Evidence for Monetary Non-Neutrality

Jon Steinsson

UC Berkeley

January 2020

Effects of Monetary Policy?

- 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?)

Effects of Monetary Policy?

- 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?)
- 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)

Effects of Monetary Policy?

- 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?)
- 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)
- Scientific question!!
  - Conclusive empirical evidence should be able to settle this issue
    (for those willing to base opinion on evidence as opposed to ideology)

Why Don't We Already Know?

Given central importance, how can we not already know?

Why Don't We Already Know?

Given central importance, how can we not already know?

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

Endogeneity of Monetary Policy

Fed lowered interest rates aggressively in fall of 2008

- Done in response to worsening financial crisis

Endogeneity of Monetary Policy

Fed lowered interest rates aggressively in fall of 2008

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

$$\Delta y_t = \alpha + \beta \Delta i_t + \epsilon_t$$

Endogeneity of Monetary Policy

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 Δi_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

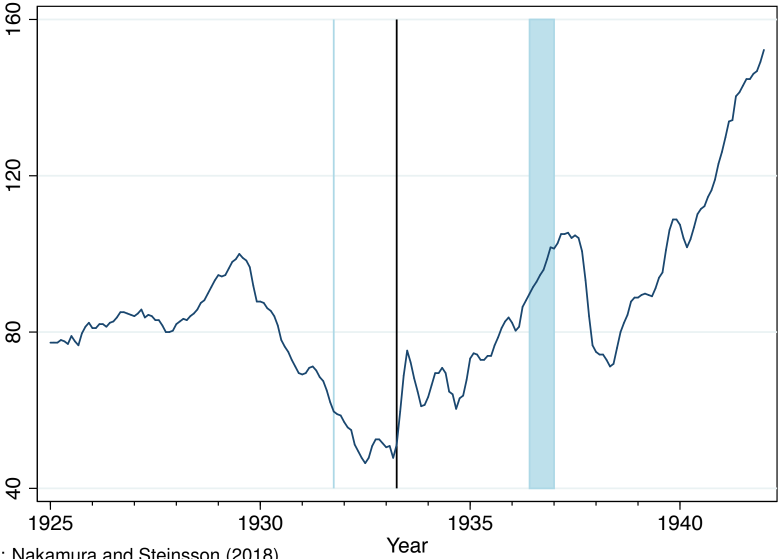
[1] Of course, a significant fraction say something along the lines of "I know it in my bones that monetary policy has no effect on output."

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)

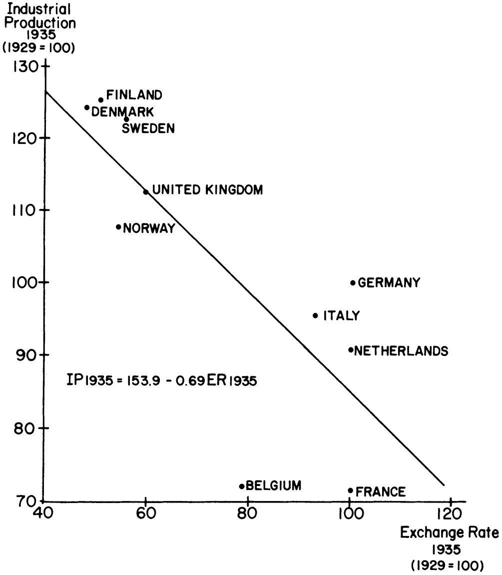
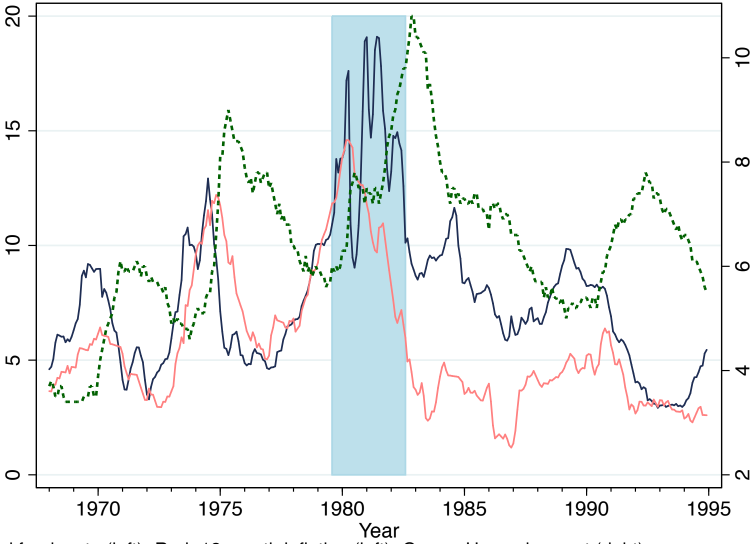


FIGURE 1
CHANGES IN EXCHANGE RATES AND INDUSTRIAL PRODUCTION, 1929–1935

Source: Eichengreen and Sachs (1985)

Volcker Disinflation

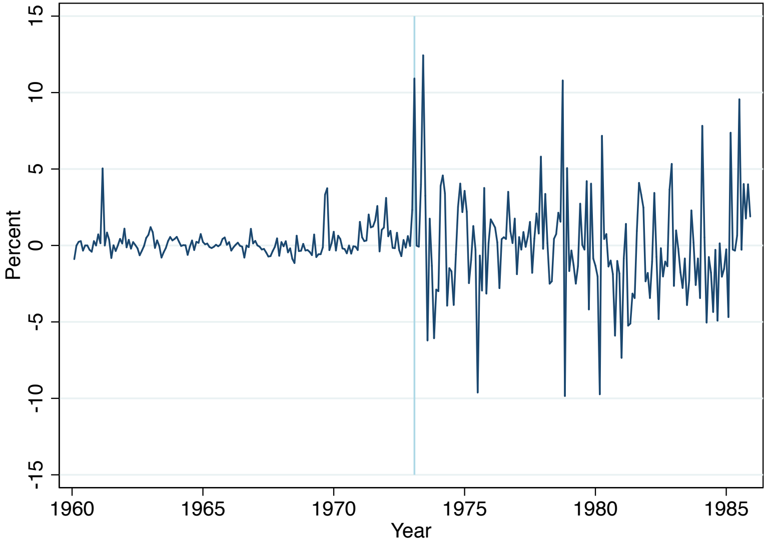


Blue: Fed funds rate (left). Red: 12-month inflation (left). Green: Unemployment (right).

Discontinuity-Based Evidence

- Strong evidence for effects of monetary policy on relative prices
- Important reason: Can be assessed using discontinuity-based identification

Mussa 86 – Breakdown of Bretton Woods



Change in U.S. - German real exchange rate. Source: Nakamura and Steinsson (2018)

Monetary Policy and Real Exchange Rate

- Bretton Woods system of fixed exchange rates breaks down in Feb 73
  - This is a pure high-frequency change in monetary policy
- Sharp break in volatility of **real** exchange rate

Monetary Policy and Real Exchange Rate

- Bretton Woods system of fixed exchange rates breaks down in Feb 73
  - This is a pure high-frequency change in monetary policy
- Sharp break in volatility of **real** exchange rate
- Identifying assumption:
  - Nothing else changed discontinuously in Feb 73
- Imbalances had been building up gradually
  - More inflationary policy in US than in Germany, Japan, etc.
  - US running substantial current account deficit
  - Intense negotiations for months about future of system
  - Hard to see anything else that discontinuously changes in Feb 73

Monetary Policy and Real Interest Rates

- 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

Evidence on Relative Prices

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

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

- 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

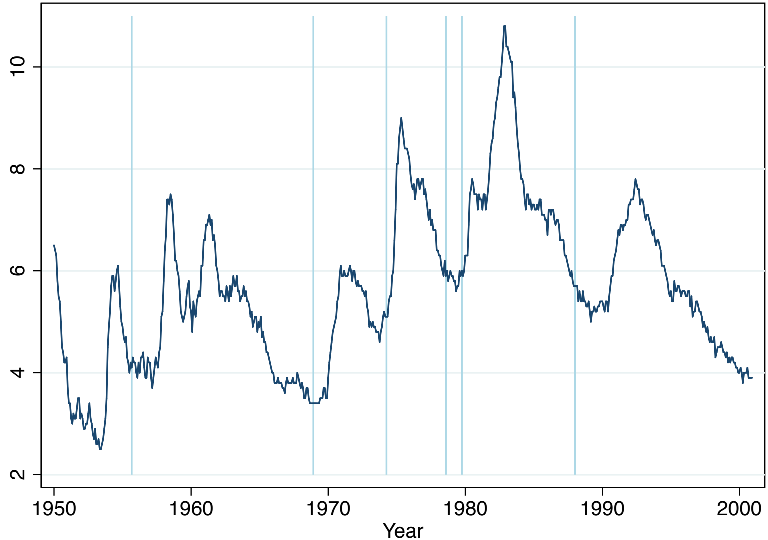
Narrative Evidence – Romer-Romer 89

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-Szhwartz 63)

Romer-Romer 89 Dates



Unemployment rate. Vertical lines are Romer-Romer 89 dates. Source: Nakamura and Steinsson (2018)

Romer-Romer 89 – Critiques

- 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

Romer and Romer Dates	Oil Shock Dates
October 1947	December 1947
	June 1953
September 1955	June 1956
	February 1957
December 1968	March 1969
	December 1970
April 1974	January 1974
August 1978	March 1978
October 1979	September 1979
	February 1981
	January 1987
December 1988	December 1988
	August 1990

Notes: Romer-Romer dates are 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

Detour: Linear RE Models and VARs

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
- $E[\epsilon_{t+1}|I_t] = 0$, $E[\eta_{t+1}|I_t] = 0$
- ϵ_{t+1} are exogenous shocks ($m_1 \times 1$ vector)
- η_{t+1} are prediction errors ($m_2 \times 1$ vector)
- Only some elements of Y_{t+1} have initial conditions

Example: New Keynesian Model

$$
\begin{aligned}
\pi_t &= E_t \pi_{t+1} + \kappa (y_t - y_t^n) \\
y_t &= E_t y_{t+1} - \sigma (i_t - E_t \pi_{t+1} - r_t^n) \\
i_t &= \phi_\pi \pi_t + \phi_y y_t + \nu_t
\end{aligned}
$$

Example: New Keynesian Model

$$
\begin{aligned}
\pi_t &= E_t\pi_{t+1} + \kappa(y_t - y_t^n) \\
y_t &= E_t y_{t+1} - \sigma(i_t - E_t\pi_{t+1} - r_t^n) \\
i_t &= \phi_\pi \pi_t + \phi_y y_t + \nu_t
\end{aligned}
$$

Some manipulation yields:

$$
\begin{aligned}
\pi_{t+1} &= \pi_t - \kappa y_t + \kappa y_t^n + \eta_{\pi,t+1} \\
y_{t+1} + \sigma\pi_{t+1} &= y_t + \sigma i_t - \sigma r_t^n + \eta_{y,t+1} + \sigma\eta_{\pi,t+1} \\
i_{t+1} - \phi_\pi\pi_{t+1} - \phi_y y_{t+1} &= \nu_{t+1}
\end{aligned}
$$

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

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

$$+ \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \epsilon_{1,t+1} \\ \epsilon_{2,t+1} \\ \epsilon_{3,t+1} \end{bmatrix} + \begin{bmatrix} 1 & 0 \\ \sigma & 1 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \eta_{\pi,t+1} \\ \eta_{y,t+1} \end{bmatrix}$$

- Have assumed that y^n_t, r^n_t, and ν_t are AR(1)
- System comes with only three initial conditions (for y^n_t, r^n_t, and ν_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

Impulse Response Functions

- 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 Σ
   - Unfortunately, Σ 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 ϵ_t
   - Example: Short-run restrictions (see Stock-Watson 01)

VAR Estimation: Empirical Challenges

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

2. Some variables in true VAR may be unobservable
   - In NK model example, (y_t^n, r_t^n, and ν_t) are unobservable
   - How about solving out for these variables?
   - This typically transforms a VAR(p) into a VARMA(∞,∞) in the remaining variables
   - Implicit assumption in VAR estimation that true VARMA(∞,∞) 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

Dynamic Causal Inference

Objective:

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

Two steps:

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

- Important to consider these two steps separately

SVAR Identification of Monetary Shocks

- 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

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

What can go wrong?

1. Reverse causation:
   - Assumption begin made: Correlation between i_t and (π_t, y_t) is due to (π_t, y_t) influencing i_t but not the other way around
   - If i_t influences (π_t, y_t) (contemporaneously), we have a "simultaneous equation problem" (ϵ_t correlated with (π_t, y_t))
   - Assumption being made: i_t is "fast-moving" variable, while π_t and y_t are slow moving. So i_t doesn't affect π_t and y_t contemporaneously

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 (π_t, y_t) is due to (π_t, y_t) influencing i_t but not the other way around
   - If i_t influences (π_t, y_t) (contemporaneously), we have a "simultaneous equation problem" (ϵ_t correlated with (π_t, y_t))
   - Assumption being made: i_t is "fast-moving" variable, while π_t and y_t are slow moving. So i_t doesn't affect π_t and y_t contemporaneously

Often, the discussion of identification stops here and seems surprisingly inocuous. Where did the rabbit go into the hat?

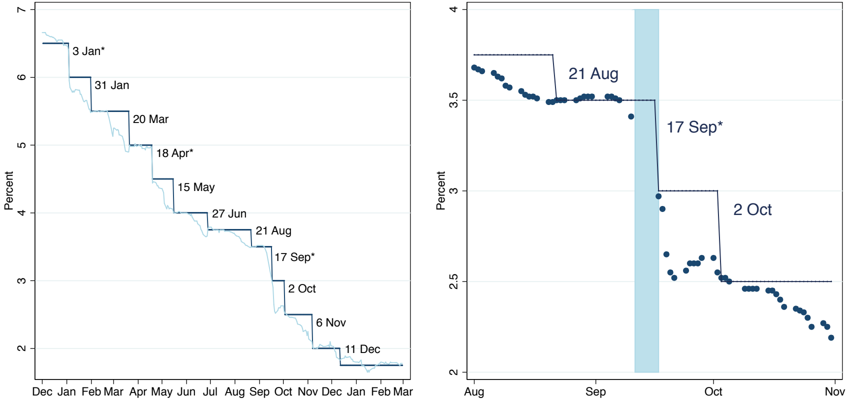
SVARs: Identifying the Shocks

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

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?



Dark line: Fed funds target. Light line/dots: 1-month eurodollar rate. * indicates unscheduled meeting.
Sample period: Dec 2000 - Feb 2002. Source: Nakamura and Steinsson (2018)

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!
  - Fed dropped rates in Sept 2001 in response to terrorist attack, which affected Fed's assessment of future output growth and inflation
- Any unusual (from perspective of VAR) weakness in output growth after 9/11, perversely, attributed to exogenous easing of monetary policy
- Highly problematic

NEWS SHOCKS AND VARS

- 9/11 an example of a news shock
    - Almost nothing happened to contemporaneous output
    - But event contains news about future output

- 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?

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)

Identifying Assumptions in SVARs

- "The" identifying assumption in a monetary VAR often described as:
  - Fed funds rate does not affect output, inflation, etc. contemporaneously
- Seems like magic:
  - You make one relatively innocuous assumption
  - Violá: You can estimate dynamic causal effects of monetary policy

Identifying Assumptions in SVARs

- Timing assumption not only identifying assumption being made
- Timing assumption rules out reverse causality
  - Contemporaneous correlation assumed to go from output to interest rates
  - Not other way around
- Bigger concern: Omitted variables bias
  - Monetary policy and output may be reacting to some other shock
  - If not sufficiently proxied by included controls, this shock will cause omitted variables bias (e.g., 9/11)

Romer-Romer 04

- 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

Constructing the Shocks Series

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

Constructing the Shocks Series

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
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)

Controlling for Greenbook Forecast

Romer-Romer's specification:

$$\begin{aligned}\Delta ff_m &= \alpha + \beta ffb_m + \sum_{i=-1}^{2} \gamma_i \Delta \tilde{y}_{mi} + \sum_{i=-1}^{2} \lambda_i (\Delta \tilde{y}_{mi} - \Delta \tilde{y}_{m-1,i}) \\ &\quad + \sum_{i=-1}^{2} \phi_i \tilde{\pi}_{mi} + \sum_{i=-1}^{2} \theta_i (\tilde{\pi}_{mi} - \tilde{\pi}_{m-1,i}) + \rho \tilde{u}_{m0} + \epsilon_m\end{aligned}$$

- Δff_m change in intended FFR at meeting
- ffb_m level before meeting
- $\tilde{y}$, $\tilde{\pi}$, $\tilde{u}$ forecasts of output, inflation, and unemployment
- Both forecasts and change in forecasts since last meeting included

Does this Make Sense?

- Residual ϵ_m considered exogenous monetary policy shock
- Does this make sense?

Does this Make Sense?

- Residual ϵ_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.

Cochrane (2004)

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.

Cochrane (2004)

Preferred specification for effects on output:

$$\Delta ff_m = \alpha + \sum_{i=-1}^{2} \gamma_i \Delta \tilde{y}_{mi} + \beta ff_{m-1} + \delta \Delta ff_{m-1} + \epsilon_m^y$$

Preferred specification for effects on inflation:

$$\Delta ff_m = \alpha + \sum_{i=-1}^{2} \gamma_i \Delta \tilde{\pi}_{mi} + \beta ff_{m-1} + \delta \Delta ff_{m-1} + \epsilon_m^\pi$$

Cochrane (2004)

Preferred specification for effects on output:

$$\Delta ff_m = \alpha + \sum_{i=-1}^{2} \gamma_i \Delta \tilde{y}_{mi} + \beta ff_{m-1} + \delta \Delta ff_{m-1} + \epsilon_m^y$$

Preferred specification for effects on inflation:

$$\Delta ff_m = \alpha + \sum_{i=-1}^{2} \gamma_i \Delta \tilde{\pi}_{mi} + \beta ff_{m-1} + \delta \Delta ff_{m-1} + \epsilon_m^\pi$$

- Lagged FFR only included to make shocks serially uncorrelated, which simplifies interpretation

Cochrane (2004)

Preferred specification for effects on output:

$$\Delta ff_m = \alpha + \sum_{i=-1}^{2} \gamma_i \Delta \tilde{y}_{mi} + \beta ff_{m-1} + \delta \Delta ff_{m-1} + \epsilon_m^y$$

Preferred specification for effects on inflation:

$$\Delta ff_m = \alpha + \sum_{i=-1}^{2} \gamma_i \Delta \tilde{\pi}_{mi} + \beta ff_{m-1} + \delta \Delta ff_{m-1} + \epsilon_m^\pi$$

- 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

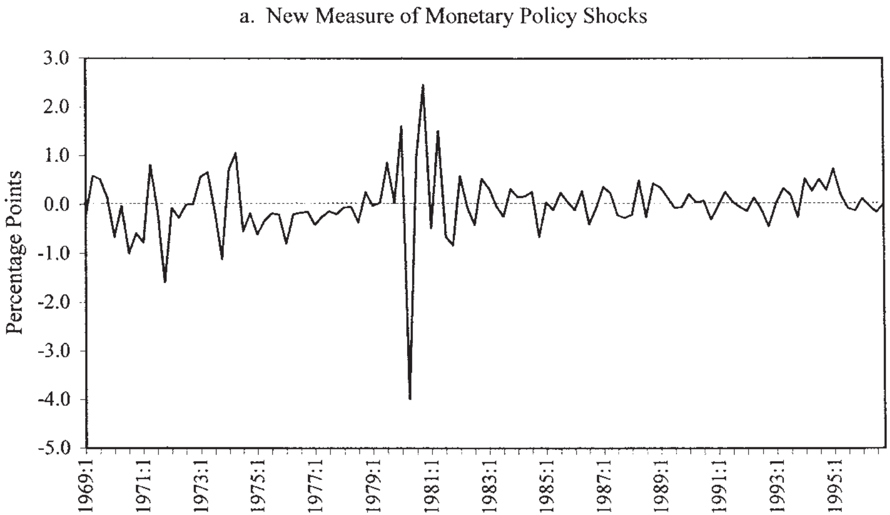
Romer-Romer 04 / Cochrane 04: What Is a Monetary Shock?

- 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

Romer-Romer Shocks



Source: Romer and Romer (2004).

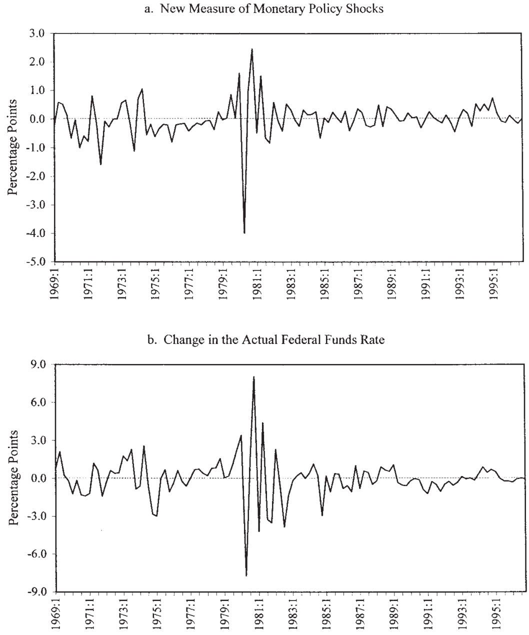


FIGURE 1. MEASURES OF MONETARY POLICY

Source: Romer and Romer (2004).

PREDICTABLE MONETARY SHOCKS?

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

Predictable Monetary Shocks?

- 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)

Direct Regressions – Jorda Specification

- 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: ν_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

Romer-Romer 04 Impulse Response

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

- Δy_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

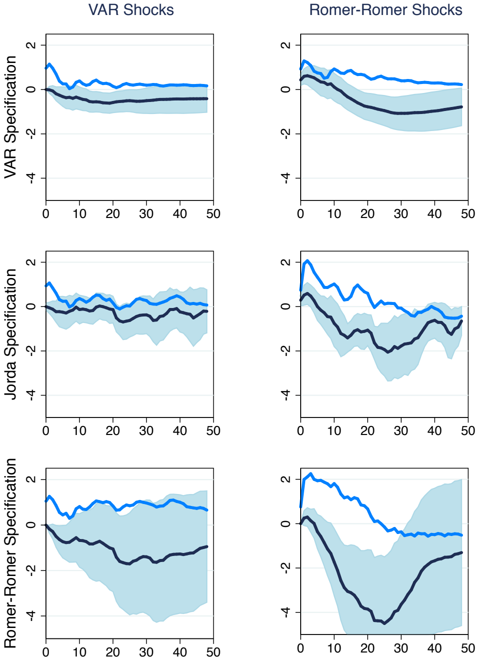
$$\Delta y_t = a_0 + \sum_{k=1}^{11} a_k D_{kt} + \sum_{i=1}^{24} b_i \Delta y_{t-i} + \sum_{j=1}^{36} c_j S_{t-j} + e_t$$

- Inclusion of lagged dependent variables may induce bias
- b_is are estimated off of dynamics of output to **all shocks**
- If dynamics after monetary shocks are different, inclusion of lagged output terms will induce bias

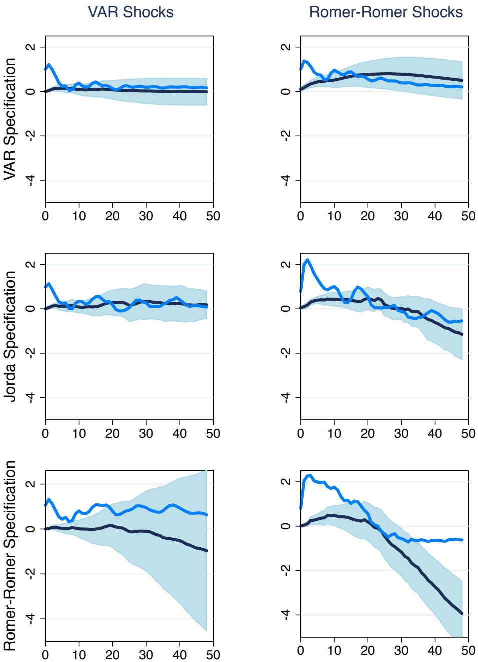
Lagged Dependent Variables

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

- Inclusion of lagged dependent variables may induce bias
- b_is 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



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



Black line: CPI. Blue line: Nominal interest rate

High Frequency Identification and the Information Effect

Jon Steinsson

UC Berkeley

January 2020

High Frequency Identification

- A substantial amount of monetary news is released at the end of each FOMC meeting
- Possible to use a “discontinuity” based identification approach
- Look at changes in interest rates during a narrow window around FOMC meeting
  - One-day window or 30-minute window
- Basic idea: Changes in interest rates at these times dominated by monetary announcement

Cook and Hahn 89

- 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]

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

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

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

[b] Significant at the 1% level, using a two-tailed test.

[c] Significant at the 5% level, using a two-tailed test.

Source: Cook and Hahn (1989).

Cook and Hahn 89

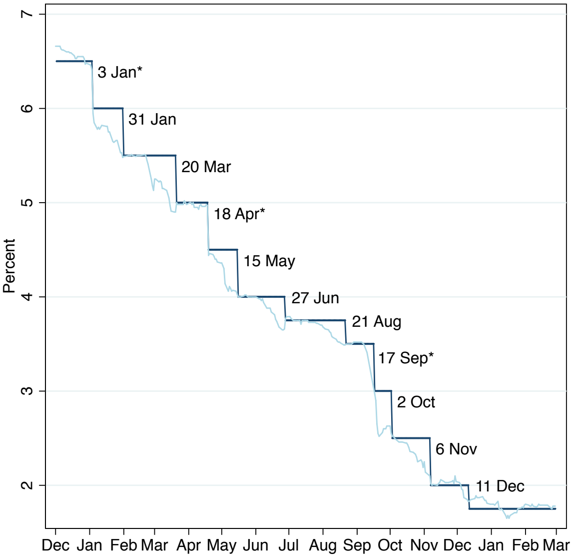
- 100bp change in fed funds target moves 3M Tbill rate by only 55bp
- Suggests that Fed can't move nominal interest rates very effectively

- Really?
- What concern might arise with this approach?

Cook and Hahn 89

- 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



Source: Nakamura and Steinsson (2018), based on Cochrane and Piazzesi (2002).

Fed funds target and 1 month Eurodollar rate in 2001. * indicates move at unscheduled meeting of FOMC

Kuttner 01

- 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

Date		FOMC	Actual	Expected	Unexpected
1989	6/6		− 25	− 24	− 1
	7/7	√	− 25	− 22	− 3
	7/27		− 25	− 25	0
	10/18		− 25	− 25	0
	11/6		− 25	− 29	+4
	12/20	√	− 25	− 8	− 17
1990	7/13		− 25	− 11	− 14
	10/29		− 25	+6	− 31
	11/14	√	− 25	− 29	+4
	12/7		− 25	+2	− 27
	12/18	√	− 25	− 4	− 21
1991	1/8		− 25	− 7	− 18
	2/1		− 50	− 25	− 25
	3/8		− 25	− 9	− 16
	4/30		− 25	− 8	− 17
	8/6		− 25	− 10	− 15
	9/13		− 25	− 20	− 5
	10/31		− 25	− 20	− 5
	11/6	√	− 25	− 13	− 12
	12/6		− 25	− 16	− 9
	12/20		− 50	− 22	− 28
1992	4/9		− 25	− 1	− 24
	7/2	√	− 50	− 14	− 36
	9/4		− 25	− 3	− 22
1994	2/4	√	+25	+13	+12
	3/22	√	+25	+28	− 3
	4/18		+25	+15	+10
	5/17	√	+50	+37	+13

Source: Kuttner (2001)

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

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

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

Source: Kuttner (2001). Responses in basis points to 100 basis point change.

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

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

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

Source: Kuttner (2001). Responses in basis points to 100 basis point change.

Summing Up

- 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!!

Do Actions Speak Loader Than Words?

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

Do Actions Speak Loader Than Words?

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)

Forward Guidance

- 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

Gurkaynak-Sack-Swanson 05

- 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

Gurkaynak-Sack-Swanson 05

- 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)

Path Factor

- 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)

Path Factor

- GSS 05 perform principle component analysis on the 5 fed funds and eurodollar futures
- Two factors needed to characterize effect of FOMC announcements:
  - Target factor (unexpected changes in current fed funds rate)
  - Path factor (changes in future rates orthogonal to changes in current rate)
- Bulk of response of longer-term rates is to path factor

Table 5. Response of Asset Prices to Target and Path Factors

	One Factor			Two Factors			
	Constant (std. err.)	*Target Factor (std. err.)*	R^2	*Constant (std. err.)*	*Target Factor (std. err.)*	*Path Factor (std. err.)*	R^2
MP Surprise	–0.021*** (0.003)	1.000*** (0.047)	.91	–0.021*** (0.003)	1.000*** (0.048)	0.001 (0.026)	.91
One-Year-Ahead Eurodollar Future	–0.018*** (0.006)	0.555*** (0.076)	.36	–0.017*** (0.001)	0.551*** (0.017)	0.551*** (0.014)	.98
S&P 500	–0.008 (0.041)	–4.283*** (1.083)	.37	–0.008 (0.040)	–4.283*** (1.144)	–0.966 (0.594)	.40
Two-Year Note	–0.011** (0.005)	0.485*** (0.080)	.41	–0.011*** (0.002)	0.482*** (0.032)	0.411*** (0.023)	.94
Five-Year Note	–0.006 (0.005)	0.279*** (0.078)	.19	–0.006** (0.002)	0.276*** (0.044)	0.369*** (0.035)	.80
Ten-Year Note	–0.004 (0.004)	0.130** (0.059)	.08	–0.004* (0.002)	0.128*** (0.039)	0.283*** (0.025)	.74
Five-Year Forward Rate Five Years Ahead	0.001 (0.003)	–0.098** (0.049)	.06	0.001 (0.003)	–0.099** (0.047)	0.157*** (0.028)	.34

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.

Source: Gurkaynak-Sack-Swanson (2005). Window length: 30-minutes.

Table 4. Ten Largest Observations of the Path Factor

Date	Z_1 (Target Factor)	Z_2 (Path Factor)	Statement	Financial Market Commentary
Jan. 28, 2004	–1.1	42.7	√	Statement drops commitment to keep policy unchanged for "a considerable period," bringing forward expectations of future tightenings
Jul. 6, 1995	–8.7	–38.4	√	First easing after long (seventeen-month) series of tightenings raises expectations of further easings; statement notes that inflationary pressures have receded
Aug. 13, 2002	8.1	–37.2	√	Statement announces balance of risks has shifted from neutral to economic weakness
May 18, 1999	0.5	32.8	√	Statement announces change in policy bias going forward from neutral to tightening
May 6, 2003	5.2	–27.0	√	Statement announces balance of risks now dominated by risk of "an unwelcome substantial fall in inflation"
Dec. 20, 1994	–15.1	26.6		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
Oct. 5, 1999	–2.7	25.8	√	Statement announces change in policy bias going forward from neutral to tightening
Oct. 28, 2003	3.9	–24.4	√	Statement leaves the "considerable period" commitment unchanged, pushing back expectations of future tightenings
Jan. 3, 2001	–32.3	22.8	√	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
Oct. 15, 1998	–24.0	–22.6	√	First intermeeting move since 1994 and statement pointing to "unsettled conditions in financial markets... restraining aggregate demand" increases expectations of further easings

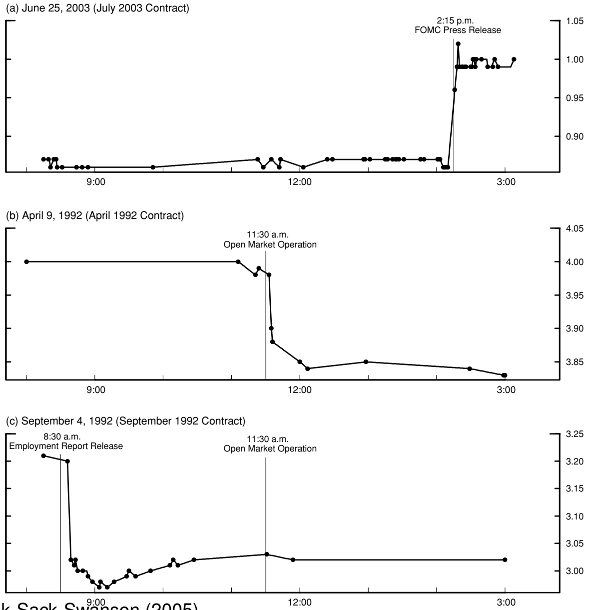
Source: Gurkaynak-Sack-Swanson (2005)

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



Source: Gurkaynak-Sack-Swanson (2005)

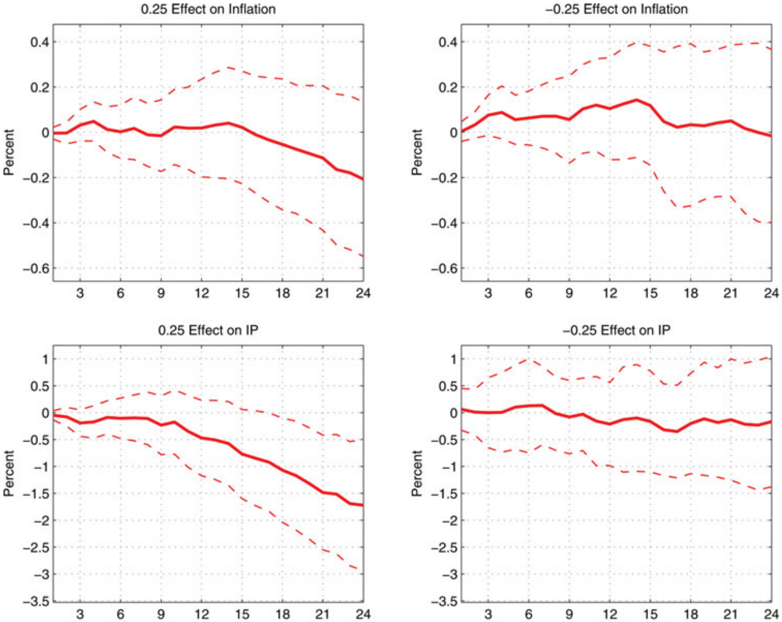
The Power Problem

- HFI arguably the cleanest way to identify monetary shocks

  ... but shocks are small and sample short

- Regressions on future output very imprecise
  (Cochrane-Piazzesi 02, Angrist-Jorda-Kuersteiner 17)

- Angrist-Jorda-Kuersteiner 17
  - Policy indicator: unexpected fed funds target changes
  - Window: one-day (although slightly unusual methods)
  - Outcome variable: inflation, industrial production
  - Allow for different effects of increases and decreases



Source: Angrist-Jorda-Kuersteiner (2017). 90% confidence bands. Vertical axis is in months.

The Power Problem

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

The Power Problem

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

Gertler-Karadi 15

- Primary interest: Effects of monetary policy on credit spreads

Gertler-Karadi 15

- 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)

VAR with External Instruments

- Neither assumption palatable
- Both MP indicator and credit spreads "fast moving" variables
  - Hard to know which direction of causation explains contemporaneous correlation

VAR with External Instruments

- 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

HFI-VAR Identification of Monetary Policy

- 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

HFI-VAR Identification of Monetary Policy

- 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

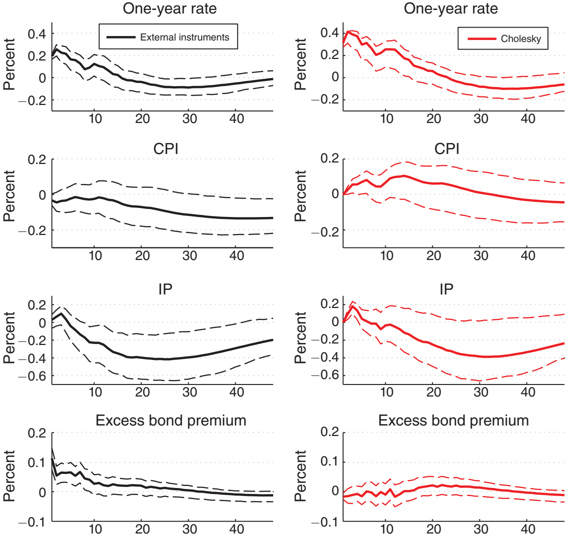
- Iterate forward VAR dynamics to construct impulse response

Gertler-Karadi 15: VAR

- 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

Gertler-Karadi 15: HFI

- External instrument: Fed funds future 3 months ahead (FF4)
- Event window for instruments: 30 minutes
- Sample period for instruments: 1991:1-2012:6



First-stage regression:
F: 21.55; Robust F: 17.64; R^2: 7.76 percent; Adjusted R^2: 7.40 percent

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

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

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

Identifictaion 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

What Can we Learn from Real Rates?

- 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

Nakamura-Steinsson 2018

- 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

	Nominal	Real	Inflation
2Y Treasury Yield	1.10	1.06	0.04
	(0.33)	(0.24)	(0.18)
5Y Treasury Yield	0.73	0.64	0.09
	(0.20)	(0.15)	(0.11)
10Y Treasury Yield	0.38	0.44	-0.06
	(0.17)	(0.13)	(0.08)
2Y Treasury Inst. Forward Rate	1.14	0.99	0.15
	(0.46)	(0.29)	(0.23)
3Y Treasury Inst. Forward Rate	0.82	0.88	-0.06
	(0.43)	(0.32)	(0.15)
5Y Treasury Inst. Forward Rate	0.26	0.47	-0.21
	(0.19)	(0.17)	(0.08)
10Y Treasury Inst. Forward Rate	-0.08	0.12	-0.20
	(0.18)	(0.12)	(0.09)

Source: Nakamura-Steinsson (2018). Window: 30-minutes.

Large Effects on Real Rates

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

BACKGROUND NOISE

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

BACKGROUND NOISE

- 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

Background Noise

- 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 (Δi_t) and other variables of interest (Δs_t) affected by monetary shock (ϵ_t) and other shocks (η_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

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

Source: Nakamura-Steinsson (2018)

Interpreting the Results

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"

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”

Additional prediction:

- Expected output should fall

Output Expectations Actually Rise!

Table 3: Response of Expected Output Growth Over the Next Year

	1995-2014	2000-2014	2000-2007	1995-2000
Policy News Shock	1.01	1.04	0.95	0.79
	(0.32)	(0.35)	(0.32)	(0.63)
Observations	120	90	52	30

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 we have data for is 1995m1-2014m4; this is also the period for which the policy news shocks is constructed. We also present results for 2000m1-2014m4 (which corresponds to the sample period used in Table 1), 2000m1-2007m12 (a pre-crisis sample period), and 1995m1-1999m12. As in our other analysis, we drop data from July 2008 through June 2009. Robust standard errors are in parentheses.

Source: Nakamura-Steinsson (2018)

Is this Crazy?

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

Is this Crazy?

- 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

The Role of Fed Information

Conventional interpretation of monetary shocks:

- Fed conveying information **only** about its own future policy

The Role of Fed Information

Conventional interpretation of monetary shocks:

- 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)

The Role of Fed Information

Conventional interpretation of monetary shocks:

- 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)

Fed information view:

- Fed conveys information about its own future policy
  but also about current and future exogenous shocks

The Role of Fed Information

Conventional interpretation of monetary shocks:

- 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)

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
  - Very limited signal space
  - 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?

- 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
- 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

$$\hat{x}_t = -\sigma \sum_{j=0}^{\infty} E_t(\hat{\imath}_{t+j} - \hat{\pi}_{t+j+1} - \hat{r}^n_{t+j})$$

Fed Information Effect

Conventional view of monetary policy shocks:

- Fed conveying information about future monetary policy

$$\hat{x}_t = -\sigma \sum_{j=0}^{\infty} E_t(\hat{\imath}_{t+j} - \hat{\pi}_{t+j+1} - \hat{r}^n_{t+j})$$

Fed Information Case:

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

$$\hat{x}_t = -\sigma \sum_{j=0}^{\infty} E_t(\hat{\imath}_{t+j} - \hat{\pi}_{t+j+1} - \hat{r}^n_{t+j})$$

Fed Information Effect

Conventional view of monetary policy shocks:

- Fed conveying information about future monetary policy

$$\hat{x}_t = -\sigma \sum_{j=0}^{\infty} E_t(\hat{\imath}_{t+j} - \hat{\pi}_{t+j+1} - \hat{r}^n_{t+j})$$

Fed Information Case:

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

$$\hat{x}_t = -\sigma \sum_{j=0}^{\infty} E_t(\hat{\imath}_{t+j} - \hat{\pi}_{t+j+1} - \hat{r}^n_{t+j})$$

In simple model: $r^n_{t+j} = \sigma^{-1}(E_t y^n_{t+j+1} - y^n_{t+j})$

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

Non-Neutrality with Fed Information

Inflation response determined by interest rate **gap**:

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

If Fed information large:

- Interest rate gap small
- Traditional power of Fed small

Non-Neutrality with Fed Information

Inflation response determined by interest rate **gap**:

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

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

Potential Policy Dilemma

- 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

New Credibility Issue

- 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

Nature of Fed Language

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)

Lunsford (2019)

- 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

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?

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

Why Care About Price Rigidity in Macro?

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

Why Care About Price Rigidity in Macro?

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

Major challenge: How to explain this empirical finding?

Why Care About Price Rigidity in Macro?

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

Major challenge: How to explain this empirical finding?

- In RBC type models, demand shocks have small effects on output

Why Care About Price Rigidity in Macro?

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

Major challenge: How to explain this empirical finding?

- In RBC type models, demand shocks have small effects on output

Leading explanation: Prices adjust sluggishly to shocks

Price Rigidity and the Business Cycles

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

Price Rigidity and the Business Cycles

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
- Sticky prices: Real rate sluggish unless nominal rate moves, output increases more

Price Rigidity and the Business Cycles

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
- Sticky prices: Real rate sluggish unless nominal rate moves, output increases more

Same logic implies muted response of real rates to other shocks such as: deleveraging shocks, financial panics, increased uncertainty, "animal spirits"

Could Price Rigidities Cause Major Recessions?

Could Price Rigidities Cause Major Recessions?

- Many people's first reaction is that this is not plausible

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

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)
  - Sharp increase in desire to save $\rightarrow$
    Sharp drop in "natural" rate of interest

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)
  - Sharp increase in desire to save $\rightarrow$
    Sharp drop in "natural" rate of interest
  - But if prices are sticky and nominal rate constrained by ZLB ...
    Real rate stuck at too high a level, output stuck at too low a level

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)
  - Sharp increase in desire to save $\rightarrow$
    Sharp drop in "natural" rate of interest
  - But if prices are sticky and nominal rate constrained by ZLB ...
    Real rate stuck at too high a level, output stuck at too low a level
- Financial disruptions and investment hang-overs have similar effects

Price Rigidity and Coordination Failure

- Nominal price stickiness not the whole story!

Price Rigidity and Coordination Failure

- Nominal price stickiness not the whole story!
- Usually combined with coordination failures among price setters
  - Staggered price setting
  - Strategic complementarity among price setters
    (firm A's optimal price increasing in firm B's price)

Price Rigidity and Coordination Failure

- Nominal price stickiness not the whole story!
- Usually combined with coordination failures among price setters
  - Staggered price setting
  - Strategic complementarity among price setters
    (firm A's optimal price increasing in firm B's price)
- These three features interact powerfully to create a lot of sluggishness and long-lived effect on output

Micro Price Rigidity and the Business Cycles

- 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

Micro Price Rigidity and the Business Cycles

- 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

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 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"

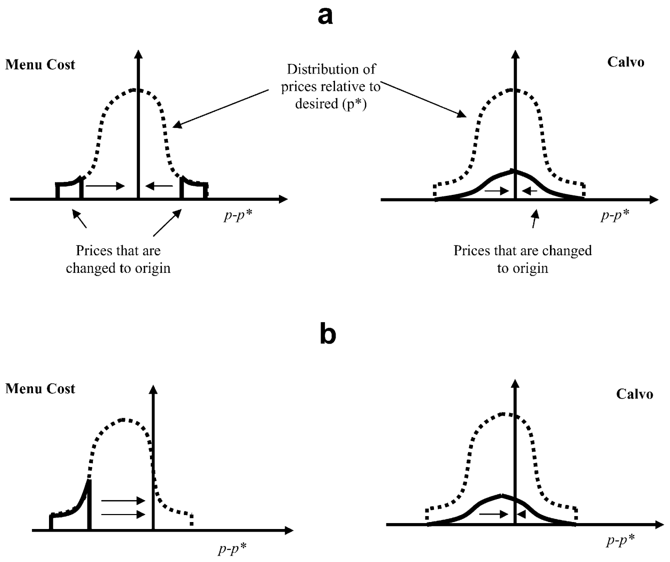


FIG. 6.—Price adjustment in menu cost and Calvo models. *a*, Price adjustment before aggregate shock. *b*, Price adjustment after aggregate shock.

Source: Golosov and Lucas (2007)

CAPLIN-SPULBER VS. CALVO

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)

Caplin-Spulber vs. Calvo

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)

Subsequent literature explores intermediate cases and uses empirical evidence on characteristics of micro price adjustment to choose between models

Golosov-Lucas (2007)

- 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?

Golosov-Lucas (2007)

- 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?
- Monetary non-neutrality is “small and transient”
  6 times smaller than in Calvo model

Assault on Keynesian Economics

Bils and Klenow (2004)

- 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

Keynesian Economics Fights Back

Perhaps Golosov-Lucas model not sufficiently realistic to yield credible policy conclusions

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?

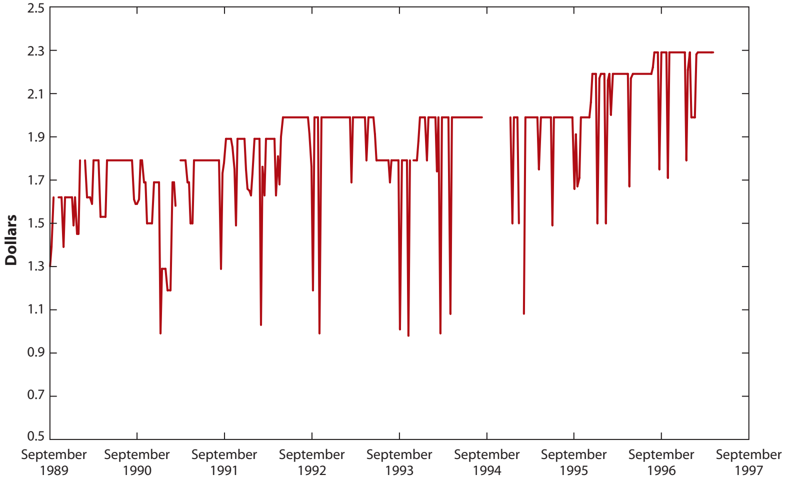


Figure 2

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

Source: Nakamura and Steinsson (2013)

Price Rigidity

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

Price Rigidity

Two features stand out:

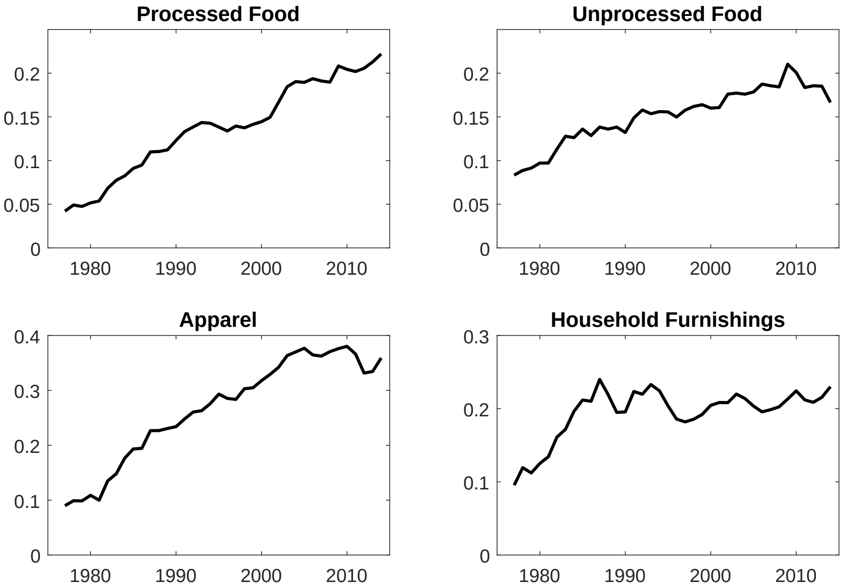
1. Change in “regular” price is infrequent and “lumpy”
   - Only 9 “regular price” changes in a 7 year period
2. Frequent temporary discounts (sales)
   - 117 price changes in 365 weeks

- Does this product have essentially flexible prices?
- Or is it’s price highly rigid?

Table: Frequency of Price Change by Major Group 1998-2005

Major Group	Weight	Reg. Price Freq.	Price Freq.	Frac. Price Ch. Sales
Processed Food	8.2	10.5	25.9	57.9
Unprocessed Food	5.9	25.0	37.3	37.9
Household Furnishing	5.0	6.0	19.4	66.8
Apparel	6.5	3.6	31.0	87.1
Transportation Goods	8.3	31.3	31.3	8.0
Recreation Goods	3.6	6.0	11.9	49.1
Other Goods	5.4	15.0	15.5	32.6
Utilities	5.3	38.1	38.1	0.0
Vehicle Fuel	5.1	87.6	87.6	0.0
Travel	5.5	41.7	42.8	1.5
Services (excl. Travel)	38.5	6.1	6.6	3.1

Source: Nakamura and Steinsson (2008)



Source: Nakamura-Steinsson-Sun-Villar (2018)

Table 1 Frequency of price change in consumer prices

	Median		Mean	
	Frequency	Implied duration	Frequency	Implied duration
Nakamura & Steinsson (2008)				
Regular prices (excluding substitutions 1988–1997)	11.9	7.9	18.9	10.8
Regular prices (excluding substitutions 1998–2005)	9.9	9.6	21.5	11.7
Regular prices (including substitutions 1988–1997)	13.0	7.2	20.7	9.0
Regular prices (including substitutions 1998–2005)	11.8	8.0	23.1	9.3
Posted prices (including substitutions 1998–2005)	20.5	4.4	27.7	7.7
Klenow & Kryvtsov (2008)				
Regular prices (including substitutions 1988–2005)	13.9	7.2	29.9	8.6
Posted prices (including substitutions 1988–2005)	27.3	3.7	36.2	6.8

Source: Nakamura and Steinsson (2013)

Is a Price Change Just a Price Change?

- 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?

Kehoe and Midrigan (2015)

- 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

Sales Orthogonal to Macro Shocks?

- 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

- 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?

Table 1 Frequency of price change in consumer prices

	Median		Mean	
	Frequency	Implied duration	Frequency	Implied duration
Nakamura & Steinsson (2008)				
Regular prices (excluding substitutions 1988–1997)	11.9	7.9	18.9	10.8
Regular prices (excluding substitutions 1998–2005)	9.9	9.6	21.5	11.7
Regular prices (including substitutions 1988–1997)	13.0	7.2	20.7	9.0
Regular prices (including substitutions 1998–2005)	11.8	8.0	23.1	9.3
Posted prices (including substitutions 1998–2005)	20.5	4.4	27.7	7.7
Klenow & Kryvtsov (2008)				
Regular prices (including substitutions 1988–2005)	13.9	7.2	29.9	8.6
Posted prices (including substitutions 1988–2005)	27.3	3.7	36.2	6.8

Source: Nakamura and Steinsson (2013)

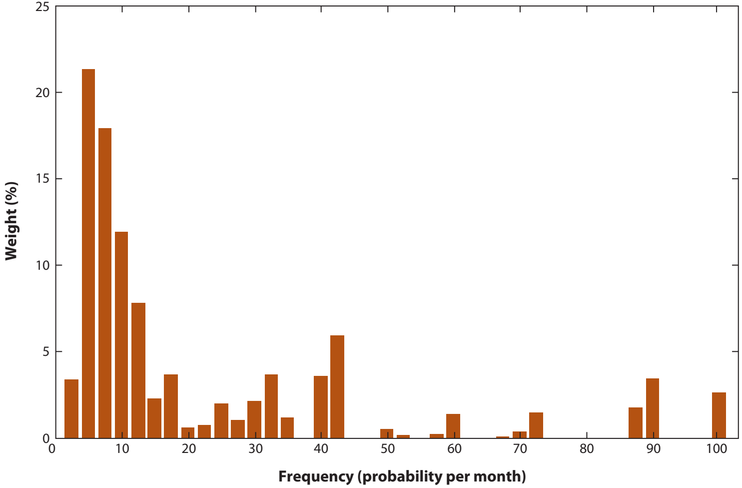


Figure 3

The expenditure weighted distribution of the frequency of regular price change (percent per month) across product categories (entry-level items) in the US Consumer Price Index (CPI) for the period 1998–2005. Data taken from Nakamura & Steinsson (2008).

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 and Monetary Non-Neutrality

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

Heterogeneity and Monetary Non-Neutrality

- Heterogeneity matters a lot!
- No model free answer for calibrating a single sector model
- In Taylor model: Bils-Klenow (2002) use median frequency

Heterogeneity and Monetary Non-Neutrality

- 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)

Heterogeneity and Monetary Non-Neutrality

- 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

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?

Figure: Seasonality in Product Substitution

Source: Nakamura and Steinsson (2008)

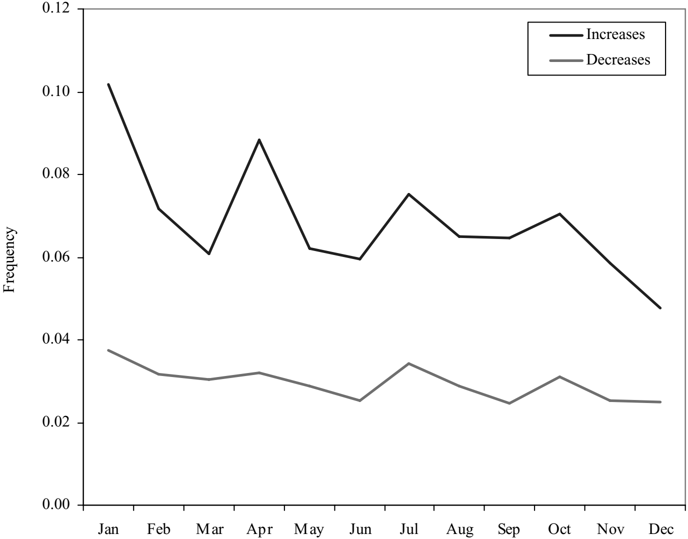
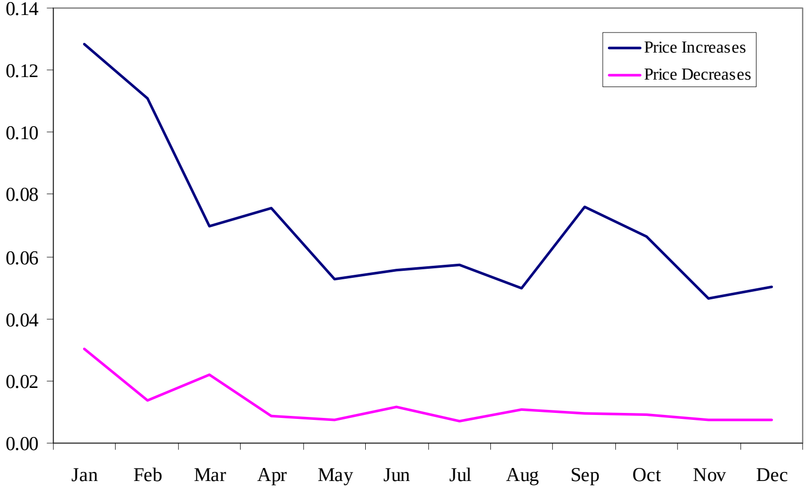


FIGURE V
Frequency of Regular Price Increases and Decreases by Month for Consumer Prices

Source: Nakamura and Steinsson (2008)

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

- How should re treat temporary sales?
- How does heterogeneity in price rigidity matter?
- Are all price changes selected?
- What is a realistic distribution of idiosyncratic shocks?

Midrigan (2011)

- Strength of selection effect highly sensitive to assumptions about distribution of idiosyncratic shocks

Midrigan (2011)

- Strength of selection effect highly sensitive to assumptions about distribution of idiosyncratic shocks
- Golosov-Lucas 07 assume normal shocks
- Suppose we instead assume shocks are either tiny or huge i.e., that they have huge kurtosis

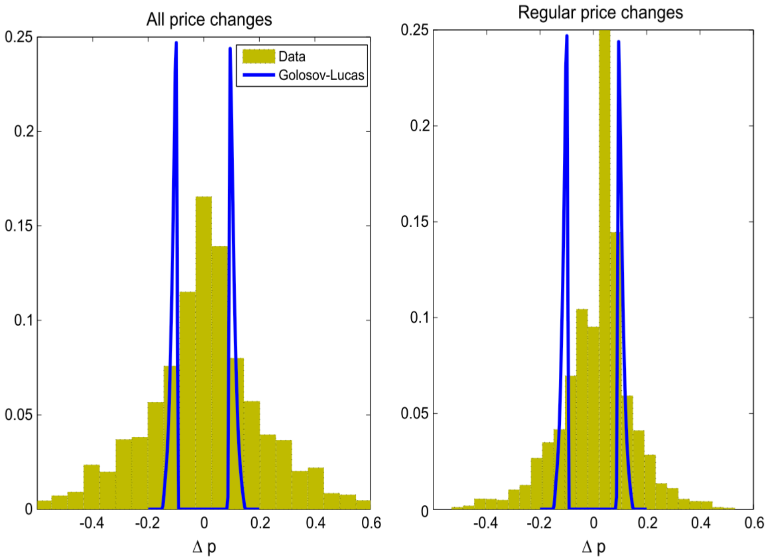
MIDRIGAN (2011)

- Strength of selection effect highly sensitive to assumptions about distribution of idiosyncratic shocks
- Golosov-Lucas 07 assume normal shocks
- Suppose we instead assume shocks are either tiny or huge i.e., that they have huge kurtosis
- In the limit, model becomes much like Calvo

Midrigan (2011)

- Strength of selection effect highly sensitive to assumptions about distribution of idiosyncratic shocks
- Golosov-Lucas 07 assume normal shocks
- Suppose we instead assume shocks are either tiny or huge i.e., that they have huge kurtosis
- In the limit, model becomes much like Calvo
- Midrigan evidence:
  - Size of price changes dispersed
  - Many small price changes
  - Coordination of timing of price changes within category

Distribution of p changes: Data vs. GL model



Source: Midrigan (2011)

Midrigan (2011)

Two changes to Golosov-Lucas model:

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

Midrigan (2011)

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:

$$\mathcal{M} = \frac{\delta}{6\epsilon} \frac{\mathrm{Kur}(\Delta p_i)}{\mathrm{N}(\Delta p_i)}$$

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

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:

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

  - δ size of monetary shock
  - $1/\epsilon - 1$ Frisch elasticity of labor supply
  - $\text{Kur}(\Delta p_i)$ kurtosis of size distribution of price changes
  - $\text{N}(\Delta p_i)$ frequency of price change
- Obviously, there are some simplifying assumptions
  (e.g., unit root shock, no inflation, no strategic complementarity, etc.)

Kurtosis is Key

$$\mathcal{M} = \frac{\delta}{6\epsilon} \frac{\mathrm{Kur}(\Delta p_i)}{\mathrm{N}(\Delta p_i)}$$

- Kurtosis in Calvo model is 6
- Kurtosis in Golosov-Lucas model is 1

Measuring Kurtosis

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

Optimal Level 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)

Optimal Level 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)

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

Benefits of Positive Inflation

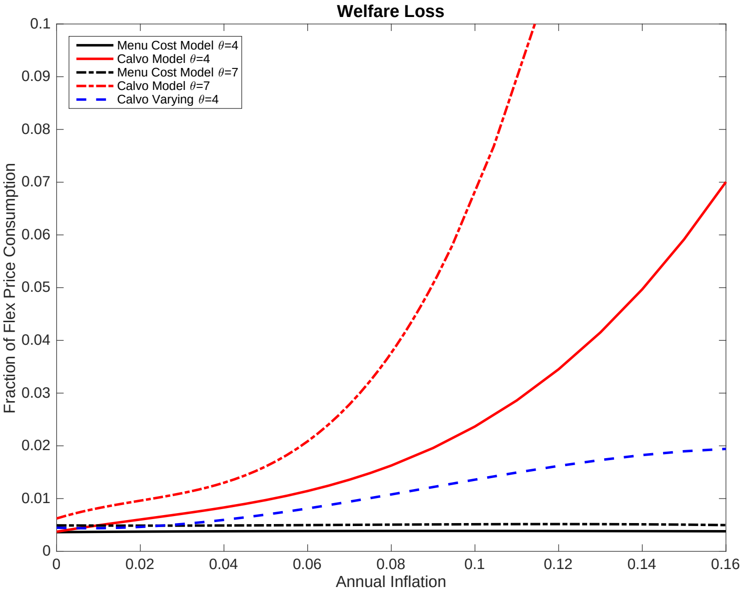
- Measured inflation is biased
- Further from ZLB
- Grease the wheels of the labor market

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

Price Dispersion and the Costs of Inflation

- 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)


Welfare Loss
Menu Cost Model θ=4
Calvo Model θ=4
Menu Cost Model θ=7
Calvo Model θ=7
Calvo Varying θ=4
Fraction of Flex Price Consumption
Annual Inflation
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16

Measuring Price Dispersion

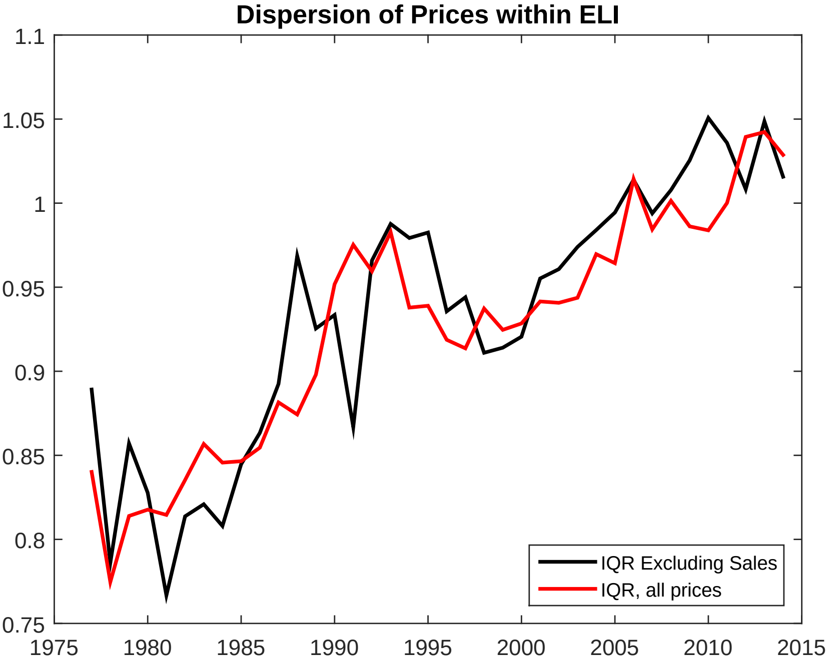
- If all products were homogenous within product category ...

  ... simply calculate cross-sectional variance

Measuring Price Dispersion

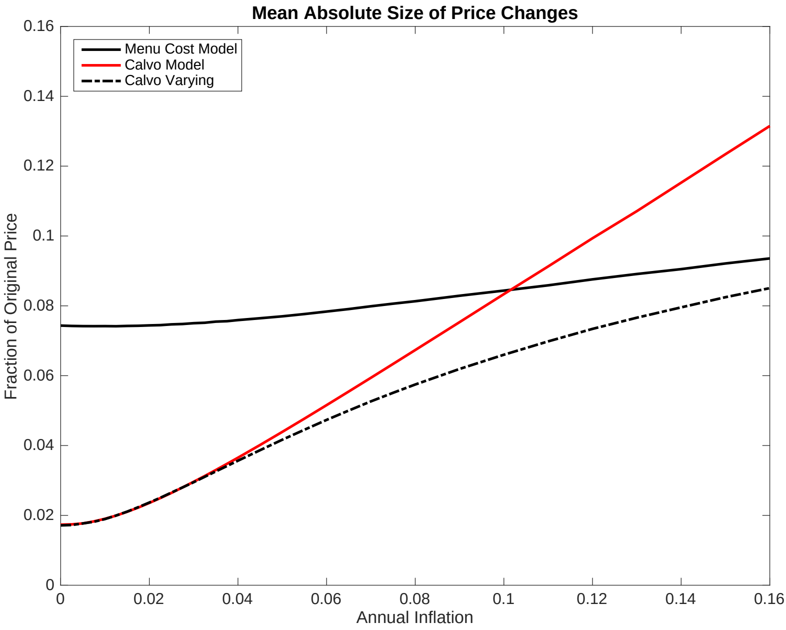
- If all products were homogenous within product category ...

  ... 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

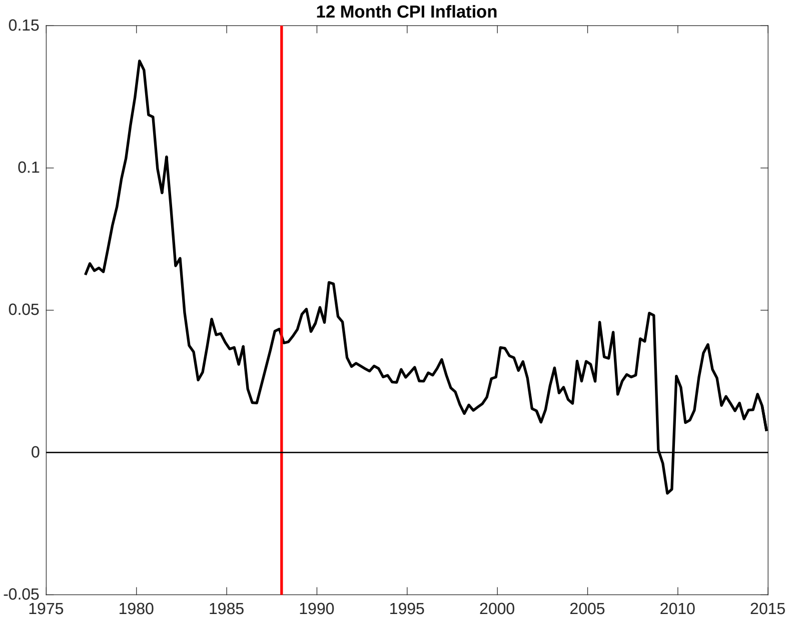

Dispersion of Prices within ELI
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
1975
1980
1985
1990
1995
2000
2005
2010
2015
IQR Excluding Sales
IQR, all prices

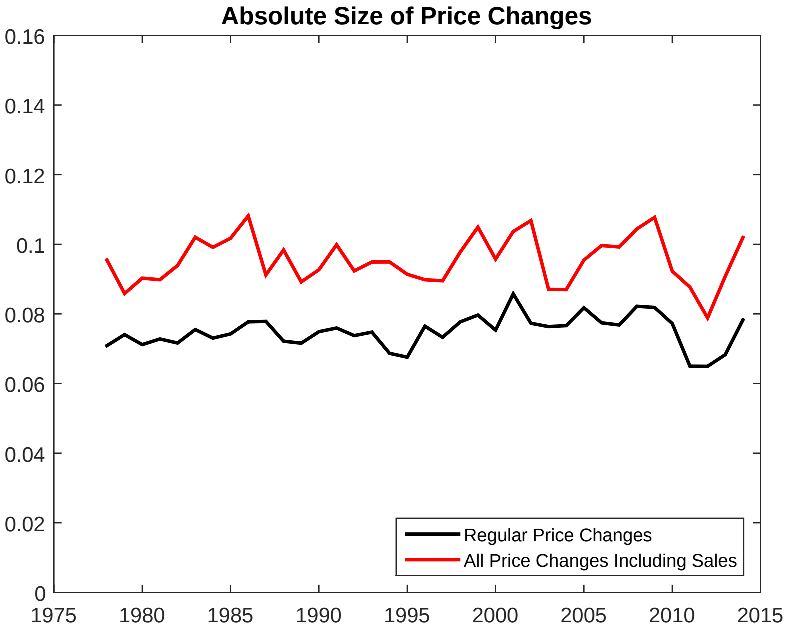
Measuring Price Dispersion

- 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 should change by more when they change



Mean Absolute Size of Price Changes
Menu Cost Model
Calvo Model
Calvo Varying
Fraction of Original Price
Annual Inflation
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16


12 Month CPI Inflation
0.15
0.1
0.05
0
-0.05
1975
1980
1985
1990
1995
2000
2005
2010
2015


Absolute Size of Price Changes
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1975
1980
1985
1990
1995
2000
2005
2010
2015
Regular Price Changes
All Price Changes Including Sales

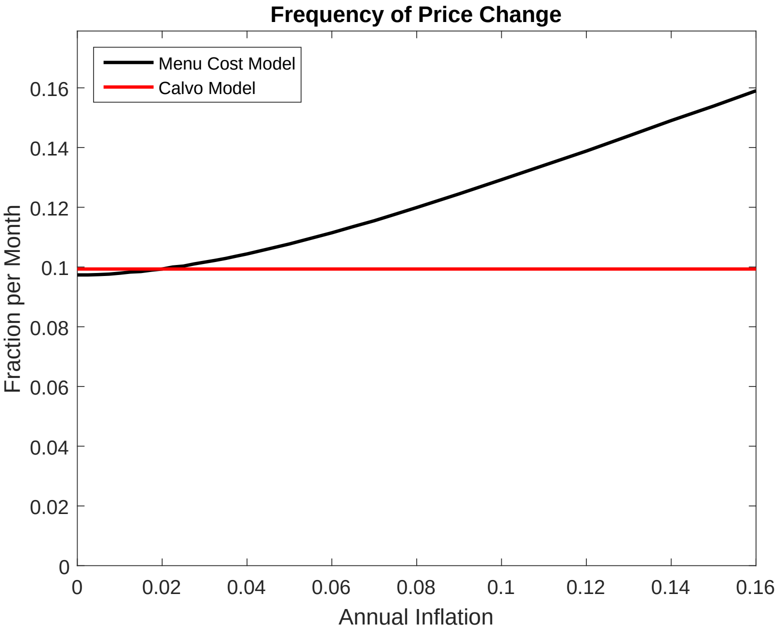
Nakamura-Steinsson-Sun-Villar 18

- 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 ...

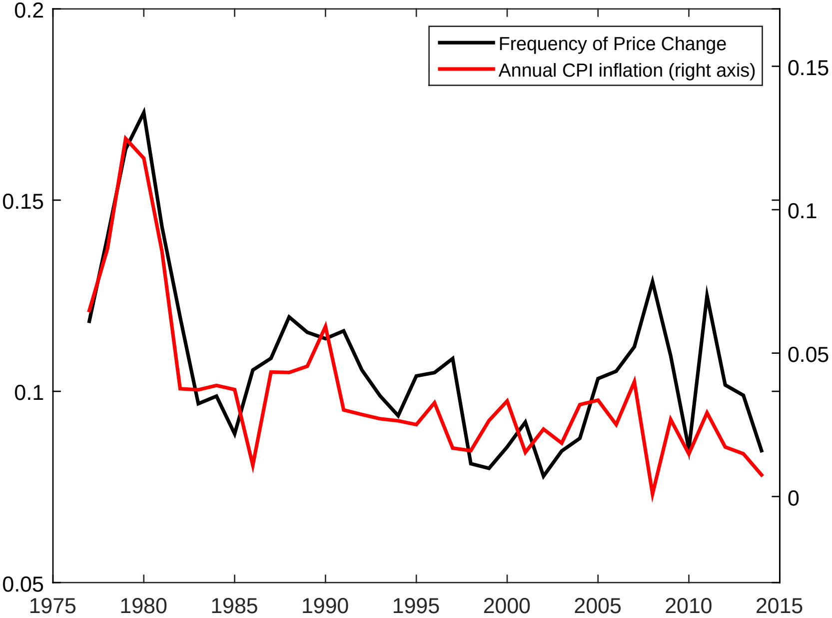
    ... but varies with inflation in menu cost model


Frequency of Price Change
Menu Cost Model
Calvo Model
Fraction per Month
Annual Inflation
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16

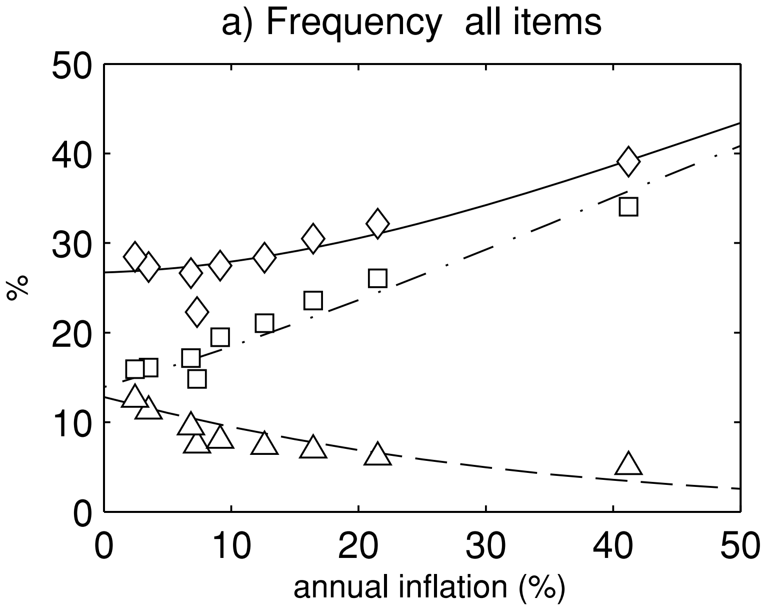
Frequency and Inflation

Evidence from three countries:

- Nakamura-Steinsson-Sun-Villar 18: U.S. 1978-2014 (Great Inflation/Volcker disinflation)
- Gagnon 09: Mexico 1994-2002 (Tequila crisis)
- Alvarez-Baraja-Gonzalez-Rozada-Neumeyer 19: Argentina 1988-1997 (Hyperinflation /Stabalization)

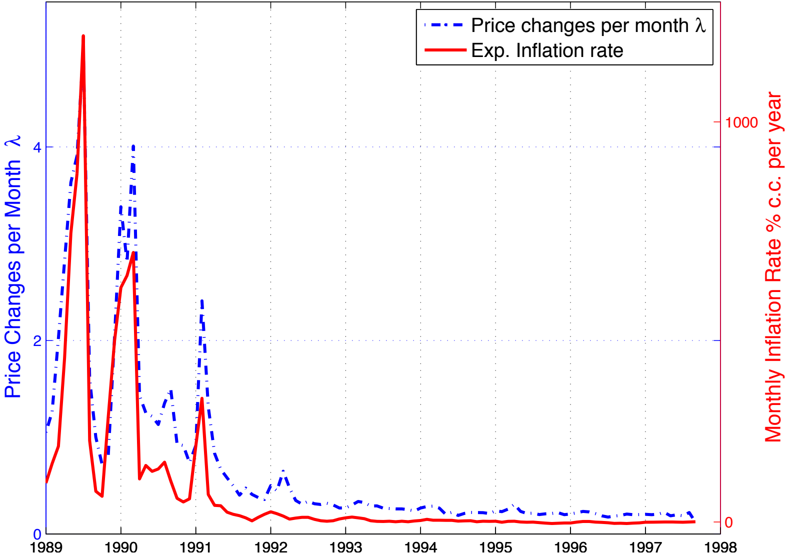


Source: Nakamura-Steinsson-Sun-Villar (2018)



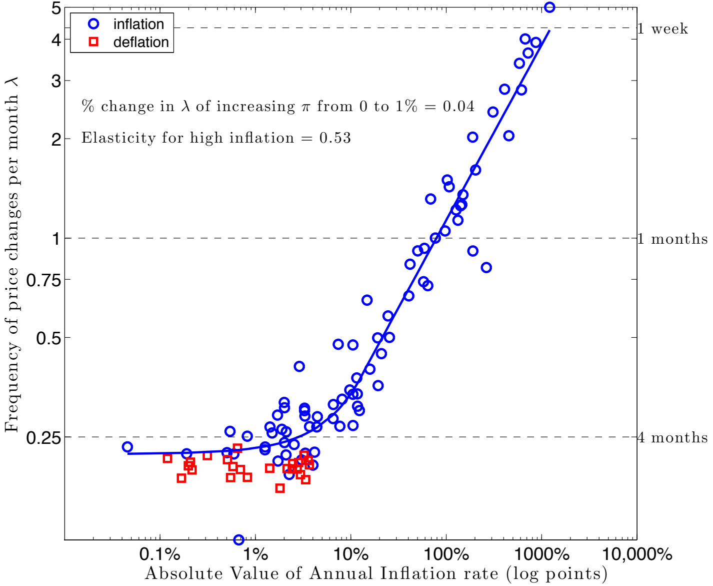
Source: Gagnon (2009). Diamonds: data on changes. Boxes: data on increases. Triangles: data on decreases. Lines: corresponding statistics from model.

Figure 5: Estimated Frequency of Price Changes λ and Expected Inflation



Source: Alverez-Beraja-Gonzalez-Rozada-Neumeyer (2019)

Figure 6: The Frequency of Price Changes (λ) and Expected Inflation.



Source: Alverez-Beraja-Gonzalez-Rozada-Neumeyer (2019)

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”

$$\pi = \lambda^+ \Delta^+ - \lambda^- \Delta^-$$

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

The Forward Guidance Puzzle

Emi Nakamura Jón Steinsson

UC Berkeley

January 2020

Deep Background

- Keynesian macroeconometric models of 1950s/60s:
  - Backward-looking system

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

DEEP BACKGROUND

- 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:

$$c_t = E_t c_{t+1} - \sigma(i_t - E_t \pi_{t+1})$$
$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t$$

Deep Background

- 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:

$$c_t = E_t c_{t+1} - \sigma(i_t - E_t \pi_{t+1})$$
$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t$$

- Maybe the world is somewhere in between??

Forward Guidance

- 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

Forward Guidance

"I have learned to mumble with great incoherence."

Alan Greenspan, 1987

"Monetary Policy is 98% talk and 2% action."

Ben Bernanke, 2015

Forward Guidance: Examples

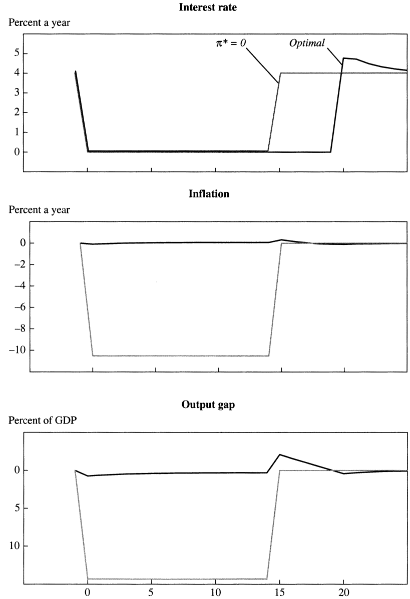
- Examples from FOMC statements:
  - 2003-04: "considerable period"
  - 2004-05: "pace that is likely to be measured"
  - 2008-09: "some time"; "an extended period".
  - 2011-12: "mid 2013"; "late 2014"; "mid 2015".
  - Dec 2012: while U above 6.5%, π below 2.5%, $E\pi$ anchored
  - 2014-15: "considerable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

Forward Guidance in Standard Models

- 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[a]



Source: Authors' calculations.
a. Response to a fall in the natural rate of interest below zero for a period of fifteen quarters.

Source: Eggertsson and Woodford (2003)

Forward Guidance in Standard Models

- 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

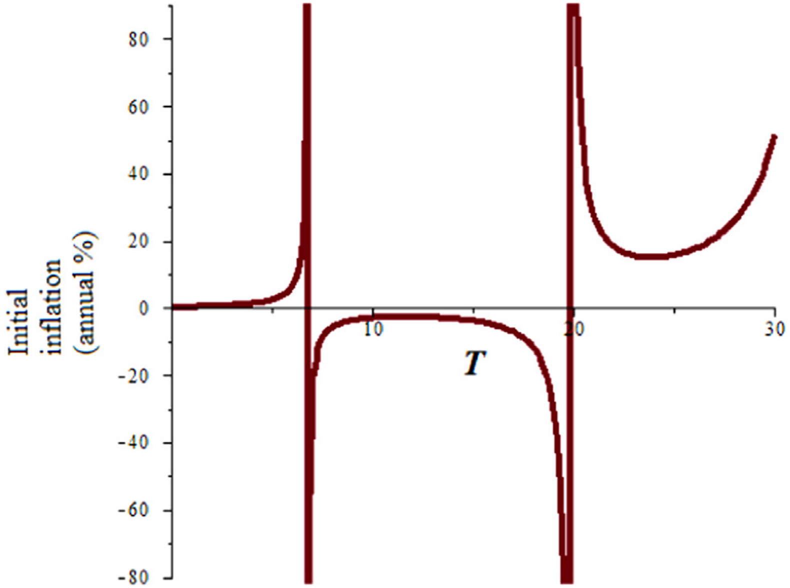


Fig. 2. Initial inflation and forward guidance (T).

Source: Carlstrom-Fuerst-Paustian (2015)

Forward Guidance in Standard Models

- 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:

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

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

Here x_t is output gap and π_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 π_t is inflation

- Simple monetary policy:

$$i_t - E_t \pi_{t+1} = r_t^n + \epsilon_{t,t-j}$$

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 π_t is inflation

- Simple monetary policy:

$$i_t - E_t \pi_{t+1} = r_t^n + \epsilon_{t,t-j}$$

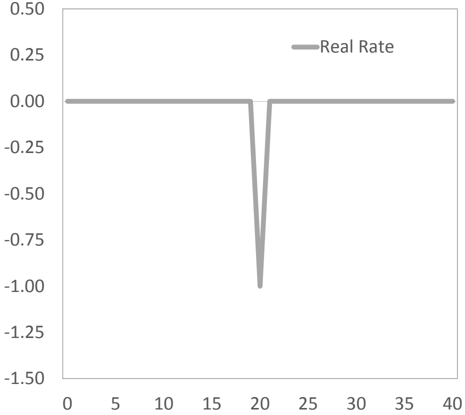
- Steady state absent monetary shocks:

$$E_t(i_{t+j} - E_{t+j}\pi_{t+j+1}) = E_t r_{t+j}^n$$

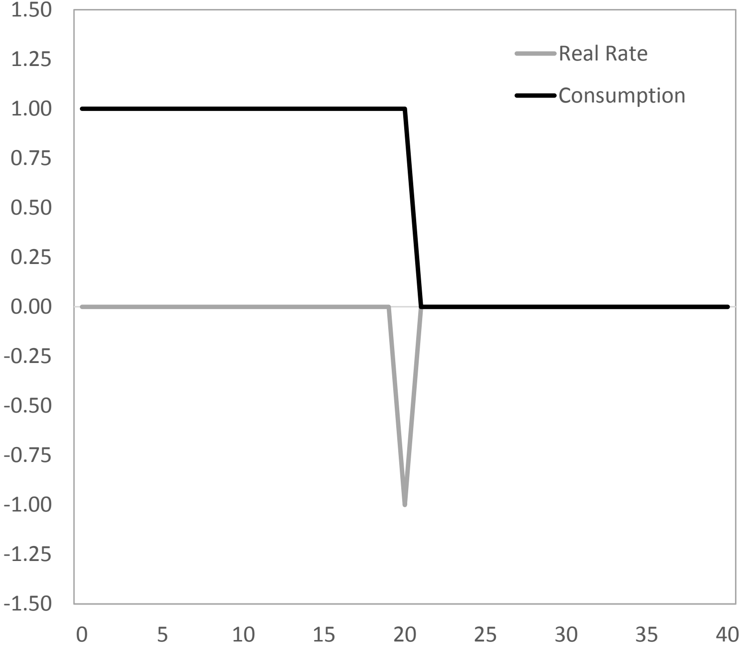
$$x_t = 0, \qquad \pi_t = 0$$

Illustrative Experiment

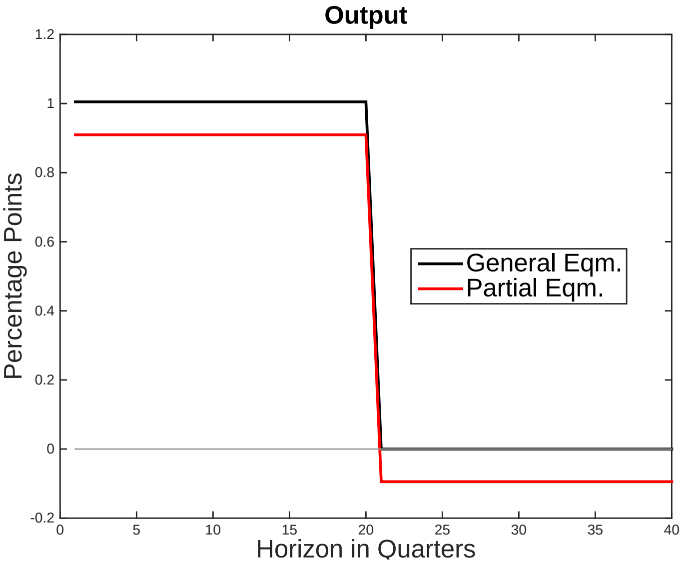
- Suppose central bank promises to lower real rates by 1% for 1 quarter 5 years from now



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


Real Rate
Consumption
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
-1.50
0
5
10
15
20
25
30
35
40

Partial equilibrium



Response of Consumption

- Raise consumption today by 1% and keep it high for 5 years
- Solve forward Euler equation:

$$x_t = -\sum_{j=0}^{\infty} E_t(i_{t+j} - E_{t+j}\pi_{t+j+1} - r^n_{t+j})$$

- Undiscounted sum of future interest rate gaps
- Response is large in that it lasts for a long time (large integral)

Response of Inflation

- 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

Systematic Monetary Policy

- Illustrative experiment: Real rate held constant in lead-up

Systematic Monetary Policy

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

Systematic Monetary Policy

- 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

Systematic Monetary Policy

- 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

Is Consumption Response 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?

Is Consumption Response 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

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

Is Consumption Response 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

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

- Gives rise to a "discounted" Euler equation:

$$c_t = \alpha E_t c_{t+1} - \sigma(i_t - E_t \pi_{t+1} - r^n_t)$$

Discounted Euler Equation

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

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

Incomplete Markets Model: Government

Fiscal authority:

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

Monetary authority:

- Sets path for real interest rate

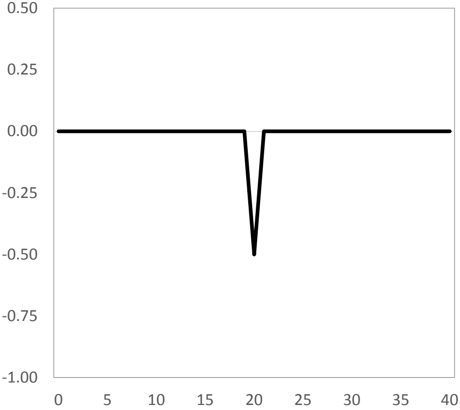
CALIBRATION

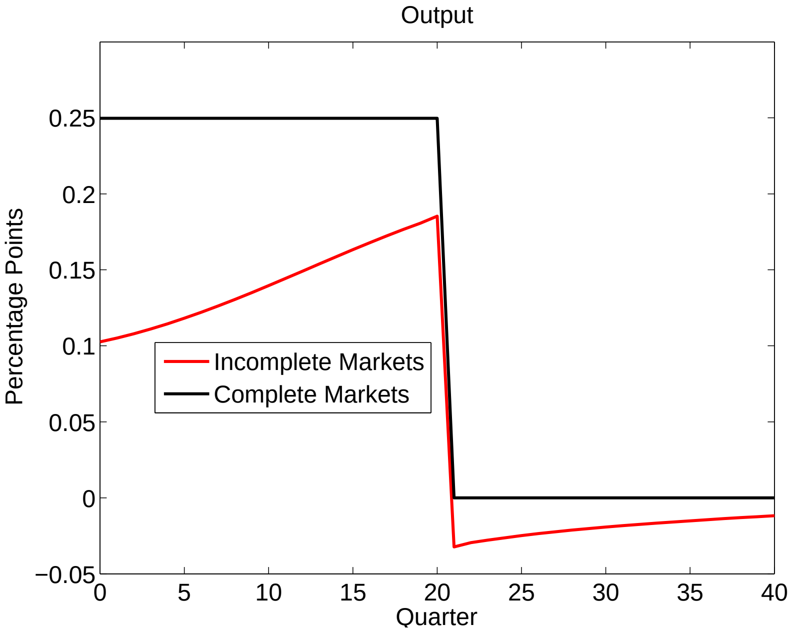
- Steady state annual interest rate equal to 2% ($\beta = 0.986$)
- CRRA = 2 ($\gamma = 2$)
- Frisch elasticity of labor supply equal to 0.5 ($\psi = 2$)
- Average markup of 20% ($\mu = 1.2$)
- 15% of price change per quarter ($\theta = 0.85$)
- Productivity AR(1) in logs with parameters set
  to match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

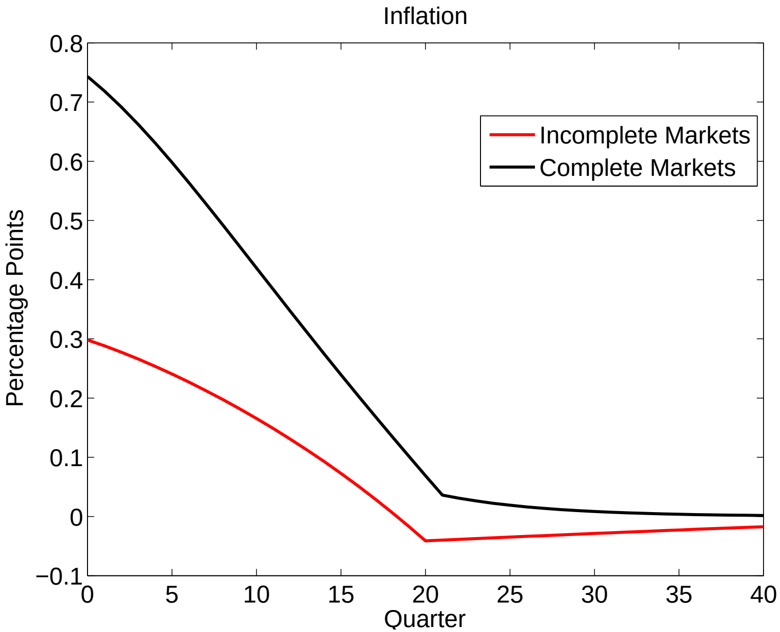
Policy Experiment

Monetary authority announces in quarter 0 that:

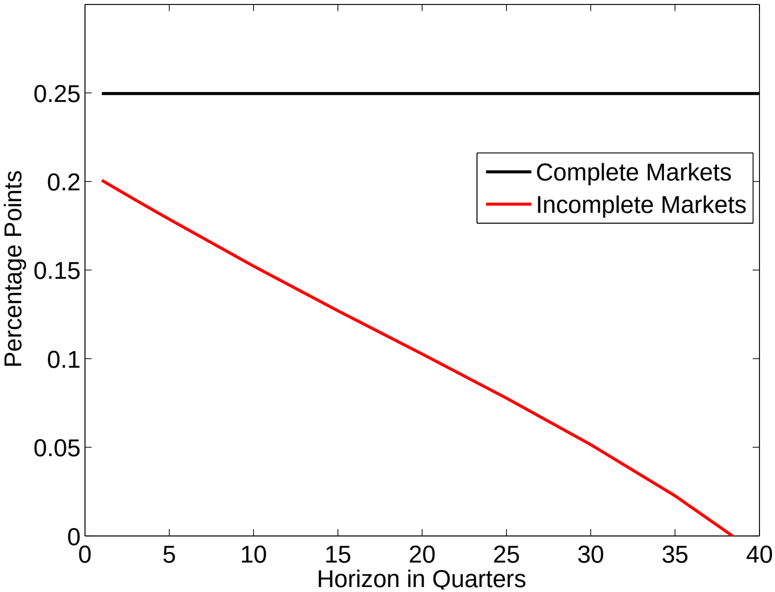
- Real interest rate in quarter 20 will be 50 bps lower
- Real rates at all other times unchanged

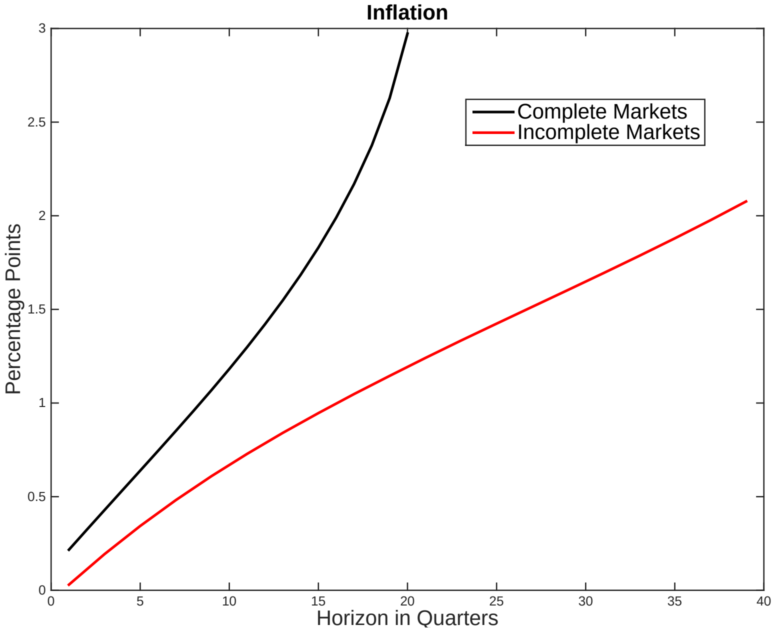



Output
0.25
0.2
0.15
0.1
0.05
0
−0.05
Percentage Points
Incomplete Markets
Complete Markets
0
5
10
15
20
25
30
35
40
Quarter


Inflation
Incomplete Markets
Complete Markets
Percentage Points
Quarter
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
0
5
10
15
20
25
30
35
40

Output


Output
Percentage Points
0.25
0.2
0.15
0.1
0.05
0
0
5
10
15
20
25
30
35
40
Horizon in Quarters
Complete Markets
Incomplete Markets

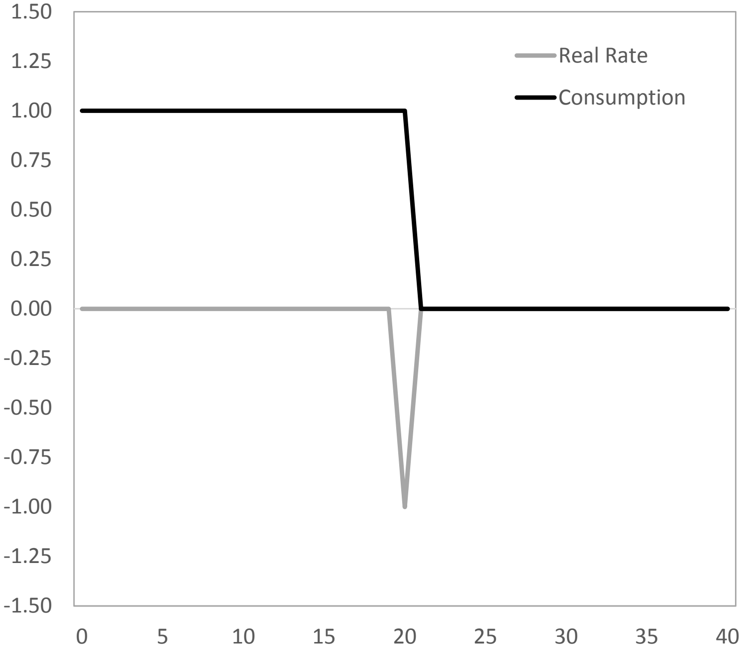

Inflation
Complete Markets
Incomplete Markets
Percentage Points
Horizon in Quarters
0
0.5
1
1.5
2
2.5
3
0
5
10
15
20
25
30
35
40

WERNING (2016)

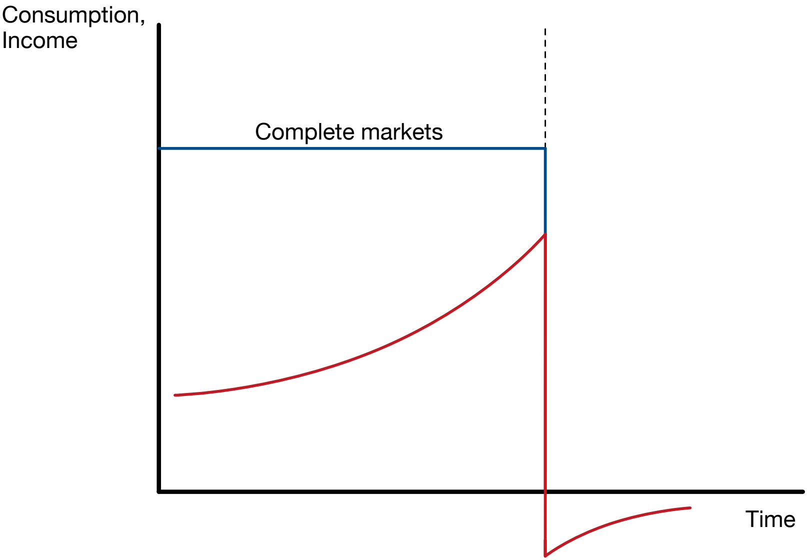
MP in HANK = MP in RANK

If:

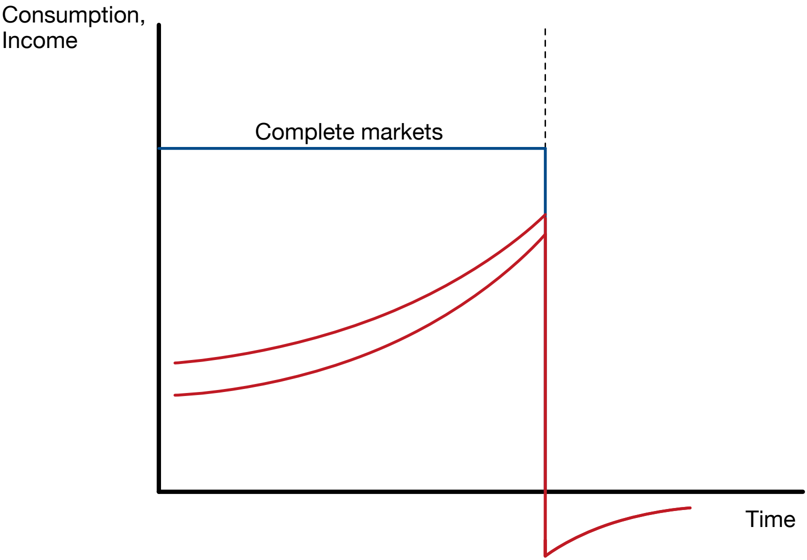
- Individual income is proportional to aggregate income for all agents (distribution of relative income is unaffected by changes in aggregate income)
- Liquidity is proportional to aggregate income for all agents (borrowing constraints and asset values)


Real Rate
Consumption
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
-1.50
0
5
10
15
20
25
30
35
40

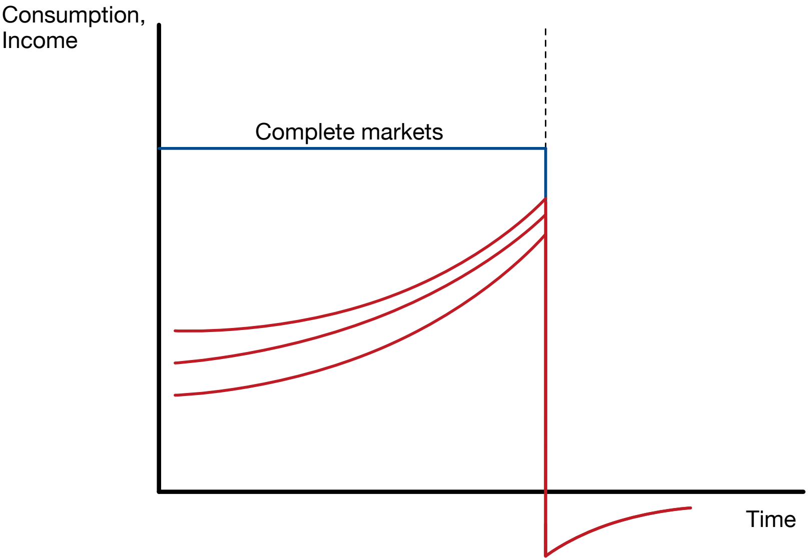
General equilibrium effects



General equilibrium effects



General equilibrium effects



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 ($w_t z_{it} \ell_{it}$)

Kaplan-Moll-Violante 16

- What is the relative size of direct effects and indirect effects of monetary policy?

Kaplan-Moll-Violante 16

- What is the relative size of direct effects and indirect effects of monetary policy?

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

Kaplan-Moll-Violante 16

- 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?

	T adjusts (1)	G adjusts (2)	B^g adjusts (3)
Change in r^b (pp)	-0.23%	-0.21%	-0.25%
Change in Y_0 (%)	0.41%	0.81%	0.13%
Implied elasticity Y_0	-1.77	-3.86	-0.52
Change in C_0 (%)	0.50%	0.64%	0.19%
Implied elasticity C_0	-2.20	-3.05	-0.77
Component of Change in C due to:			
Direct effect: r^b	12%	9%	37%
Indirect effect: w	59%	91%	48%
Indirect effect: T	32%	0%	15%
Indirect effect: r^a	0%	0%	0%

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 of small
  - Depends on a lot of stuff

Direct versus Indirect Effects

Alternative summary:

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

Direct versus Indirect Effects

Alternative summary:

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

Why do we care?

Direct versus Indirect Effects

Alternative summary:

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

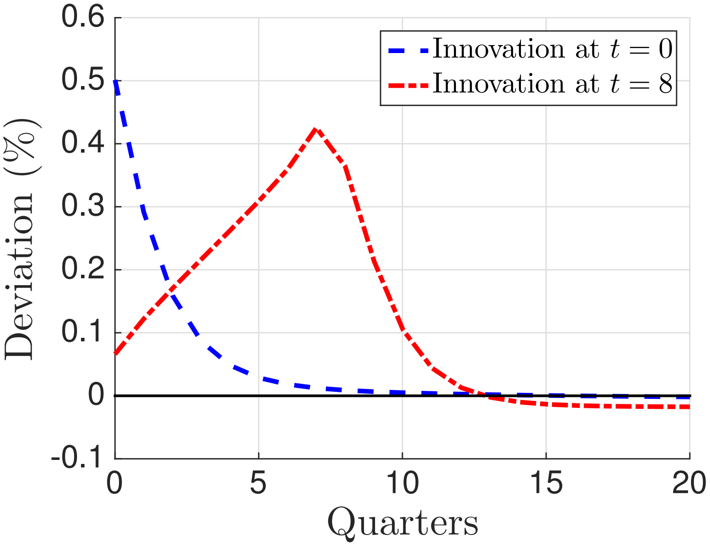
Why do we care?

- Usual reason why structural models are useful (Lucas critique)
- Don't have empirical evidence on all types of policy experiments

Forward Guidance Robustly Less Powerful

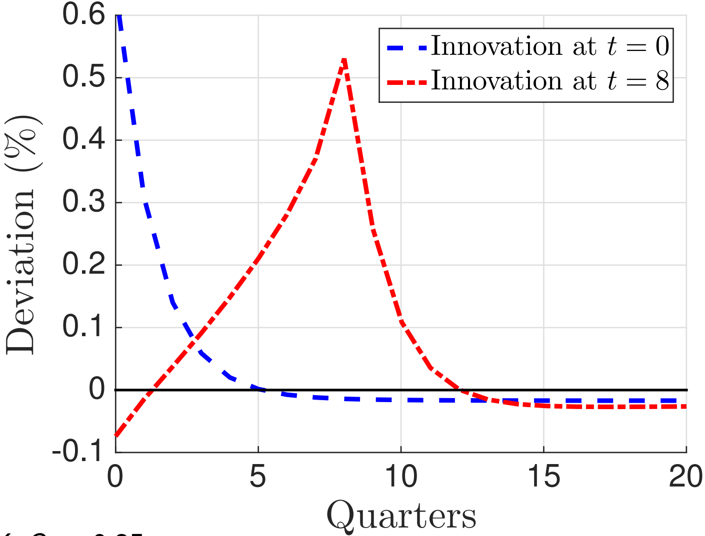
- Power of contemporaneous monetary policy sensitive to specification of fiscal policy
- Power of forward guidance smaller in HANK than RANK

Forward Guidance when T Adjusts



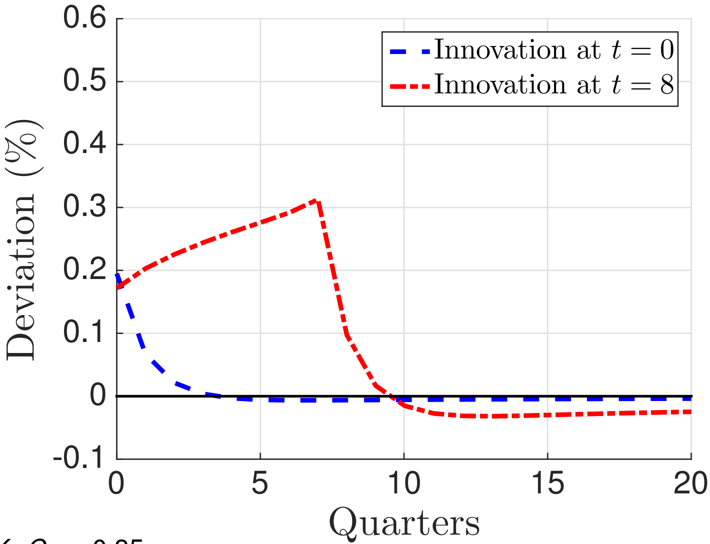
In RANK: $C_0 = 0.35$

FORWARD GUIDANCE WHEN G ADJUSTS



In RANK: $C_0 = 0.35$

Forward Guidance when B Adjusts



In RANK: $C_0 = 0.35$

Way Forward

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

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
- Asset liquidity / duration

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
- Asset liquidity / duration
- Durables / investment / financial intermediation / etc.

REFERENCES

- Angeletos, G.M. and C. Lian (2018): "Forward Guidance without Common Knowledge," American Economic Review, 108(9), 2477-2512.
- Campbell, J.R., C.L. Evans, J.D.M. Fisher, A. Justiniano (2012): "Macroeconomic Effects of Federal Reserve Forward Guidance," Brookings Papers on Economic Activity, 2012, 1-80.
- Carlstrom, C.T., T.S. Fuerst, M. Paustian (2015): "Inflation and Output in New Keynesian Models with a Transient Interest Rate Peg," Journal of Monetary Economics, 76, 230-243.
- Del Negro, M., M. Giannoni, C. Patterson (2013): "The Forward Guidance Puzzle," Working Paper, Federal Reserve Bank of New York.
- Eggertsson, G.B. and M. Woodford (2003): "The Zero Bound on Interest Rates and Optimal Monetary Policy," Brookings Papers on Economic Activity, 2003(1), 139-211.
- Eggertsson, G.B. and N. Mehrotra (2015): "A Model of Secular Stagnation," Working Paper, Brown University.
- Farhi, E. and I. Werning (2019): "Monetary Policy, Bounded Rationality, and Incomplete Markets," American Economic Review, 109(11), 3887-3928.

REFERENCES

- Floden, M. and J. Linde (2001): "Idiosyncratic Risk in the United States and Sweden: Is There a Role for Government Insurance?," Review of Economic Dynamics, 4(2), 406-437.
- Gabaix, X. (2016): "A Bahavioral New Keynesian Model," NBER Working Paper No. 22954.
- Gurkaynak, R.S., B. Sack, and E.T. Swanson (2005): "Do Actions Speak Louder than Words? The Response of Asset Prices to Monetary Policy Actions and Statements," International Journal of Central Banking, 1(1), 55-93.
- Kaplan, G., B. Moll, G.L. Violante (2018): "Monetary Policy According to HANK," American Economic Review, 108(3), 697-743.
- Lunsford, K.G. (2019): "Policy Language and Information Effects in the Early Days of Federal Reserve Forward Guidance," Working Paper, Federal Reserve Bank of Cleveland.

References

- McKay, A., E. Nakamura, J. Steinsson (2016): "The Power of Forward Guidance Revisited," American Economic Review, 106(10), 3133-3358.
- McKay, A., E. Nakamura, J. Steinsson (2017): "The Discounted Euler Equation: A Note," Economica, 84, 820-831.
- Michaillat, P. and E. Saez (2018): "Resolving New Keynesian Anomalies with Wealth in the Utility Function," NBER Working Paper No. 24971.
- Rudebusch, G.D. and J.C. Williams (2008): "Revealing the Secrets of the Temple: The Value of Publishing Central Bank Interest Rate Projections," in *Asset Prices and Monetary Policy*, ed. John Y. Campbell, Chicago, IL: University of Chicago Press.