46, 0.24]</td>
<td>[-0.13, 0.35]</td>
</tr>
<tr>
<td><strong>Policy News Shock, 1-Day Window:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OLS</td>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>[-0.20, 0.29]</td>
<td>[-0.10, 0.39]</td>
</tr>
<tr>
<td>Rigobon</td>
<td>-0.51</td>
<td>-0.04</td>
</tr>
<tr>
<td></td>
<td>[-1.93, -0.08]</td>
<td>[-0.51, 0.45]</td>
</tr>
<tr>
<td><strong>2-Year Nominal Yield, 1-Day Window</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OLS</td>
<td>0.18</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>[0.01, 0.35]</td>
<td>[0.02, 0.38]</td>
</tr>
<tr>
<td>Rigobon (90% CI)</td>
<td>-0.79</td>
<td>-0.08</td>
</tr>
<tr>
<td></td>
<td>[-10.00, -0.21]</td>
<td>[-4.57, 0.38]</td>
</tr>
</tbody>
</table>

Source: Nakamura-Steinsson (2018)
Result:

- Monetary news leads to large and persistent change in real interest rates but small change in expected inflation
Interpreting the Results

Result:
- Monetary news leads to large and persistent change in real interest rates but small change in expected inflation

Conventional interpretation:
- Prices must be very sticky. World very “Keynesian”
Result:

- Monetary news leads to large and persistent change in real interest rates but small change in expected inflation

Conventional interpretation:

- Prices must be very sticky. World very “Keynesian”

Additional prediction:

- Expected output should fall
Table 3: Response of Expected Output Growth Over the Next Year

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy News Shock</td>
<td>1.01</td>
<td>1.04</td>
<td>0.95</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>(0.32)</td>
<td>(0.35)</td>
<td>(0.32)</td>
<td>(0.63)</td>
</tr>
<tr>
<td>Observations</td>
<td>120</td>
<td>90</td>
<td>52</td>
<td>30</td>
</tr>
</tbody>
</table>

We regress changes from one month to the next in survey expectations about output growth over the next year from the Blue Chip Economic Indicators on the policy news shock that occurs in that month (except that we drop policy news shocks that occur in the first week of the month since we do not know whether these occurred before or after the survey response). Specifically, the dependent variable is the change in the average forecasted value of output growth over the next three quarters (the maximum horizon over which forecasts are available for the full sample). See Appendix F for details. We present results for four sample periods. The longest sample period for which we are able to construct our policy news shock is 1995-2014. We also present results for the sample period 2000-2014, which corresponds to the sample period we use in most of our other analysis. For robustness, we also present results for two shorter sample periods (1995-2000 and 2000-2007). The results are similar across all four sample periods, but of course less precisely estimated for the shorter sample periods.

Figure 2 presents a binned scatter plot of the relationship between changes expected output growth and our policy news shock over the 1995-2014 sample period. This scatter plot shows that the results in Table 3 are not driven by outliers. Finally, Table A.5 presents the response of output growth expectations separately for each quarter that the Blue Chip survey asks about. These are noisier but paint the same picture as the results in Table 3.

A natural interpretation of this evidence is that FOMC announcements lead the private sector to update its beliefs not only about the future path of monetary policy, but also about other economic

---

Source: Nakamura-Steinsson (2018)
Maybe not

When Fed raises rates, people may conclude that economy is stronger than they thought
Maybe not

When Fed raises rates, people may conclude that economy is stronger than they thought

Fed has little private data, but hundreds of PhD economists

Following Romer-Romer 00, we call this the Fed Information Effect

Campbell et al. (2012) present similar evidence
Conventional interpretation of monetary shocks:

Fed conveying information **only** about its own future policy
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- Fed conveying information only about its own future policy
  - Public learning about policy maker’s preferences
  - Public learning about how policy maker thinks the world works
    (but not updating own beliefs about how world works)
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Fed information view:

- Fed conveys information about its own future policy
  but also about current and future exogenous shocks
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  - Public learning about how policy maker thinks the world works
    (but not updating own beliefs about how world works)

Fed information view:

- Fed conveys information about its own future policy
  but also about current and future exogenous shocks
  - Suppose Fed tightens policy ...
  - Public infers that Fed is more optimistic about economic outlook ...
  - Public updates its own assessment of economic outlook in response
HOW TO MODEL FED INFORMATION?

- Which fundamentals should Fed be modeled as affecting beliefs about?
- Prior literature assumes Fed signals through actions
  - Very limited signal space
  - Literature about limits to Feds ability to signal
HOW TO MODEL FED INFORMATION?

- Which fundamentals should Fed be modeled as affecting beliefs about?
- Prior literature assumes Fed signals through actions
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  - Literature about limits to Feds ability to signal
- Recent literature makes clear that Fed can signal with statements
  - Could signal about anything at any horizon
  - Very high dimensional!
- Crucial to find a parsimonious specification
How to Model Fed Information?

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  - Literature about limits to Feds ability to signal
- Recent literature makes clear that Fed can signal with statements
  - Could signal about anything at any horizon
  - Very high dimensional!
- Crucial to find a parsimonious specification

- We assume Fed affects beliefs about path of natural rate of interest
Fed Information Effect

Conventional view of monetary policy shocks:

- Fed conveying information about future monetary policy

\[
\hat{x}_t = -\sigma \sum_{j=0}^{\infty} E_t(\hat{i}_{t+j} - \hat{\pi}_{t+j+1} - \hat{r}_{t+j}^n)
\]
Fed Information Effect

Conventional view of monetary policy shocks:

- Fed conveying information about future monetary policy

\[ \hat{x}_t = -\sigma \sum_{j=0}^{\infty} E_t(\hat{i}_{t+j} - \hat{\pi}_{t+j+1} - \hat{r}_{t+j}) \]

Fed Information Case:

- Fed conveys information about future monetary policy but also about current and future natural rates of interest

\[ \hat{x}_t = -\sigma \sum_{j=0}^{\infty} E_t(\hat{i}_{t+j} - \hat{\pi}_{t+j+1} - \hat{r}_{t+j}) \]
Fed Information Effect

Conventional view of monetary policy shocks:
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\[ \hat{x}_t = -\sigma \sum_{j=0}^{\infty} E_t(\hat{\pi}_{t+j} - \hat{\pi}_{t+j+1} - \hat{r}_{t+j}^n) \]

Fed Information Case:
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\[ \hat{x}_t = -\sigma \sum_{j=0}^{\infty} E_t(\hat{\pi}_{t+j} - \hat{\pi}_{t+j+1} - \hat{r}_{t+j}^n) \]

In simple model: \[ r_{t+j}^n = \sigma^{-1}(E_t y_{t+j+1}^n - y_{t+j}^n) \]
Fed Information Effect

Why model Fed info this way?

- Tractable with forward guidance shocks
- Optimal monetary policy for Fed to track natural rate of interest
- Natural to think of monetary policy as revealing information about natural rate of interest
Inflation response determined by interest rate gap:

\[ \hat{\pi}_t = -\kappa \zeta \sigma \sum_{j=0}^{\infty} \beta^j E_t(\hat{r}^e_{t+j} - \hat{r}^{nl}_t) \]

If Fed information large:

- Interest rate gap small
- Traditional power of Fed small
Inflation response determined by interest rate gap:

\[ \hat{\pi}_t = -\kappa \zeta \sigma \sum_{j=0}^{\infty} \beta^j E_t (\hat{r}_{t+j}^\ell - \hat{r}_t^{nl}) \]

If Fed information large:

- Interest rate gap small
- Traditional power of Fed small
- But Fed not powerless
- Fed has enormous power over beliefs about fundamentals which may in turn affect economic activity
How should the FOMC handle situations where it’s own assessment of the economic situation is more pessimistic than that of the private sector?

Should it refrain from easing policy for fear of causing information effects?

Answer not well understood
(see Tang, 2015, Jia, 2019)
TWO SITUATIONS

1. Fed has enough policy room to counter weakness
   - Information effect should not be a worry
   - Policy easing should prevent pessimism

2. Fed does not have enough room to counter weakness
   - Revealing information truthfully may make economic situation worse
If Fed starts to systematically withhold bad news in certain situations, private sector will eventually catch on to this

Will undermine credibility of Fed communication

Private sector will adjust for the bias
... which may defeat the purpose
Two types of forward guidance:

1. Easing because economy is doing worse than private sector thinks
2. Economy no worse, but more accommodation warranted than private sector thinks

Important to distinguish between forward guidance that provides information about:

1. How economy is doing (first type)
2. Reaction function of the Fed (second type)
• February 2000 to June 2003
  • Forward guidance solely about economic outlook
    (e.g., “risks weighted mainly toward conditions that may generate economic weakness in the foreseeable future”)
  • Strong information effects

• August 2003 to May 2006
  • Forwards guidance about policy rate
    (e.g., “considerable period” and “measured pace”)
  • Much weaker information effects
PRICE RIGIDITY, MONETARY NON-NEUTRALITY, AND THE COST OF INFLATION

Jón Steinsson

UC Berkeley

January 2020
Long tradition of research on price rigidity in macro

But why devote such energy to how often the price of toothpaste changes?
Why Care About Price Rigidity in Macro?

- Long tradition of research on price rigidity in macro
- But why devote such energy to how often the price of toothpaste changes?
- Good example of empirical work guided by theory
Diverse evidence that demand shocks affect output:

- Monetary shocks: Friedman-Schwartz 63, Eichengreen-Sachs 85, Mussa 86, Christiano-Eichenbaum-Evans 99, Romer-Romer 04, Gertler-Karadi 15, Nakamura-Steinsson 18
- Fiscal shocks: Blanchard-Perotti 02, Ramey 11, Barro-Redlick 11, Nakamura-Steinsson 14, Guajardo-Leigh-Pescatori 14
- Household deleveraging shocks: Mian-Sufi 14
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Leading explanation: Prices adjust sluggishly to shocks
Monetary shock: Increase in money supply

- Flexible prices: Prices increase, while output and real rate unchanged
- Sticky prices: Reduction in nominal interest rate reduces real rates

Fiscal shock: Increase in government spending

- Flexible prices: Real rates rise, which crowds out private spending
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Same logic implies muted response of real rates to other shocks such as: deleveraging shocks, financial panics, increased uncertainty, "animal spirits"
Price Rigidity and the Business Cycles

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Could Price Rigidities Cause Major Recessions?

Many people’s first reaction is that this is not plausible. But many shocks call for sharp movements in the real interest rate. Deleveraging shocks (Eggertsson-Krugman 12 and Guerrieri-Lorenzoni 17) lead to a sharp increase in the desire to save, which results in a sharp drop in the “natural” rate of interest. But if prices are sticky and nominal rate constrained by the zero lower bound (ZLB) ... the real rate is stuck at too high a level, output is stuck at too low a level. Financial disruptions and investment hang-overs have similar effects.
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- Staggered price setting
- Strategic complementarity among price setters
  (firm A’s optimal price increasing in firm B’s price)
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Usually combined with coordination failures among price setters
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These three features interact powerfully to create a lot of sluggishness and long-lived effect on output
Evidence on price rigidity potential source of indirect evidence on extent of monetary non-neutrality and effects of demand shocks on output

For this, what matters is the extent to which micro price rigidity lead to a sluggish response of the aggregate price level
Evidence on price rigidity potential source of indirect evidence on extent of monetary non-neutrality and effects of demand shocks on output

For this, what matters is the extent to which micro price rigidity lead to a sluggish response of the aggregate price level

This depends on the nature of the micro price rigidity

Stark comparison: Calvo model vs. Caplin-Spulber model
Calvo model:

- Timing of price changes random
- Random assortment of firms that change prices
- Some don’t really need to change
- Aggregate price level responds modestly
**Caplin-Spulber vs. Calvo**

**Calvo model:**
- Timing of price changes random
- Random assortment of firms that change prices
- Some don’t really need to change
- Aggregate price level responds modestly

**Caplin-Spulber model:**
- Timing of price changes chosen optimally
- Firms with biggest “pent-up” desire to change price do
- Aggregate price level responds a great deal
- Golosov-Lucas call this “selection effect”
Fig. 6.—Price adjustment in menu cost and Calvo models. a, Price adjustment before aggregate shock. b, Price adjustment after aggregate shock.

Source: Golosov and Lucas (2007)
Both models extreme cases

- **Calvo**: Aggregate conditions have no effect on which firms or how many firms change prices.
- **Caplin-Spulber model**: Aggregate shocks only determinant of which firms and how many firms change prices (+ other special assumption that matter for result)
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- **Caplin-Spulber model**: Aggregate shocks only determinant of which firms and how many firms change prices
  (+ other special assumption that matter for result)

Subsequent literature explores intermediate cases and uses empirical evidence on characteristics of micro price adjustment to choose between models
Add large idiosyncratic shocks to menu cost model

Motivating facts:
- Bils-Klenow (2004): Prices change on average every 4-5 months
- Klenow-Kryvstov (05,08): Average absolute size of price changes 10%

Is this model closer to Calvo or Caplan-Spulber?
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Monetary non-neutrality is “small and transient”
6 times smaller than in Calvo model
Assault on Keynesian Economics

- Prices change every 4-5 months

Golosov and Lucas (2007)
- Monetary non-neutrality is “small and transient”
Perhaps Golosov-Lucas model not sufficiently realistic to yield credible policy conclusions
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Empirical Issues:

- How should we treat temporary sales?
- How does heterogeneity in price rigidity matter?
- Are all price changes selected?
- What is a realistic distribution of idiosyncratic shocks?
price rigidity is more informative? Which should we use if we wish to calibrate the frequency of price change in the model in Section 3?

One view is simply that a price change is a price change; in other words, all price changes should be counted equally. However, Figure 2 also illustrates that sales have very different empirical characteristics than regular price changes do. Whereas regular price changes are in most cases highly persistent, sales are highly transient.

In fact, in most cases, the posted price returns to its original value following a sale. Table 2 reports results from Nakamura & Steinsson (2008) on the fraction of prices that return to the original regular price after one-period temporary sales in the four product categories of the BLS CPI data for which temporary sales are most prevalent. This fraction ranges from 60% to 86%.

Clearance sales are not included in these statistics because a new regular price is not observed after such sales. Nakamura & Steinsson (2008, supplementary material) argue that clearance sales, like other types of sales, yield highly transient price changes.

It is noticeable that the fraction of prices that return to the original price after a sale is negatively correlated with the frequency of regular price change across these categories. In fact, Table 2 shows that the probability that the price returns to its previous regular price can be explained with a frequency of regular price change over this period that is similar to the frequency of regular price change at other times (the third data column). In addition, higher-frequency data sets indicate that many sales are shorter than one month. This suggests that the estimates in Table 2 for the fraction of sales that return to the original price are downward biased.

Figure 2
Price series of Nabisco Premium Saltines (16 oz) at a Dominick’s Finer Foods store in Chicago.

Source: Nakamura and Steinsson (2013)
Two features stand out:

1. Change in “regular” price is infrequent and “lumpy”
   - Only 9 “regular price” changes in a 7 year period

2. Frequent temporary discounts (sales)
   - 117 price changes in 365 weeks
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1. Change in “regular” price is infrequent and “lumpy”
   - Only 9 “regular price” changes in a 7 year period
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- Does this product have essentially flexible prices?
- Or is its price highly rigid?
### Table: Frequency of Price Change by Major Group 1998-2005

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<tbody>
<tr>
<td>Processed Food</td>
<td>8.2</td>
<td>10.5</td>
<td>25.9</td>
<td>57.9</td>
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<tr>
<td>Unprocessed Food</td>
<td>5.9</td>
<td>25.0</td>
<td>37.3</td>
<td>37.9</td>
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<tr>
<td>Household Furnishing</td>
<td>5.0</td>
<td>6.0</td>
<td>19.4</td>
<td>66.8</td>
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<td>Apparel</td>
<td>6.5</td>
<td>3.6</td>
<td>31.0</td>
<td>87.1</td>
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<tr>
<td>Transportation Goods</td>
<td>8.3</td>
<td>31.3</td>
<td>31.3</td>
<td>8.0</td>
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<tr>
<td>Recreation Goods</td>
<td>3.6</td>
<td>6.0</td>
<td>11.9</td>
<td>49.1</td>
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<tr>
<td>Other Goods</td>
<td>5.4</td>
<td>15.0</td>
<td>15.5</td>
<td>32.6</td>
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<tr>
<td>Utilities</td>
<td>5.3</td>
<td>38.1</td>
<td>38.1</td>
<td>0.0</td>
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<tr>
<td>Vehicle Fuel</td>
<td>5.1</td>
<td>87.6</td>
<td>87.6</td>
<td>0.0</td>
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<td>Travel</td>
<td>5.5</td>
<td>41.7</td>
<td>42.8</td>
<td>1.5</td>
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<tr>
<td>Services (excl. Travel)</td>
<td>38.5</td>
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Source: Nakamura and Steinsson (2008)
Source: Nakamura-Steinsson-Sun-Villar (2018)
The results in Table 1 illustrate two important issues that arise when assessing price rigidity. First, the extent of price rigidity is highly sensitive to the treatment of temporary price discounts or sales. For posted prices, the median implied duration is roughly 1.5 quarters, whereas for regular prices, it is roughly three quarters depending on the sample period and the treatment of substitutions.

But why is it interesting to consider the frequency of price change excluding sales? Isn’t a price change just a price change? The sensitivity of summary measures of price rigidity to the treatment of sales implies that these are first-order questions, and recent work has shed a great deal of light on them. This work has developed several arguments, based on the special empirical characteristics of sales price changes, for why macro models aiming to characterize how sluggishly the overall price level responds to aggregate shocks should be calibrated to a frequency of price change substantially lower than that for posted prices. We discuss this work in Section 4.

A second important issue that is illustrated by the results reported in Table 1 is the distinction between the mean and the median frequencies of price change. For example, in Nakamura & Steinsson’s (2008) results on the frequency of regular price changes including substitutions for the sample period 1998–2005, the median monthly frequency of regular price change is 11.8%, whereas

| Source: Nakamura and Steinsson (2013) |

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Temporary sales have very special empirical characteristics
- They are highly transient
- They very often return to the original price
- Strongly suggests that firms are not reoptimizing

How do these empirical characteristics affect degree to which temporary sales enhance the flexibility of the aggregate price level?
Menu cost model (also consider Calvo model)

- Firms can change prices for one period at lower cost
  - Change regular price permanently ("buy" a new price)
  - Temporary sale ("rent" a new price)

- Timing of sales chosen optimally and responds to macro shocks

- Nevertheless, sales generate very little aggregate price flexibility

- Results on monetary non-neutrality close to those if sales had been excluded
Two Views of Sales:

- Intertemporal price discrimination (e.g., Varian, 1980)
- Inventory Management (e.g., Lazear, 1986)
  - Due to unpredictable shifts in taste (fashion)?

Evidence: Nakamura (2008), Anderson et al. (2017)
Empirical Issues

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- How does heterogeneity in price rigidity matter?
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Source: Nakamura and Steinsson (2013)
5. HETEROGENEITY IN THE FREQUENCY OF PRICE CHANGE

There is a huge amount of heterogeneity in the frequency of price change across sectors of the US economy. Figure 3 illustrates this in a histogram of the frequency of regular price change across different CPI product categories from Nakamura & Steinsson (2008). Whereas many service sectors have a frequency of price change below 5% per month, prices in some sectors, such as gasoline, change several times a month. A key feature of this distribution is that it is strongly right-skewed. It has a large mass at frequencies between 5% and 15% per month, but then it has a long right tail, with some products having a frequency of price change above 50% and a few close to 100%. As a consequence, the expenditure-weighted median frequency of regular price change across industries is about half the mean frequency of regular price change (see Table 1).

The simple model in Section 3 assumes a common frequency of price adjustment for all firms in the economy. The huge amount of heterogeneity and skewness in the frequency of price change across products begs the question, how does this heterogeneity affect the speed at which the aggregate price level responds to shocks? In other words, will the price level respond more sluggishly to shocks in an economy in which half the prices adjust all the time (e.g., gasoline) and half hardly ever adjust (e.g., haircuts) or one in which all prices adjust half of the time? A related question is, if one wishes to approximate the behavior of the US economy using a model with homogeneous firms, should one calibrate the frequency of price change to the mean or median frequency of price change?

Figure 3


Source: Nakamura and Steinsson (2013)
Heterogeneity in Price Rigidity

- Distribution is skewed: long right tail
  - Many products with low frequency
  - Some products with very high frequency
- Different summary statistics give impressions:
  - Excl. sales: Mean freq: 23%, median freq: 11%
- Questions:
  - Does this heterogeneity matter for aggregate monetary non-neutrality?
  - What statistic should single sector models be calibrated to?
Heterogeneity matters a lot!

No model free answer for calibrating a single sector model
Heterogeneity matters a lot!

No model free answer for calibrating a single sector model

In Taylor model: Bils-Klenow (2002) use median frequency

In Calvo model: Carvalho (2007) use mean implied duration (NOT = inverse of mean frequency)

In menu cost model: Nakamura and Steinsson (2010) say use median frequency for US data (no general theorem)

Intuition: Extra price change not as useful in high frequency sector since everyone has already changed
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Empirical Issues

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- What is a realistic distribution of idiosyncratic shocks?
Figure: Seasonality in Product Substitution

Source: Nakamura and Steinsson (2008)
VI. SEASONALITY OF PRICE CHANGES

The synchronization or staggering of price change is an important determinant of the size and persistence of business cycles in models with price rigidity. One form of synchronization of price change is seasonality. We find a substantial seasonal component of price changes for the U.S. economy, for both consumer and producer goods.

Figure V presents the weighted median frequency of price increases and decreases by month for consumer prices excluding sales over the period 1988–2005. Three results emerge. First, the frequency of regular price change declines monotonically over the four quarters. It is 11.1% in the first quarter, 10.0% in the second quarter, 9.8% in the third quarter, and only 8.4% in the fourth quarter. Second, in all four quarters, the frequency of price change is largest in the first month of the quarter and declines...
Figure 18: Frequency of Regular Price Change by Quarter for Finished Producer Goods
The figure plots the weighted median frequency of regular price change by quarter.

Figure 19: Frequency of Regular Price Increases and Decreases by Month for Finished Producer Goods
The figure plots the weighted median frequency of price increase and decrease by month.

Source: Nakamura and Steinsson (2008 Supplement)
Empirical Issues

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Strength of selection effect highly sensitive to assumptions about distribution of idiosyncratic shocks
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Golosov-Lucas 07 assume normal shocks.

Suppose we instead assume shocks are either tiny or huge, i.e., that they have huge kurtosis.
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Midrigan evidence:
- Size of price changes dispersed
- Many small price changes
- Coordination of timing of price changes within category
Distribution of $\Delta p$ changes: Data vs. GL model

Source: Midrigan (2011)
Two changes to Golosov-Lucas model:

- Leptokurtic distribution of idiosyncratic shocks
- Returns to scale in price adjustment
Two changes to Golosov-Lucas model:

- Leptokurtic distribution of idiosyncratic shocks
- Returns to scale in price adjustment

- Selection effect much smaller.
- Model yields similar conclusions as Calvo model
Sufficient Statistic for Real Effects

Alvarez-Le Bihan-Lippi 15:

- In a wide class of models ...
  (Calvo, Taylor, Golosov-Lucas, Reis, Midrigan, etc.)
- Cumulative output effect of money shock:

\[ M = \frac{\delta}{6\epsilon} \frac{\text{Kur}(\Delta p_i)}{N(\Delta p_i)} \]

- \( \delta \) size of monetary shock
- \( 1/\epsilon - 1 \) Frisch elasticity of labor supply
- Kur(\( \Delta p_i \)) kurtosis of size distribution of price changes
- N(\( \Delta p_i \)) frequency of price change

Obviously, there are some simplifying assumptions (e.g., unit root shock, no inflation, no strategic complementarity, etc.)
Sufficient Statistic for Real Effects

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  \]

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  - \(\text{Kur}(\Delta p_i)\) kurtosis of size distribution of price changes
  - \(N(\Delta p_i)\) frequency of price change

- Obviously, there are some simplifying assumptions
  
  (e.g., unit root shock, no inflation, no strategic complementarity, etc.)
Kurtosis is Key

\[ M = \frac{\delta}{6\epsilon} \frac{\text{Kur}(\Delta p_i)}{N(\Delta p_i)} \]

- Kurtosis in Calvo model is 6
- Kurtosis in Golosov-Lucas model is 1
Kurtosis is hard to measure!!

- **Heterogeneity:**
  - Mixture of distributions with different variances but same kurtosis will have higher kurtosis
  - Authors divide by standard deviation at category level

- **Measurement errors:**
  - Standard to drop large observations. Kurtosis very sensitive to this!!
  - Authors drop largest 1% of price changes
  - Spurious small price changes also a problem
    (product not held constant, coupons)
  - Authors drop price changes that are smaller than 1 cent or 0.1%
Costs of Inflation
What level of inflation should central banks target?

- Pre-crisis policy consensus to target roughly 2% inflation per year
- Academic studies argued for still lower rates
  (Schmitt-Grohe and Uribe, 2011; Coibion et al., 2012)
What level of inflation should central banks target?

- Pre-crisis policy consensus to target roughly 2% inflation per year
- Academic studies argued for still lower rates
  (Schmitt-Grohe and Uribe, 2011; Coibion et al., 2012)

- Great Recession has lead to increasing calls for higher inflation targets
  - Blanchard, Dell’Ariccia, Mauro (2010), Ball (2014), Krugman (2014)
  - Blanco (2015)
Measured inflation is biased

Further from ZLB

Grease the wheels of the labor market
Costs of Moderate Inflation

- Costs of stable inflation not been well articulated
  - Economize on money (shoe-leather costs)
  - Menu costs
  - Non-indexed tax system
  - Increased price dispersion

- Easier to articulate cost of unanticipated inflation
  - Wealth redistribution
  - Screwed up prices in long-term contracts

- Is moderate stable inflation possible?
  - Many have argued not based on history
  - But correlation does not imply causation
Higher inflation will lead to higher price dispersion
  - Prices will drift further from optimum between times of adjustment
  - Distorts allocative role of the price system

In standard New Keynesian models, these costs are very large
  - Going from 0% to 12% inflation per year yields a 10% loss of welfare
  - Much more costly than business cycle fluctuations in output in these same models

However, this conclusion is very sensitive to nature of price setting
(Calvo versus menu cost)
If all products were homogenous within product category ... 
... simply calculate cross-sectional variance
If all products were homogenous within product category ...

... simply calculate cross-sectional variance

In practice, large amount of product heterogeneity (e.g., quality and size) within product category

This creates “efficient” dispersion in prices

“Efficient” dispersion may dwarf “inefficient” dispersion
Dispersion of Prices within ELI

IQR Excluding Sales
IQR, all prices

Steinsson (UC Berkeley)
Measuring price dispersion directly is difficult.

But distinguishing between Calvo model and menu cost model provides indirect evidence on price dispersion.

Particularly useful indirect evidence: absolute size of price changes.

- Absolute size reveals distance of prices from desired prices.
- If prices are drifting further from desired level due to inflation, they should change by more when they change.
Steinsson (UC Berkeley)
No evidence that absolute size of price changes rose during Great Inflation

Suggests inefficient price dispersion not any higher during Great Inflation

Costs of inflation emphasized in New Keynesian models elusive
Frequency of Price Change

- Flip-side of “size” is frequency of price change
  - If size unaffected by inflation, frequency must vary

- Useful to distinguish between models of price setting:
  - Frequency constant in Calvo model ...
  - ... but varies with inflation in menu cost model
Evidence from three countries:

- Gagnon 09: Mexico 1994-2002 (Tequila crisis)
Source: Nakamura-Steinsson-Sun-Villar (2018)
a) Frequency  all items

Time rate, \( \dot{\omega} \), refers to the "instantaneous" frequency of price changes, which has the dimension of the number of price changes per month.

Later we perform robustness checks by using different methods of aggregation across goods, by considering different treatments for sales, substitutions and missing observations, and by dropping the assumption that price changes follow a Poisson process.

Figure 5: Estimated Frequency of Price Changes \( \lambda \) and Expected Inflation

Note: Simple estimator of \( \hat{\lambda} = \log(1 + f_t) \), where \( f_t \) is the fraction of outlets that changed price in period \( t \). \( \hat{\lambda} \) is estimated separately for homogeneous goods (bi-weekly sample) and for differentiated goods (monthly sample). Homogeneous goods frequencies are converted to monthly by adding the bi-weekly ones for each month pair. The aggregate number is obtained by averaging with the respective expenditure shares in the Argentine CPI. Inflation is the average of the log-difference of monthly prices multiplied by 1200 and weighted by expenditure shares. Expected inflation is the average inflation rate \( \frac{1}{\hat{\lambda}} \) periods ahead.

Figure 5 plots the monthly time series of the simple pooled estimator of \( \lambda \) as well as of the expected inflation rate. It assumes that all homogeneous and all differentiated goods have the same frequency of price changes and estimates this aggregate frequency by using the simple pooled estimator for the homogeneous and for the differentiated goods. The bi-weekly estimates of the homogeneous goods are aggregated to a monthly frequency, and the monthly frequency is the sum of the bi-weekly frequencies of each month.
Figure 6: The Frequency of Price Changes ($\lambda$) and Expected Inflation.

% change in $\lambda$ of increasing $\pi$ from 0 to 1% = 0.04
Elasticity for high inflation = 0.53

Source: Alverez-Beraja-Gonzalez-Rozada-Neumeyer (2019)
At zero inflation:

- Derivative of frequency = 0
- Derivative of price dispersion = 0
- Inflation 9/10th due to “extensive margin”

\[ \pi = \lambda^+ \Delta^+ - \lambda^- \Delta^- \]
Alvarez et al. (2019): Theoretical Results

At zero inflation:

- Derivative of frequency = 0
- Derivative of price dispersion = 0
- Inflation 9/10th due to “extensive margin”

\[ \pi = \lambda^+ \Delta^+ - \lambda^- \Delta^- \]

At high inflation:

- Elasticity of frequency with inflation equal to 2/3
- Elasticity of dispersion with inflation equal to 1/3
Inflation and Price Dispersion

- Strong evidence favoring menu cost model over Calvo model
- Strong indirect evidence that price dispersion does not rise much with moderate inflation
Keynesian macroeconometric models of 1950s/60s:
- Backward-looking system

\[ c_t = \alpha c_{t-1} + \beta y_t \]
Keynesian macroeconometric models of 1950s/60s:
- Backward-looking system

\[ c_t = \alpha c_{t-1} + \beta y_t \]

Paradigm shift: People are forward looking
- Friedman, Lucas, etc.
- Pendulum eventually swung really, really far:

\[ c_t = E_t c_{t+1} - \sigma (i_t - E_t \pi_{t+1}) \]
\[ \pi_t = \beta E_t \pi_{t+1} + \kappa x_t \]
• Keynesian macroeconometric models of 1950s/60s:
  • Backward-looking system
    \[ c_t = \alpha c_{t-1} + \beta y_t \]

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• Maybe the world is somewhere in between??
Central banks use statements / public forecasts to guide expectations about future policy

Key part of modern central banking

Important prior to Great Recession / ZLB
FORWARD GUIDANCE: A HISTORY

United States:
- Feb 1994: First post-meeting statement
- May 1999: Statement after every scheduled FOMC meeting
- Always two key sentences: 1) action, 2) forward guidance
  (Rudebusch and Williams, 2008, Lunsford, 2019)

Other countries:
- Norges Bank pioneered publishing interest rates forecasts in 2005
- Others have since followed suite
- See Woodford (2007) for discussion of debate surrounding this
“I have learned to mumble with great incoherence.”
Alan Greenspan, 1987

“Monetary Policy is 98% talk and 2% action.”
Ben Bernanke, 2015
Examples from FOMC statements:

- 2003-04: "considerable period"
- 2004-05: "pace that is likely to be measured"
- 2008-09: "some time"; "an extended period".
- 2011-12: "mid 2013"; "late 2014"; "mid 2015".
- Dec 2012: while U above 6.5%, $\pi$ below 2.5%, $E\pi$ anchored
- 2014-15: "considerable time", "patient"

Typically, action expected (i.e., change in current fed funds rate)

News (shock) mostly about future evolution of fed fund rate

(Gurkaynak-Sack-Swanson 05, Campbell et al. 12)
Far future forward guidance has immense effects on current outcomes

- Eggertsson-Woodford 03: Modest far future forward guidance can eliminate huge recession at ZLB
Figure 5. Response of the Nominal Interest Rate, Inflation, and the Output Gap to a Shock of Specific Duration

Source: Authors’ calculations.

a. Response to a fall in the natural rate of interest below zero for a period of fifteen quarters.
Far future forward guidance has immense effects on current outcomes

- Eggertsson-Woodford 03: Modest far future forward guidance can eliminate huge recession at ZLB
- Carlstrom-Fuerst-Paustian 15: Standard monetary models “blow up” when interest rates are held low for about 2 years
The solution to the system during the periods with a pegged rate is characterized by three eigenvalues. One eigenvalue is a complex root if and only if

\[ \text{initial in} \frac{\pi}{8}, \ \text{initial in} \frac{995}{6.7968}, \ \text{initial in} \frac{6.7968}{\text{fl}} \]

As forward guidance approaches an asymptote, the effect of all shocks is magnified. Reversals are independent of the nature of shocks in the model. As forward guidance approaches an asymptote, the effect of all shocks is magnified.

Reversals are independent of the nature of shocks in the model. As forward guidance approaches an asymptote, the effect of all shocks is magnified.

**Fig. 2.** Initial inflation and forward guidance (T).

Source: Carlstrom-Fuerst-Paustian (2015)
Far future forward guidance has immense effects on current outcomes

- Eggertsson-Woodford 03: Modest far future forward guidance can eliminate huge recession at ZLB
- Carlstrom-Fuerst-Paustian 15: Standard monetary models “blow up” when interest rates are held low for about 2 years
- Del Negro-Giannoni-Patterson 13 call this “forward guidance puzzle”
Why is forward guidance so powerful in standard monetary models?
Why So Powerful?

- Textbook New Keynesian model:

\[ x_t = E_t x_{t+1} - \sigma (i_t - E_t \pi_{t+1} - r^n_t) \]

\[ \pi_t = \beta E_t \pi_{t+1} + \kappa x_t \]

Here \( x_t \) is output gap and \( \pi_t \) is inflation
Why So Powerful?

- Textbook New Keynesian model:

\[ x_t = E_t x_{t+1} - \sigma (i_t - E_t \pi_{t+1} - r_t^n) \]

\[ \pi_t = \beta E_t \pi_{t+1} + \kappa x_t \]

Here \( x_t \) is output gap and \( \pi_t \) is inflation

- Simple monetary policy:

\[ i_t - E_t \pi_{t+1} = r_t^n + \epsilon_{t,t-j} \]
Why So Powerful?

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Here \( x_t \) is output gap and \( \pi_t \) is inflation

- Simple monetary policy:

\[ i_t - E_t \pi_{t+1} = r^n_t + \epsilon_{t,t-j} \]

- Steady state absent monetary shocks:

\[ E_t(i_{t+j} - E_t \pi_{t+j+1}) = E_t r^n_{t+j} \]

\[ x_t = 0, \quad \pi_t = 0 \]
ILLUSTRATIVE EXPERIMENT

- Suppose central bank promises to lower real rates by 1% for 1 quarter 5 years from now

- How do consumers react in standard model? (assuming $\sigma = 1$)
Partial Equilibrium

Output

Percentage Points

Horizon in Quarters

-0.2
0
0.2
0.4
0.6
0.8
1
1.2

Output

General Eqm.
Partial Eqm.
Raise consumption today by 1% and keep it high for 5 years

Solve forward Euler equation:

\[ x_t = - \sum_{j=0}^{\infty} E_t (i_{t+j} - E_{t+j} \pi_{t+j+1} - r_{t+j}^n) \]

Undiscounted sum of future interest rate gaps

Response is large in that it lasts for a long time (large integral)
How does this affect inflation?

Solve Phillips curve forward:

\[ \pi_t = \kappa \sum_{j=0}^{\infty} \beta^j E_t x_{t+j} \]

Entire integral of change in expected output (with some discounting) feeds into inflation immediately

Contemporaneous response gets bigger and bigger the further out in the future the forward guidance
Illustrative experiment: Real rate held constant in lead-up
Illustrative experiment: Real rate held constant in lead-up

In normal times:
  - Real rate increases in response to higher inflation
  - Counteracts boom
Illustrative experiment: Real rate held constant in lead-up

In normal times:
- Real rate increases in response to higher inflation
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At zero lower bound:
- Real rate falls because inflation rises
- Reinforces boom
Illustrative experiment: Real rate held constant in lead-up

In normal times:
- Real rate increases in response to higher inflation
- Counteracts boom

At zero lower bound:
- Real rate falls because inflation rises
- Reinforces boom

Even though policy is systematic, it is made up of a sequence of actions

Useful to focus on one action to understand how model works
Response of $c_t$ to $r_t$ the same as response of $c_t$ to $E_t r_{t+40}$ (or $E_t r_{t+400}$)

- Is this realistic?
Response of $c_t$ to $r_t$ the same as response of $c_t$ to $E_t r_{t+40}$ (or $E_t r_{t+400}$)

- Is this realistic?
- Perhaps more realistic that households react less to future rates

\[
  c_t = -\sigma E_t \sum_{j=0}^{\infty} \alpha^j (i_{t+j} - E_t \pi_{t+j+1} - r_{t+j}^n)
\]
Response of \( c_t \) to \( r_t \) the same as response of \( c_t \) to \( E_t r_{t+40} \) (or \( E_t r_{t+400} \))

- Is this realistic?
- Perhaps more realistic that households react less to future rates

\[
c_t = -\sigma E_t \sum_{j=0}^{\infty} \alpha^j (i_{t+j} - E_t \pi_{t+j+1} - r^n_{t+j})
\]

- Gives rise to a “discounted” Euler equation:

\[
c_t = \alpha E_t c_{t+1} - \sigma (i_t - E_t \pi_{t+1} - r^n_t)
\]
How do we get discounting in the Euler equation?

- Incomplete markets (McKay-Nakamura-Steinsson 16, 17)
- OLG (Eggertsson-Mehrotra 14, Del Negro-Giannoni-Patterson 15)
- Households don’t pay attention to far future? (Gabaix 16)
- Lack of common knowledge (Angeletos-Lian 16)
- Level-K thinking + incomplete markets (Farhi-Werning 16)
- Wealth in utility function (Michiallat-Saez 19)
Incomplete markets model
INCOMPLETE MARKETS MODEL: HOUSEHOLDS

Households maximize:

$$
\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{c_{it}^{1-\gamma}}{1 - \gamma} - \frac{\ell_{it}^{1+\psi}}{1 + \psi} \right]
$$

subject to:

$$
\frac{b_{it+1}}{1 + r_t} + c_{it} = b_{it} + w_t z_{it} \ell_{it} - \tau_t(z_{it}) + d_t,
$$

$$
b_{it} \geq 0
$$

- Stochastic individual productivity $z_{it}$ (finite state Markov process)
- Idiosyncratic income risk uninsurable (no state contingent assets)
- Save in risk-free real bond subject to debt limit $b_{it} \geq 0$
**Incomplete Markets Model: Firms**

- Final good production function

\[ y_t = \left( \int_0^1 y_t(j)^{1/\mu} dj \right)^\mu \]

- Intermediate good production function

\[ y_t(j) = N_t(j) \]

- Market for final good competitive
- Markets for intermediate goods monopolistically competitive with Calvo-style sticky prices
- Dividends distributed evenly to households
Fiscal authority:

- Fixed real value $B$ of government debt outstanding (hence balanced budget)
- Taxes a function of productivity: $\tau_t \bar{T}(z_{it})$
  (only high productivity households pay taxes)

Monetary authority:

- Sets path for real interest rate
Calibration

- Steady state annual interest rate equal to 2% ($\beta = 0.986$)
- CRRA = 2 ($\gamma = 2$)
- Frisch elasticity of labor supply equal to 0.5 ($\psi = 2$)
- Average markup of 20% ($\mu = 1.2$)
- 15% of price change per quarter ($\theta = 0.85$)
- Productivity AR(1) in logs with parameters set to match Floden and Lindé (2001)
- Assets: Ratio of liquid assets to annual GDP of 1.4 from Flow of Funds
Monetary authority announces in quarter 0 that:

- Real interest rate in quarter 20 will be 50 bps lower
- Real rates at all other times unchanged
The graph illustrates the output in percentage points over quarters for both incomplete and complete markets. The red line represents the output for incomplete markets, showing a significant drop at quarter 20, while the black line represents complete markets, remaining constant.

**Legend**:
- **Red Line**: Incomplete Markets
- **Black Line**: Complete Markets

**Axes**:
- **X-axis**: Quarter
- **Y-axis**: Percentage Points

**Scale**:
- Percentage Points range from -0.05 to 0.25
- Quarter range from 0 to 40
MP in HANK = MP in RANK

If:

- Individual income is proportional to aggregate income for all agents (distribution of relative income is unaffected by changes in aggregate income)
- Liquidity is proportional to aggregate income for all agents (borrowing constraints and asset values)
General equilibrium effects

Consumption, Income

Complete markets

Time
GENERAL EQUILIBRIUM EFFECTS

Consumption, Income

Complete markets

Time

Forced Guidance Puzzle
When is MP in HANK weaker?

- MP involves redistribution of wealth towards less constrained agents.
- Income of more constrained agents doesn’t rise proportionally with aggregate income.
- Borrowing constraints and value of asset doesn’t change proportionally with aggregate income.
- Risk is pro-cyclical.
**General Equilibrium Effects**

Three things that limit GE effects in McKay-Nakamura-Steinsson:

- High-skill households gain the most from increase in wages
  - Redistribution towards low MPC households
- $B/Y$ falls as $Y$ rises
- Risk pro-cyclical ($w_t z_{it} \ell_{it}$)
What is the relative size of direct effects and indirect effects of monetary policy?
What is the relative size of direct effects and indirect effects of monetary policy?

- RANK: 95% direct effects
- HANK: Mostly indirect effects
What is the relative size of direct effects and indirect effects of monetary policy?

- RANK: 95% direct effects
- HANK: Mostly indirect effects

Same general thrust as in Werning’s paper

But what about aggregate effects?
<table>
<thead>
<tr>
<th></th>
<th>$T$ adjusts</th>
<th>$G$ adjusts</th>
<th>$B^g$ adjusts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Change in $r^b$ (pp)</td>
<td>-0.23%</td>
<td>-0.21%</td>
<td>-0.25%</td>
</tr>
<tr>
<td>Change in $Y_0$ (%)</td>
<td>0.41%</td>
<td>0.81%</td>
<td>0.13%</td>
</tr>
<tr>
<td>Implied elasticity $Y_0$</td>
<td>-1.77</td>
<td>-3.86</td>
<td>-0.52</td>
</tr>
<tr>
<td>Change in $C_0$ (%)</td>
<td>0.50%</td>
<td>0.64%</td>
<td>0.19%</td>
</tr>
<tr>
<td>Implied elasticity $C_0$</td>
<td>-2.20</td>
<td>-3.05</td>
<td>-0.77</td>
</tr>
</tbody>
</table>

Component of Change in $C$ due to:

<table>
<thead>
<tr>
<th>Effect</th>
<th>$T$ adjusts</th>
<th>$G$ adjusts</th>
<th>$B^g$ adjusts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct effect: $r^b$</td>
<td>12%</td>
<td>9%</td>
<td>37%</td>
</tr>
<tr>
<td>Indirect effect: $w$</td>
<td>59%</td>
<td>91%</td>
<td>48%</td>
</tr>
<tr>
<td>Indirect effect: $T$</td>
<td>32%</td>
<td>0%</td>
<td>15%</td>
</tr>
<tr>
<td>Indirect effect: $r^a$</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 6: Decomposition of monetary shock on non-durable consumption

RANK implied elasticity $C_0$: -1.50
Redistribution Important

- T adjusts case > RANK because of redistribution towards poor
- G adjusts case > T adjusts because of “redistribution” towards government (MPC = 1 agents)
- B adjusts case small (no such redistribution)
Redistribution Important

- T adjusts case > RANK because of redistribution towards poor
- G adjusts case > T adjusts because of “redistribution” towards government (MPC = 1 agents)
- B adjusts case small (no such redistribution)

- Redistribution clearly very important in HANK
- Redistribution too powerful??
- No gross positions important limitation
Direct versus Indirect Effects

Alternative summary:
- Direct effects are robustly small
- Indirect effects can be either large or small
  - Depends on a lot of stuff
Direct versus Indirect Effects

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- Direct effects are robustly small
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- Empirical evidence gives some guide as to how large indirect effects are
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Why do we care?
Alternative summary:

- Direct effects are robustly small
- Indirect effects can be either large or small
  - Depends on a lot of stuff
- Empirical evidence gives some guide as to how large indirect effects are

Why do we care?

- Usual reason why structural models are useful (Lucas critique)
- Don’t have empirical evidence on all types of policy experiments
Power of contemporaneous monetary policy sensitive to specification of fiscal policy

Power of forward guidance smaller in HANK than RANK
**Forward Guidance when T Adjusts**

![Graph](image)

In RANK: $C_0 = 0.35$
**Forward Guidance when G Adjusts**

![Graph](image)

- **In RANK:** $C_0 = 0.35$
**Forward Guidance Puzzle**

**January 2020**

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In RANK: $C_0 = 0.35$
Many things matter that didn’t before:

- Gross positions
- Response of labor income to product demand
Way Forward

Many things matter that didn’t before:

- Gross positions
- Response of labor income to product demand
- Response of borrowing limits to lower interest rates and higher output
Many things matter that didn’t before:

- Gross positions
- Response of labor income to product demand
- Response of borrowing limits to lower interest rates and higher output
- Asset liquidity / duration
Many things matter that didn’t before:

- Gross positions
- Response of labor income to product demand
- Response of borrowing limits to lower interest rates and higher output
- Asset liquidity / duration
- Durables / investment / financial intermediation / etc.


References


