# Advances in the Identification of Monetary Policy Shocks

Silvia Miranda-Agrippino
Bank of England and CFM

Centre for Central Banking Studies
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# The Identification Problem

# Monetary Policy Shocks

Monetary policy shocks ($e_t^p$) are defined as the unexpected part of the equation for the monetary policy instrument ($i_t$)

$$i_t = f(\widehat{\Omega}_{t|t}^{CB}) + e_t^p$$

where

- $f(\,\cdot\,)$ : is the reaction function of the monetary authority
- $\widehat{\Omega}_{t|t}^{CB}$ : is the central bank's information set

↓

$f(\widehat{\Omega}_{t|t}^{CB})$ is the systematic component of policy

# Identification of the Effects of Monetary Policy

- Most of the variation in the policy instrument ($i_t$) is accounted for by the way the monetary authority systematically reacts to the state of the economy – $f(\widehat{\Omega}_{t|t}^{CB})$ –, and not by random disturbances

- The same policy instrument ($i_t$) is used to both induce changes in the economy and to react to them

- The identification of the effects of a shock to monetary policy requires finding an exogenous "shifter" in the policy equation

[Sims (1998)]

## Responses to Structural Shocks

Consider the n-dimensional zero-mean process

$$\underset{[n\times 1]}{y_t} \equiv (y_{1,t}, \ldots, y_{n,t})'$$

of observable variables driven by the vector of structural shocks $e_t$

**SVAR**

$$y_t = \mathcal{B}(L) \underset{[n\times 1]}{e_t}$$

$$= B_0 e_t + B_1 e_{t-1} + B_2 e_{t-2} + \ldots$$

**Structural IRFs**

$$B_h = \frac{\partial y_{t+j}}{\partial e_t'}$$

**Structural Model:**

- $y_t = B_0 e_t + B_1 e_{t-1} + B_2 e_{t-2} + \dots \qquad e_t \sim NW(0, \mathbb{I}_n)$
- $\mathcal{I}_{t-1} = \text{span}\{e_t, e_{t-1}, \dots\}$ ➔ Information Set Agents
- $B_0 e_t = y_t - \text{Proj}(y_t | \mathcal{I}_{t-1})$

**Forecasting Model:**

- $y_t = u_t + \psi_1 u_{t-1} + \psi_2 u_{t-2} + \dots \qquad u_t \sim NW(0, \Sigma_u)$
- $\mathcal{O}_{t-1} = \text{span}\{y_t, y_{t-1}, \dots\}$ ➔ Information Set Econometrician
- $u_t = y_t - \text{Proj}(y_t | \mathcal{O}_{t-1})$

# Identification

$$\mathcal{O}_{t-1} = \mathcal{I}_{t-1}$$

$$\Downarrow$$

$$y_t - \text{Proj}(y_t | \mathcal{O}_{t-1}) = y_t - \text{Proj}(y_t | \mathcal{I}_{t-1})$$

$$\Downarrow$$

$$u_t = B_0 e_t$$

$$\Downarrow$$

$$\Sigma_u = B_0 B_0'$$

# INFORMATION SUFFICIENCY

- $\mathcal{O}_t = \mathcal{I}_t \Rightarrow$ the structural shocks ($e_t$) can be recovered as a linear combination of the reduced-form VAR innovations ($u_t$) ➔ the information in the history of $y_t$ is sufficient to estimate the shocks

- If the econometrician's information set does not span that of the agents, the structural shocks are non-fundamental and cannot be obtained from a VAR

- Test for informational sufficiency:
  - i. **Global:** there is no $x_t \notin y_t$ such that $x_t$ Granger causes $y_t$
  - ii. **Partial:** there is no $x_t \notin y_t$ such that $x_t$ Granger causes $\hat{e}_t$

[Hansen and Sargent (1991), Lippi and Reichlin (1993, 1994), Forni and Gambetti (2014)]

## Foresight

Policy changes may be anticipated:

- **by the agents**: agents can know at time $t$ of a shock that will affect variables at $t + h$ – e.g. forward guidance

$$e_t \notin \text{span}\{y_t, y_{t-1}, \dots\}$$

- **by the policymaker**: the central bank can have superior information – e.g. forecasts of inflation [Romer and Romer (2000)]

confound $e_t$ with $f(\widehat{\Omega}^{CB}_{t|t})$

[see Ramey (2016) for a review]

# Empirically

- Set up a model for the joint dynamic of the variables in $y_t$ – e.g. VAR(p)

- Enlarge the information set $\mathcal{O}_t$ to match (approximate) $\mathcal{I}_t$

   i. CB foresight ➔ Likely inputs of the central bank's reaction function $f(\cdot)$ – e.g. internal forecasts for inflation and output

   ii. Agents' foresight ➔ Measures of agents' expectations and "news" – e.g. survey forecasts, market-based forecasts

- Find a suitable identification scheme – e.g. timing restrictions, external instruments

# Market-Based Measures of Unexpected Policy Decisions

# Intuition

- The price of an interest rate futures contract is a function of agents' expectations about future interest rates

↓

Futures prices measure expected path of policy

- Reactions following central banks' announcements measure the unexpected component of policy

↓

Monetary surprises measure monetary policy shocks

Contract that pays (a function of) the interest rate at time $t + h$

$$p_t^{(h)} = \mathbb{E}_t\left(i_{t+h}\right) + \zeta_t^{(h)}$$

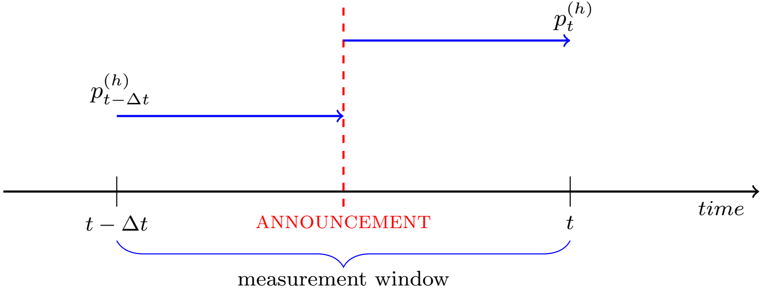
i. $p_t^{(h)}$ ➔ price of futures contract expiring at $t + h$

ii. $\mathbb{E}_t\left(i_{t+h}\right)$ ➔ $t + h$ interest rate expected at time $t$

iii. $\zeta_t^{(h)}$ ➔ risk compensation/premium

[Rudebusch (1989), Kuttner (2001), Sack (2004)]

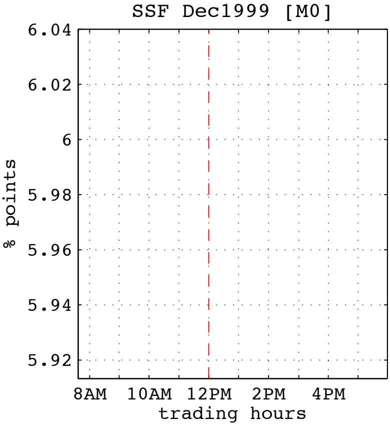
# Monetary Surprises




$$mps_t^{(h)} \equiv p_t^{(h)} - p_{t-\Delta t}^{(h)} = \underbrace{\left[\mathbb{E}_t\left(i_{t+h}\right) - \mathbb{E}_{t-\Delta t}\left(i_{t+h}\right)\right]}_{\text{expectation revision}} + \underbrace{\left[\zeta_t^{(h)} - \zeta_{t-\Delta t}^{(h)}\right]}_{\simeq 0}$$

[Gürkaynak, Sack, Swanson (2005)]

# A Typical Announcement Day



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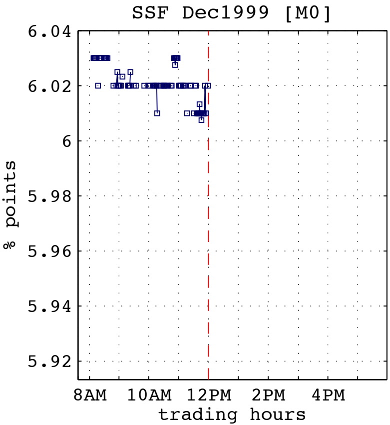

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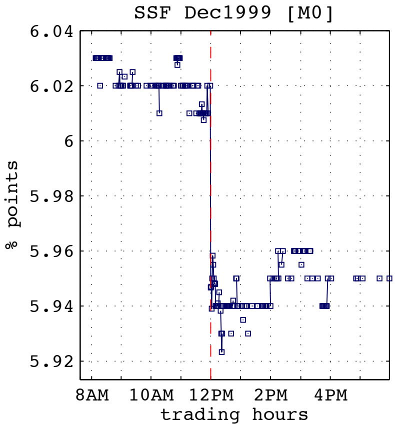

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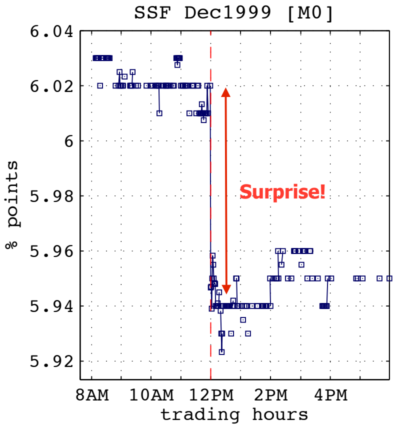


**Assumptions**:

i. Markets efficiently incorporate all available information as soon as it is released

ii. The announcement is the only event in $\Delta t$

iii. The risk compensation $\zeta_t^{(h)}$ is unaffected by the monetary policy shock

↓

**price updates $\Longleftrightarrow$ monetary policy shock**

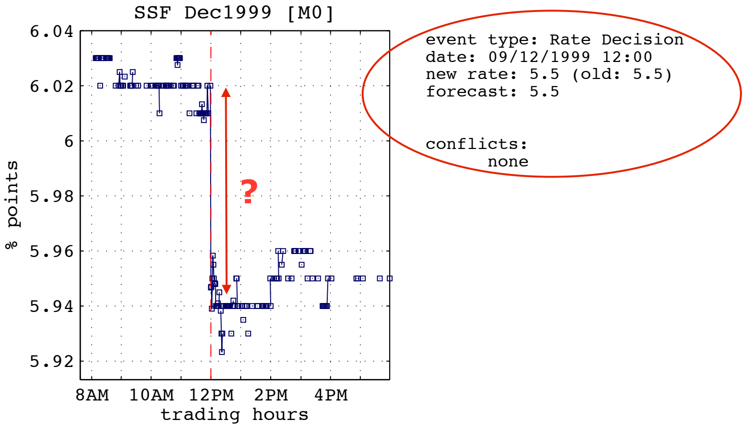
$$mps_t = e_t^p + \text{measurement error}$$

[Gürkaynak, Sack, Swanson (2005), Gertler and Karadi (2015), and many more]

# Uses of Monetary Surprises

- Conventional and unconventional monetary policy on asset prices: stock prices, nominal and real long-term rates, currency, ... [Nakamura and Steinsson (2013), Hanson and Stein (2015), Glick an Leduc (2015), Rogers, Scotti and Wright (2014)]
- Domestic and international effects on credit costs, premia and economic activity [Gertler and Karadi (2015), Passari and Rey (2015)]
- Multidimensionality of monetary policy [Gürkaynak, Sack and Swanson (2005), Swanson (2015)]

# A Typical Announcement Day



## The Informational Content of Monetary Surprises

IMPLICIT ASSUMPTION: market participants and the central bank share the **same information set**

In fact:

i. Before the announcement: $p_{t-\Delta t} = f\left(\widehat{\Omega}^{M}_{t|t}\right) + \zeta\left(\widehat{\Omega}^{M}_{t|t}\right)$

ii. After the announcement: $p_t = e^p_t + f\left(\widehat{\Omega}^{CB}_{t|t}\right) + \zeta\left(\widehat{\Omega}^{CB}_{t|t}\right)$

↓

$$mps_t = e^p_t + f\left(\widehat{\Omega}^{CB}_{t|t} - \widehat{\Omega}^{M}_{t|t}\right) + \zeta\left(\widehat{\Omega}^{CB}_{t|t} - \widehat{\Omega}^{M}_{t|t}\right)$$

[Miranda-Agrippino (2016)]

# The Informational Content of Monetary Surprises

$$mps_t = e_t^p + f\left(\widehat{\Omega}_{t|t}^{CB} - \widehat{\Omega}_{t|t}^{M}\right) + \zeta\left(\widehat{\Omega}_{t|t}^{CB} - \widehat{\Omega}_{t|t}^{M}\right)$$

- unexpected by markets $\neq$ exogenous shift to policy rule $\Rightarrow$ unfit to isolate monetary policy shocks without further assumptions
- $\widehat{\Omega}_{t|t}^{CB} \neq \widehat{\Omega}_{t|t}^{M} \Rightarrow$ agents update their forecasts at announcement
- following an interest rate rise:
  i. forecasts of unemployment are revised *downward*
  ii. forecasts of output and inflation are revised *upward*

[Nakamura and Steinsson (2008), Campbell *et al.* (2012), Campbell *et al.* (2016)]

# Surprises Predictability

Table I:
PREDICTABILITY OF MONETARY SURPRISES: US CASE

| | $MP1_t$ | | $FF4_t$ | | $ED2_t$ | | $ED3_t$ | | $ED4_t$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $R^2$ | $F$ | $R^2$ | $F$ | $R^2$ | $F$ | $R^2$ | $F$ | $R^2$ | $F$ |
| Macro-Financial Factors | 0.042 | 2.040** | 0.078 | 2.994*** | 0.095 | 3.502*** | 0.068 | 2.739*** | 0.055 | 2.379*** |
| *Lagged Observables* | | | | | | | | | | |
| ISM Composite | 0.0394 | 10.71*** | 0.0682 | 18.36*** | 0.0964 | 26.28*** | 0.0802 | 21.66*** | 0.0673 | 18.11*** |
| Consumer Sentiment | 0.0103 | 3.46* | 0.0221 | 6.35** | 0.0374 | 10.22*** | 0.035 | 9.70*** | 0.0273 | 7.65*** |
| Effective Fed Funds Rate | 0.016 | 4.88*** | 0.0437 | 11.78*** | 0.076 | 20.40*** | 0.0618 | 16.56*** | 0.0517 | 13.87*** |
| 3M T-bill FFR Spread | 0.0839 | 22.72*** | 0.0464 | 12.53*** | 0.0233 | 6.64** | 0.019 | 5.50** | 0.0123 | 3.95** |
| AAA-FFR Spread | 0.006 | 2.36 | 0.003 | 0.23 | 0.003 | 0.25 | 0.003 | 0.23 | 0.003 | 0.24 |
| 1Y T-Bond FFR Spread | 0.0549 | 14.76*** | 0.036 | 9.84*** | 0.0225 | 6.47** | 0.0181 | 5.37** | 0.0134 | 4.23** |
| S&P 500 Composite | 0.0108 | 3.59* | 0.0203 | 5.89** | 0.0404 | 10.95*** | 0.049 | 13.22*** | 0.0416 | 11.25*** |
| CBOE VIX | 0.0214 | 6.19** | 0.0239 | 6.79*** | 0.0682 | 18.33*** | 0.0685 | 18.42*** | 0.063 | 16.93*** |
| *Greenbook Forecasts* | | | | | | | | | | |
| Output | 0.056 | 3.825** | 0.083 | 5.301*** | 0.118 | 7.379*** | 0.092 | 5.832*** | 0.057 | 3.856** |
| Inflation | 0.007 | 1.359 | 0.015 | 1.712 | 0.007 | 1.329 | 0.015 | 1.747 | 0.005 | 1.237 |
| Unemployment | 0.038 | 2.863** | 0.048 | 3.414** | 0.098 | 6.156*** | 0.056 | 3.827** | 0.034 | 2.69** |
| *Greenbook Forecasts Revisions* | | | | | | | | | | |
| Output | 0.071 | 5.557*** | 0.078 | 6.019*** | 0.11 | 8.391*** | 0.079 | 6.114*** | 0.047 | 3.941*** |
| Inflation | 0.004 | 1.218 | -0.009 | 0.468 | -0.006 | 0.650 | 0.010 | 1.589 | 0.015 | 1.904 |
| Unemployment | 0.042 | 3.619** | 0.088 | 6.763*** | 0.082 | 6.284*** | 0.051 | 4.230** | 0.039 | 3.432** |

Predictability of US raw surprises. The table reports adjusted $R^2$ and $F$-statistics for the null $\mathrm{H}_0 : \kappa_x = 0$ in (18) estimated at monthly frequency over the sample 1990:1 - 2012:6 (1990:1 - 2009:12 for Greenbook forecasts). Variables in $\mathrm{X}_{t-1}$ are listed in the first column. The ten factors are extracted from the set of 134 monthly macroeconomic and financial variables in McCracken and Ng (2015). Lagged observables are taken in first difference with the exception of surveys and spreads. ***, ** and * denote significance at 1, 5 and 10% level respectively. The raw monetary surprises are extracted from the first and fourth fed funds futures (MP1 and FF4 and the second, third and fourth Eurodollar future (ED2, ED3, ED4). Monthly raw surprises are obtained as the sum of the daily series in Gürkaynak et al. (2005). See main text for details. Full regression output is reported in the Online Appendix.

[Miranda-Agrippino (2016)]

# Identification With External Instruments

# Intuition

- Isolate exogenous variation in the innovation of the policy variable (i.e. residuals of the policy equation) using information not included in the system (e.g. VAR)

- Works through the use of *external instruments* that proxy for the unobserved policy shock

- If a valid instrument is found, the contemporaneous transmission coefficients are consistently estimated using moments of observables

# External Proxy for the Shock

$$u_t = \underset{[n \times n]}{B_0} \; e_t$$

$$\begin{pmatrix} u_t^p \\ u_t^o \end{pmatrix} = \begin{pmatrix} \underset{[n \times 1]}{b_1} & \vdots & \underset{[n \times (n-1)]}{b_2} \end{pmatrix} \begin{pmatrix} e_t^p \\ e_t^o \end{pmatrix}$$

**IDENTIFYING ASSUMPTIONS**

Find $z_t \notin y_t$ such that:

$$\text{i. } \mathbb{E}[\; z_t e_t^{p\prime} \;] = \phi$$

$$\text{ii. } \mathbb{E}[\; z_t \epsilon_t^{o\prime} \;] = 0$$

# Contemporaneous Transmission Coefficients

$$u_t = \left( \underset{[n\times 1]}{b_1} \;\vdots\; \underset{[n\times(n-1)]}{b_2} \right) e_t$$

$$\begin{pmatrix} u_t^p \\ u_t^o \end{pmatrix} = \begin{pmatrix} \underset{[1\times 1]}{b_{11}} & b_{21} \\ \underset{[(n-1)\times 1]}{b_{12}} & b_{22} \end{pmatrix} \begin{pmatrix} e_t^p \\ e_t^o \end{pmatrix}$$

Let $\dim(z_t) = \dim(e_t^p)$

$$\begin{pmatrix} \mathbb{E}(u_t^p z_t') \\ \mathbb{E}(u_t^o z_t') \end{pmatrix} = \left( b_1 \;\vdots\; b_2 \right) \begin{pmatrix} \mathbb{E}(e_t^p z_t') \\ \mathbb{E}(e_t^o z_t') \end{pmatrix} = b_1 \phi'$$

↓

$$\mathbb{E}(u_t^p z_t')^{-1} \mathbb{E}(u_t^o z_t') = b_{11}^{-1} b_{12}$$

[Montiel-Olea, Stock and Watson (2012), Mertens and Ravn (2013)]

# Contemporaneous Transmission Coefficients

$$\mathbb{E}(u_t^p z_t')^{-1}\mathbb{E}(u_t^o z_t') = b_{11}^{-1} b_{12}$$

- $b_1$ is consistently estimated up to scale convention
- Equivalent to regressing $u_t^o$ on $u_t^p$ using $z_t$ as external instrument
- Method:
  i. Get an estimate of $u_t$ – e.g. VAR(p) residuals
  ii. Regress $\hat{u}_t$ on $z_t$
  iii. Calculate $b_{11}^{-1} b_{12}$ as ratio of regression coefficients
  iv. Choose normalization – e.g. $b_{11} = 1$

# Information Still Matters!

$$\mathbb{E}(u_t^p z_t')^{-1}\mathbb{E}(u_t^o z_t') = b_{11}^{-1} b_{12}$$

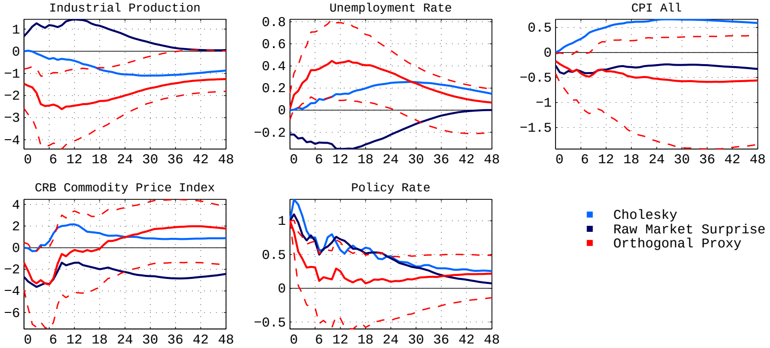
- If $\exists\ x_t$ such that $x_t \notin \mathcal{O}_t$ but
  i. $\mathbb{E}(u_t x_t') \neq 0$
  ii. $\mathbb{E}(z_t x_t') \neq 0$

  estimates of $b_1$ are inconsistent ➔ IRFs highly distorted

If $z_t$ is a market-based monetary surprise

- agents' foresight is potentially accounted for
- **but** can confound $e_t^p$ with $f(\widehat{\Omega}_{t|t}^{CB})$ if $\widehat{\Omega}_{t|t}^{M} \neq \widehat{\Omega}_{t|t}^{CB}$

# Information Still Matters!




[Miranda-Agrippino (2016)]

# The Transmission of Monetary Policy Shocks

Miranda-Agrippino and Ricco (2016)

# Setup

Study the transmission of (conventional) monetary policy shocks on a large and heterogeneous set of variables:

- **Real Activity**: production, employment, investments
- **Prices**: consumer price inflation, consumption deflator
- **Credit Channel**: credit costs and credit supply
- **Asset Prices**: equity indices, currency
- **Interest Rates**: maturity and horizons
- **Expectations**: agents' forecasts

IDENTIFICATION

$$y_t = \mathcal{C}(L) B_0 e_t$$

Shocks are:

- unanticipated by market participants
- orthogonal to CB assessment of macroeconomic outlook

$$mps_t = \alpha_0 + \underbrace{\sum_{j=1}^{p} \alpha_j mps_{t-j}}_{\text{Agents' } \mathcal{I}} + \underbrace{\sum_{q=-1}^{3} \left( \theta\, \widehat{\Omega}^{CB}_{q|t} + \rho \left[ \widehat{\Omega}^{CB}_{q|t} - \widehat{\Omega}^{CB}_{q|t-1} \right] \right)}_{\text{Central Bank's } \mathcal{I}} + z_t$$

↓

PROXY FOR THE SHOCK

## Transmission of MP Shocks

**IRFS**

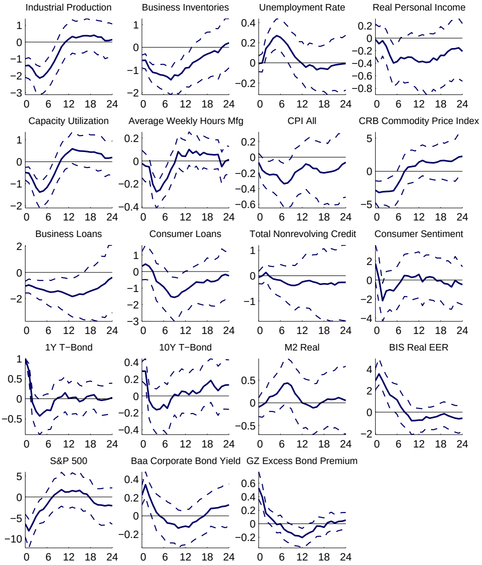
$$y_t = \mathcal{C}(L) B_0 e_t$$

- if VAR misspecified, errors compound at larger horizon $h$
- optimal deviation from VAR-IRFs as $h$ grows

**Bayesian Local Projection (BLP)**

$$B_{BLP}^{(h)} \quad \propto \left( X'X + \frac{1}{\lambda^{(h)}} \right)^{-1} \left( \frac{1}{\lambda^{(h)}} B_{VAR}^{h} + X'Y^{(h)} \right)$$

# The Transmission of Monetary Policy Shocks



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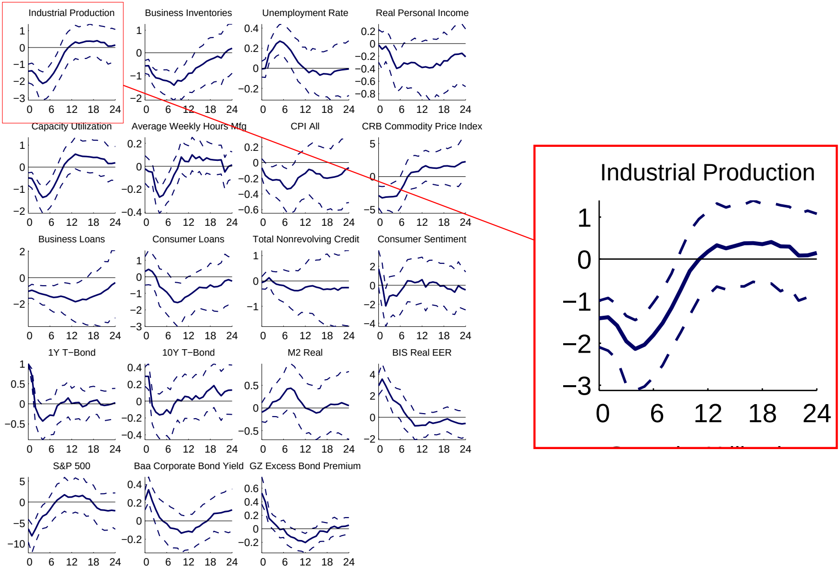

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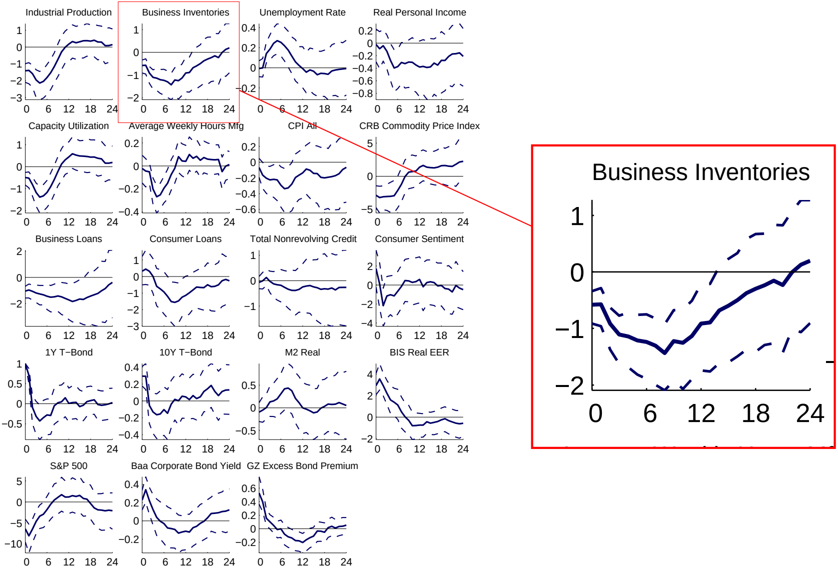

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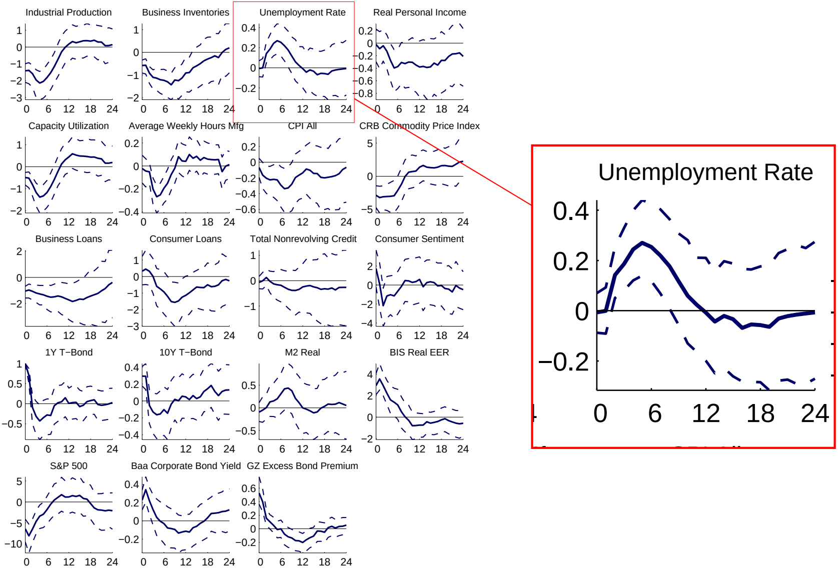

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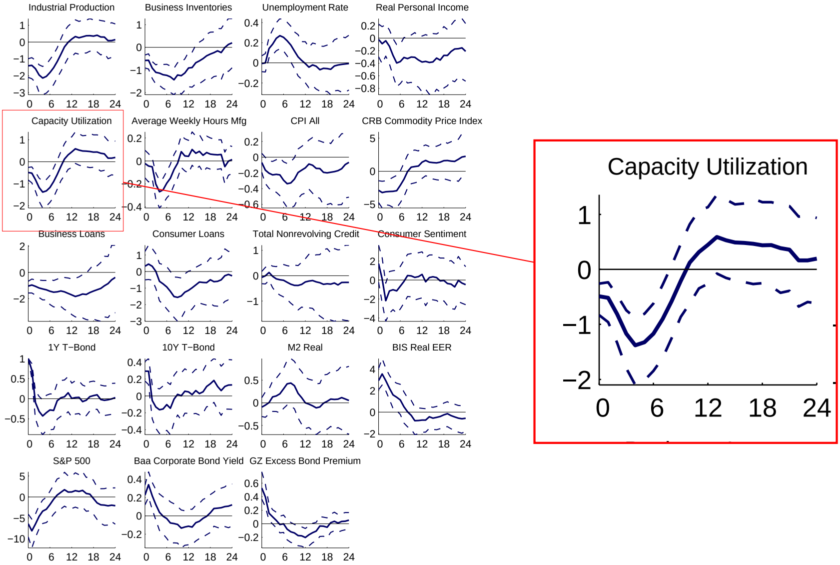

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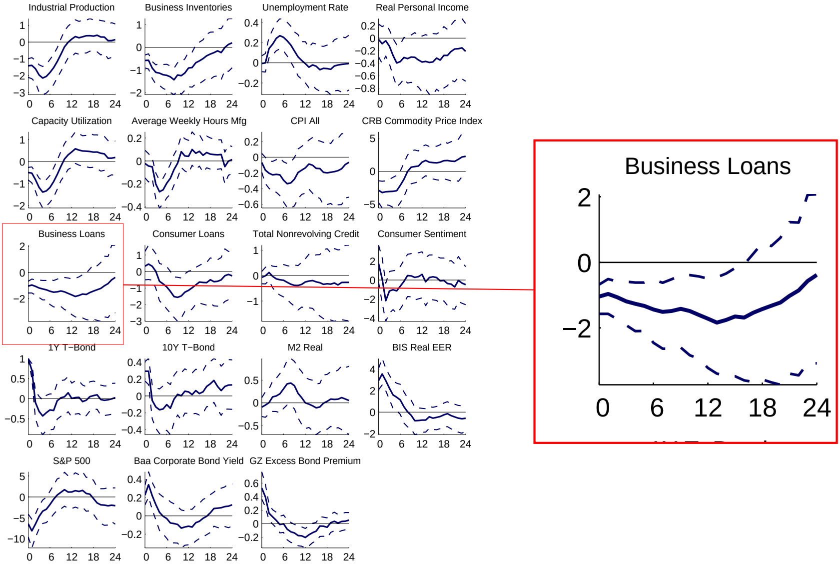

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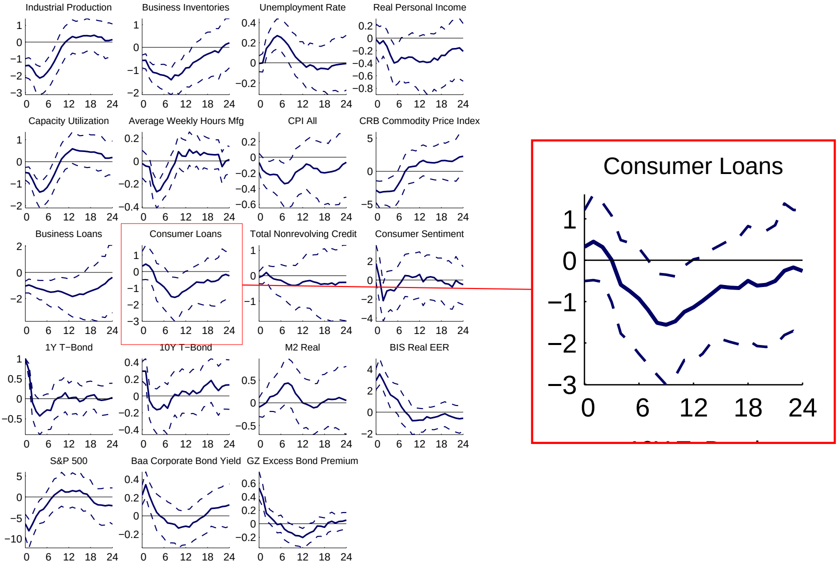

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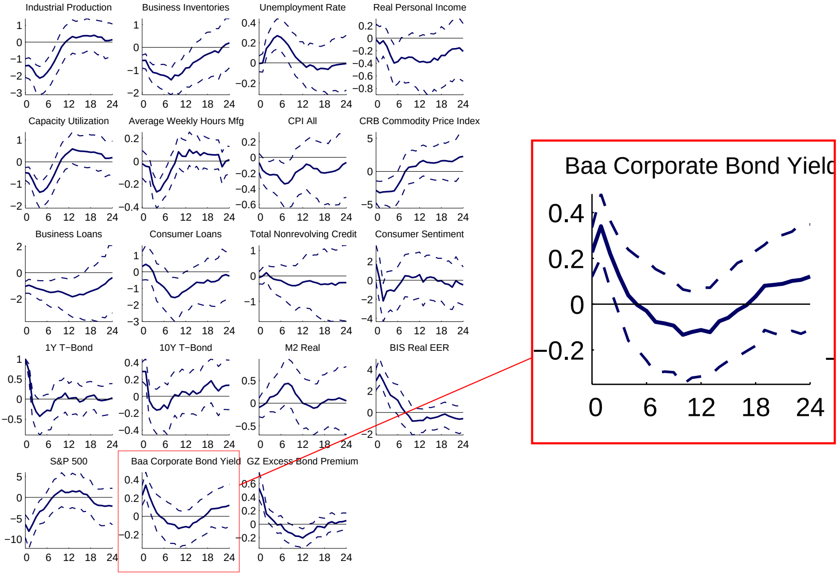

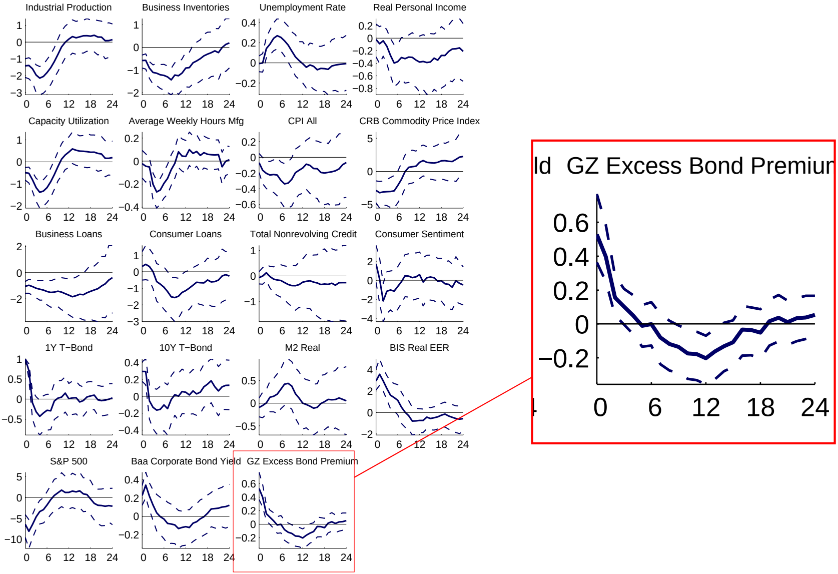
Industrial Production
Business Inventories
Unemployment Rate
Real Personal Income
Capacity Utilization
Average Weekly Hours Mfg
CPI All
CRB Commodity Price Index
Business Loans
Consumer Loans
Total Nonrevolving Credit
Consumer Sentiment
1Y T−Bond
10Y T−Bond
M2 Real
BIS Real EER
S&P 500
Baa Corporate Bond Yield
GZ Excess Bond Premium

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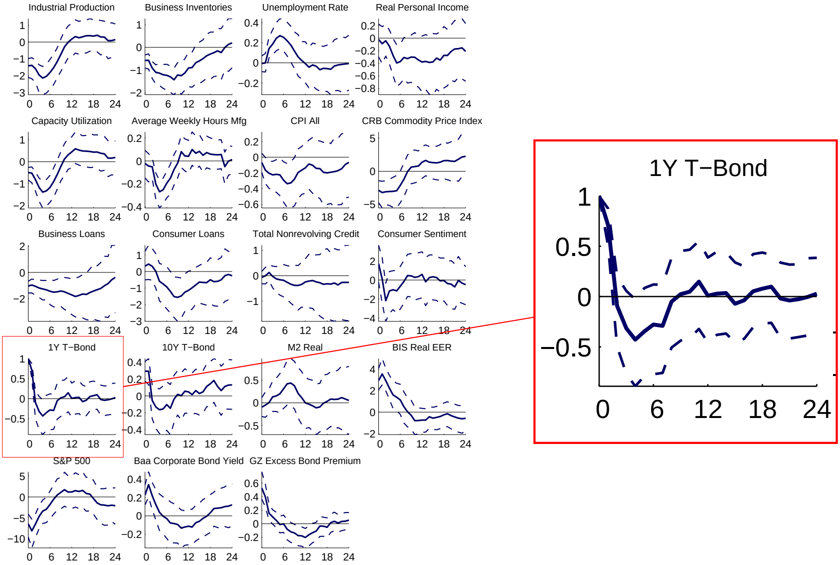

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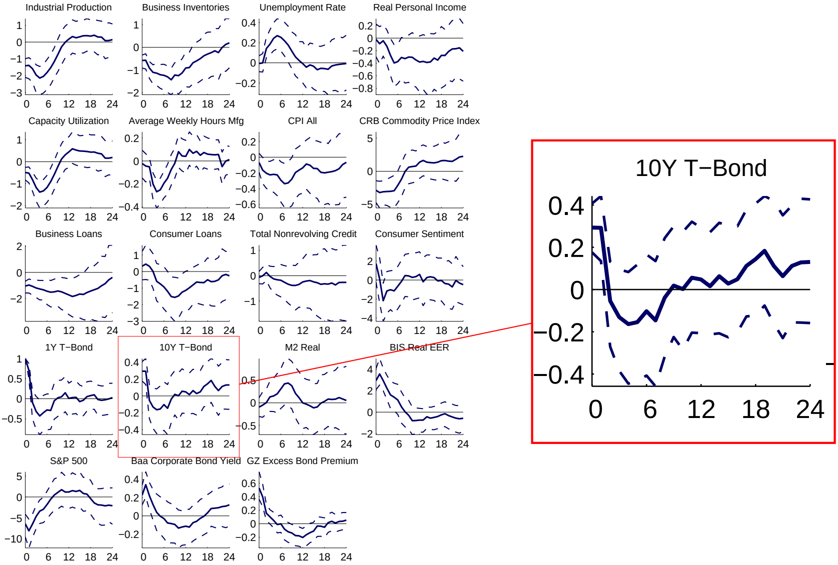

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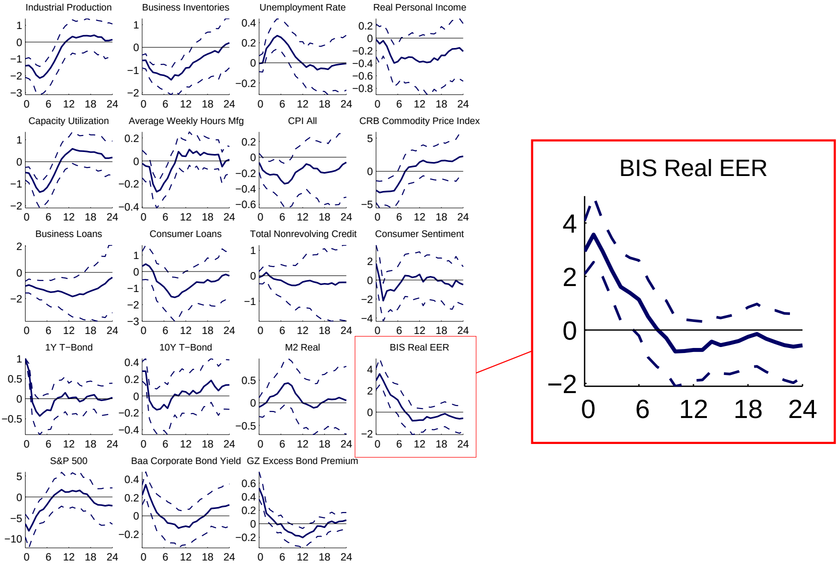

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