Identifying Monetary Policy Shocks Through External Variable Constraints

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EEA ESEM 2022

August 23, 2022

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- Early literature based on short-run restrictions (*e.g.* Christiano *et al.* 1999) consistently found that US contractionary monetary policy shocks have negative effects on output.
- This evidence has later been challenged by Uhlig (2005), who achieves set-identification through milder sign restrictions on the impulse responses.
- At odds with theoretical predictions, contractionary monetary policy shocks identified by sign restrictions are consistent with expansionary effects on output.

This paper

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..but why sign restrictions are not enough to recover monetary policy shocks?

Motivation

- I find that monetary policy shocks identified by standard sign restrictions display two undesirable properties.

  1. Correlation with the central bank information set about the future state of the economy, proxied by the Greenbook projections. Details
  2. Weak (or even negative) comovement with high-frequency monetary surprises, that capture the unpredictable component of changes in monetary policy. Details

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- These limitations also apply to shocks identified through narrative sign restrictions and restrictions on the monetary policy equation. Tables

The model

Same vector of US monthly variables as Uhlig (2005), over the period 1965:M1-2007M11.

$$Y_t' = \begin{bmatrix} gdp_t & pi_t & ff_t & ci_t & tr_t & nr_t \end{bmatrix} \quad (1)$$

- gdp_t and pi_t are respectively the log of real GDP and of the GDP deflator;
- ff_t is the federal funds rate;
- ci_t is the log of a commodity price index;
- tr_t and nr_t are respectively the log of total reserves and of nonborrowed reserves.

The econometric framework

I estimate the following reduced-form VAR

$$Y_t = \sum_{j=1}^{12} B_j L^j Y_t + e_t, \quad e_t \sim (0, \Sigma_e) \tag{2}$$

where $\Sigma_e = SS'$ is the reduced-form variance-covariance matrix and S is its Cholesky factor. The vector-moving average (VMA) representation associated to (2) is given by

$$Y_t = \sum_{j=0}^{\infty} C_j e_{t-j} \tag{3}$$

where C_j is the *j-th* coefficient matrix of $(I_k - \sum_{j=1}^{p} B_j L^j)^{-1}$ that collects the reduced-form impulse responses at horizon j.

Identification by sign restrictions

For any orthonormal matrix Q, the identification of the structural shocks ε_t can be achieved through a linear transformation of e_t of the form

$$e_t = A\varepsilon_t \tag{4}$$

where $A = SQ$ is such that $\Sigma_\varepsilon = I$. At horizon h, the structural impulse responses are given by

$$IRF_h^s = C_h A \tag{5}$$

Uhlig (2005) only retains matrices A such that $\varepsilon_t^m(A)$ satisfy *Restriction SR*.

Restriction SR. A monetary policy shock $\varepsilon_t^m(A)$ leads to a negative response of pi_t, ci_t and nr_t and to a positive response of ff_t at horizons $h = 0, \ldots, 5$.

Identification by external variable constraints

1. I retain 100000 draws of A satisfying *Restriction SR* into the set of solutions $\mathcal{P}$.
2. I store the matrices $A \in \mathcal{P}$ such that $\varepsilon_t^m(A)$ satisfy *Restriction ER* into the set $\mathcal{P}_k^*$.

Restriction ER. Over the period 1990:M1-2007:M11, $\varepsilon_t^m(A)$ must satisfy:

$$corr(\varepsilon_t^m, FF4_t) > k \quad \text{Details} \tag{6}$$

$$corr(\varepsilon_t^m, FI_t) = 0 \quad \text{Details} \tag{7}$$

where $FF4_t$ are the high-frequency monetary surprises and FI_t is the Fed's information set about current and future economic conditions, as summarized by Greenbook forecasts.

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Three alternative calibrations for k, set equal to the $75th$, $90th$ or $99th$ percentile value of the set of correlation coefficients between $FF4_t$ and $\varepsilon_t^m(A)$ formed from $A \in P$.

Impulse response functions

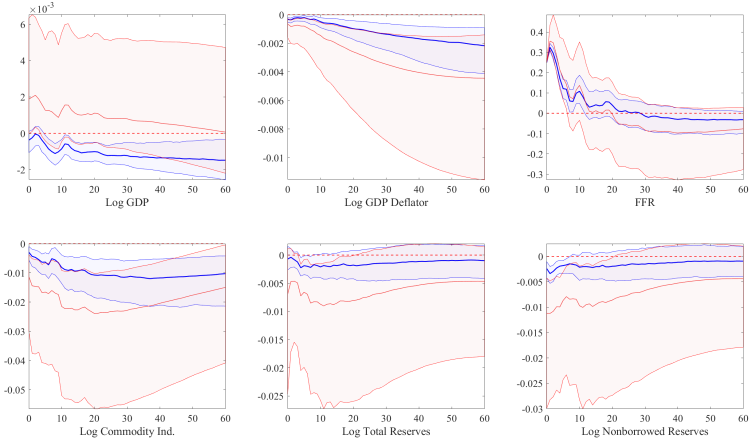

Figure 1: Responses to contractionary ε_t^m formed from $A \in \mathcal{P}^*_{99th}$ (in blue) and under sign restrictions (in red)
Notes: The shaded bands are the 68% equal-tailed point-wise posterior probability bands.

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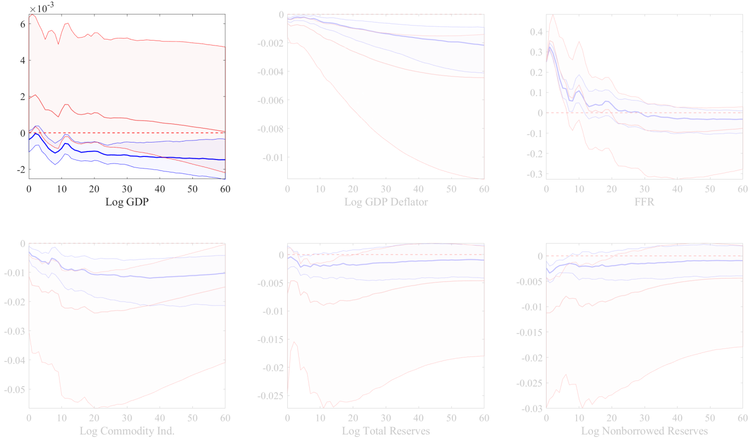

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Relationship with alternative set-identification strategies

- This result contributes to restore the conventional wisdom about the transmission of US monetary policy shocks in set-identified SVARs.
- Similar findings have been obtained under alternative identification schemes, as narrative sign restrictions and restrictions on monetary policy equations.
- Taking them as a reference, I show that my approach ensures: (i) narrative consistency of monetary policy shocks; (ii) Taylor-rule consistency of monetary policy equations.

Narrative consistency of monetary policy shocks (1)

Antolín-Díaz and Rubio-Ramírez (2018) combine standard sign restrictions with narrative sign restrictions around key historical events.

Restriction NR1. The monetary policy shock ε_t^m for the observation corresponding to October 1979 must be of positive value.

Restriction NR2. For the observation corresponding to October 1979, the absolute value of the contribution of ε_t^m to the unexpected change in the federal funds rate is larger than the sum of the absolute value of the contributions of all other structural shocks.

Narrative consistency of monetary policy shocks (2)

Alternatively, they impose *Restriction NR3* and *Restriction NR4* on a larger set of events for which there is a reasonable agreement that a monetary policy shock occurred.

Restriction NR3. The monetary policy shock ε_t^m must be of positive value for the observations corresponding to April 1974, October 1979, December 1988, and February 1994, and negative for December 1990, October 1998, April 2001, and November 2002.

Restriction NR4. For the episodes in *Restriction NR3*, the absolute value of the contribution of ε_t^m is larger than the absolute value of the contribution of any other structural shock.

Narrative consistency of monetary policy shocks (3)

Restriction	**1974:4**	**1979:10**	**1988:12**	**1990:12**	**1994:2**	**1998:10**	**2001:4**	**2002:11**
NR1	-	100.0%	-	-	-	-	-	-
NR2	-	90.3%	-	-	-	-	-	-
NR3	99.6%	100.0%	40.0%	94.3%	68.8%	100.0%	100.0%	100.0%
NR4	96.5%	97.4%	32.6%	71.8%	45.0%	99.1%	95.1%	88.6%

Table 1: % of ε_t^m formed from $SQ \in \mathcal{P}^*_{99th}$ satisfying narrative sign restrictions

- Monetary policy shocks formed from $A \in \mathcal{P}^*_{99th}$ are overall consistent with narrative sign restrictions and therefore reconcilable with an historical reading of the times.
- The episodes occurred in December 1988 and February 1994 are two partial exceptions: however, the exogeneity of these federal funds rate hikes is rather questionable. Details

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Taylor-rule consistency of monetary policy equations (1)

Arias *et al.* (2019) achieve identification through sign and zero restrictions on the coefficients of the monetary policy equation,

$$ff_t = \phi_{gdp} gdp_t + \phi_{pi} pi_t + \phi_{ci} ci_t + \phi_{tr} tr_t + \phi_{nr} nr_t + b_{13}\varepsilon_t^m \tag{8}$$

where $B = A^{-1}$ and $\phi_{gdp} = -\frac{b_{11}}{b_{13}}$, $\phi_{pi} = -\frac{b_{12}}{b_{13}}$, $\phi_{ci} = -\frac{b_{14}}{b_{13}}$, $\phi_{tr} = -\frac{b_{15}}{a_{13}}$, $\phi_{nr} = -\frac{b_{16}}{a_{13}}$.

Restriction TR1. The federal funds rate is the monetary policy instrument and it only reacts contemporaneously to output, prices and commodity prices. Thus, $\phi_{tr} = \phi_{nr} = 0$.

Restriction TR2. The contemporaneous reaction of the federal funds rate to output and prices is positive, that is $\phi_{gdp}, \phi_{pi} > 0$.

Taylor-rule consistency of monetary policy equations (2)

- When only standard sign restrictions are imposed, the resulting monetary policy equations display rather puzzling coefficients.

Coefficient	ϕ_{gdp}	ϕ_{pi}	ϕ_{ci}	ϕ_{tr}	ϕ_{nr}
Median	-0.37	1.92	0.11	0.09	0.04
68% Prob. Interval	[-2.44;0.80]	[-0.01;6.05]	[0.00;0.35]	[-0.39;0.63]	[-0.40;0.66]

Table 2: Coefficients in the monetary policy equations under only sign restrictions.

- On the contrary, when sign restrictions are combined with external variable constraints, the estimated coefficients turn out to be fully reconcilable with *Restriction TR1* and *TR2*.

Coefficient	ϕ_{gdp}	ϕ_{pi}	ϕ_{ci}	ϕ_{tr}	ϕ_{nr}
Median	0.28	1.10	0.03	0.03	-0.03
68% Prob. Interval	[0.07;0.51]	[0.66;1.75]	[0.01;0.06]	[-0.05;0.12]	[-0.10;0.05]

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Conclusions

- When sign restrictions are combined with external variable constraints, contractionary monetary policy shocks are unequivocally found to decrease output.
- This finding contributes to restore the conventional wisdom on the transmission of US monetary policy shocks in set-identified SVARs.
- The identified shocks turn out to be reconcilable with a narrative reading of the times and the resulting monetary policy equations are consistent with Taylor-type rules.
- On the contrary, shocks recovered through alternative methodologies are correlated with Greenbook forecasts and weakly (or even negatively) correlated with monetary surprises.

Appendix

Impulse response functions under alternative calibrations for k

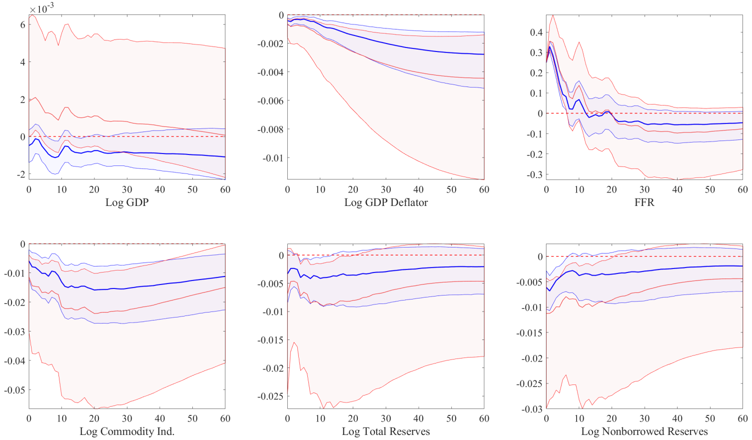


Figure A.1: Responses to contractionary ε_t^m formed from $A \in \mathcal{P}^*_{75th}$ (in blue) and under sign restrictions (in red)

Notes: The shaded bands are the 68% equal-tailed point-wise posterior probability bands.

Impulse response functions under alternative calibrations for k

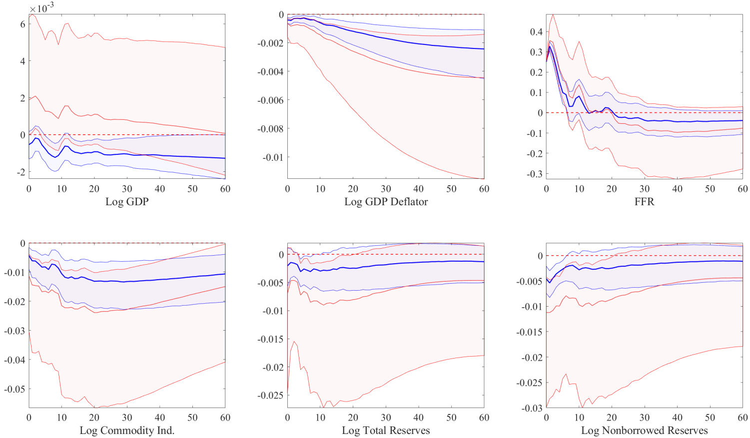


Figure A.2: Responses to contractionary ε_t^m formed from $A \in \mathcal{P}^*_{90th}$ (in blue) and under sign restrictions (in red)
Notes: The shaded bands are the 68% equal-tailed point-wise posterior probability bands.

Limitations of alternative set-identification strategies

Joint-significance of Greenbook projections	SR	SR+NR1+NR2	TR1+TR2
Accepted	73.1%	64.0%	51.4%
Rejected	26.9%	36.0%	48.6%

Table A.1: Percentages of shocks correlated with the Fed's information set, 1990:M1-2007:M11.

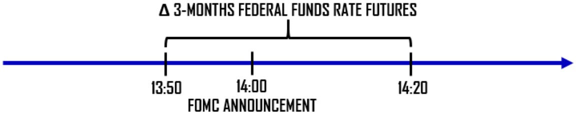
Correlation with monetary policy surprises	SR	SR+NR1+NR2	TR1+TR2
> 0	76.2%	100.0%	99.9%
> 0.2	1.1%	8.9%	10.3%

Table A.2: Percentages of shocks whose correlation with monetary policy surprises is > 0 and > 0.2, 1990:M1-2007:M11.

Back

High-frequency monetary surprises

- High-frequency monetary surprises are computed as the changes in the 3-months ahead federal funds rate futures in the 30-minute window around the FOMC announcement.



- If more than one FOMC meeting is held during the month, the monthly series is obtained by summing the high-frequency monetary surprises measured for each episode. Back

High-frequency monetary surprises and monetary policy shocks

- High-frequency monetary surprises should not be taken as direct observations of monetary policy shocks (*e.g.* central bank's information channel, serial autocorrelation).
- Moreover, the correlation between monetary policy shocks and high-frequency monetary surprises can only be imperfect.

    1. The monthly series of surprises contains random zero observations, since there are months during which an FOMC meeting does not take place.
    2. Within a month, a range of other monetary policy news is released that is not taken into account, for example through speeches of FOMC members. Back

Greenbook forecast

- The Greenbook is a document containing forecasts of various economic indicators for the US economy produced by the Federal Reserve Board before each meeting of the FOMC.
- It is released eight times per year: FOMC meetings are usually held in the first and third month of each quarter, when the forecasts prepared for the first meeting are revised.
- In converting Greenbook data to monthly frequency, I keep unchanged the forecasts for the first two months of each quarter and I update them in the last month. Back

Greenbook forecast and monetary policy shocks

- The Greenbook proxies the information set of the Fed about the current and future state of the economy and "true" monetary policy shocks should thus be uncorrelated with it.
- If not, two factors could bias the analysis of dynamic effects of monetary policy shocks.
  1. Release of central bank private information.
  2. Realization of the expected future developments to which the Fed is reacting. Back

Enforcing uncorrelation with the Fed's information set

- I require the coefficients in the regression of $\varepsilon_t^m(A)$ on the Greenbook projections to be jointly not significant at the 5% level.
- Specifically, I estimate the following regression at the monthly frequency over the period 1990:M1-2007:M11:

$$\varepsilon_t^{m,i} = \alpha_m^i + \sum_{p=-1}^{3} \phi_p^i G_{t,p}^{gdp} + \sum_{p=-1}^{3} \psi_p^i G_{t,p}^{\pi} + \vartheta_0^u G_{t,0}^u + u_{m,t}^i$$

where $\varepsilon_t^{m,i}$, with $i = 1, \dots, 100000$, is the i-th candidate shock that satisfies *Restriction SR* and $G_{t,p}^i$ denotes the p-quarters ahead Greenbook projection for variable i.

Impulse response functions under minimal external variable constraints

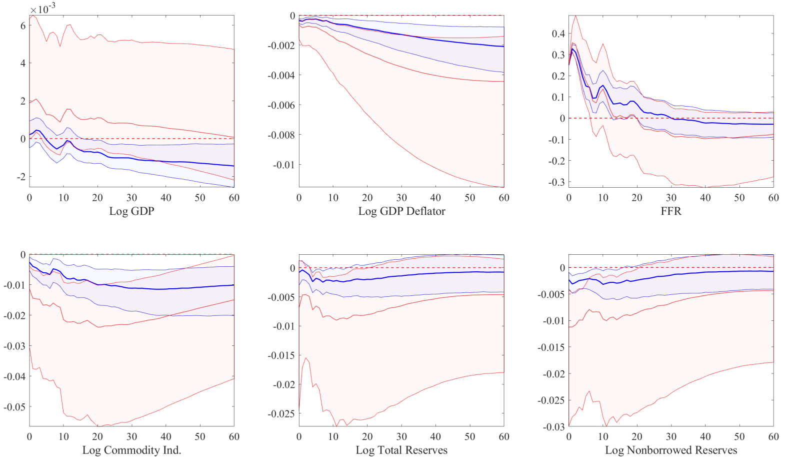


Figure A.3: Responses to contractionary ε_t^m formed from $A \in \mathcal{P}_{99th}^{*,m}$ (in blue) and under sign restrictions (in red)
Notes: The shaded bands are the 68% equal-tailed point-wise posterior probability bands.

Impulse response functions under minimal external variable constraints

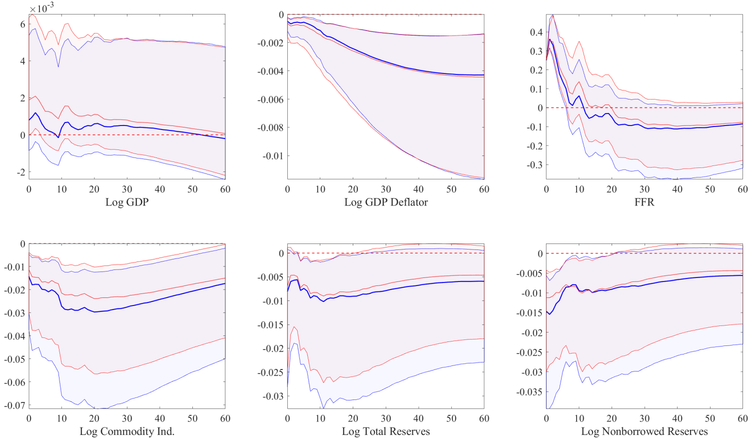


Figure A.4: Responses to contractionary ε_t^m formed from $A \in \mathcal{P}_{gb}^*$ (in blue) and under sign restrictions (in red)
Notes: The shaded bands are the 68% equal-tailed point-wise posterior probability bands.

Impulse response functions under only external variable constraints

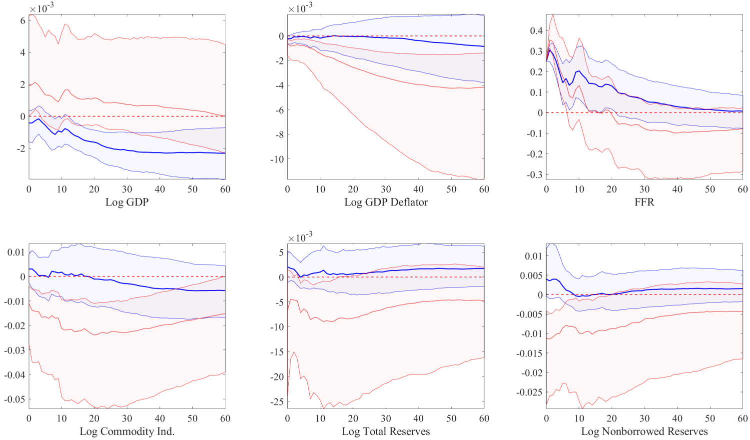


Figure A.5: Responses to contractionary ε_t^m formed from $A \in \bar{\mathcal{P}}^*_{99th}$ (in blue) and under sign restrictions (in red)

Notes: The shaded bands are the 68% equal-tailed point-wise posterior probability bands.

Comparison with narrative sign restrictions

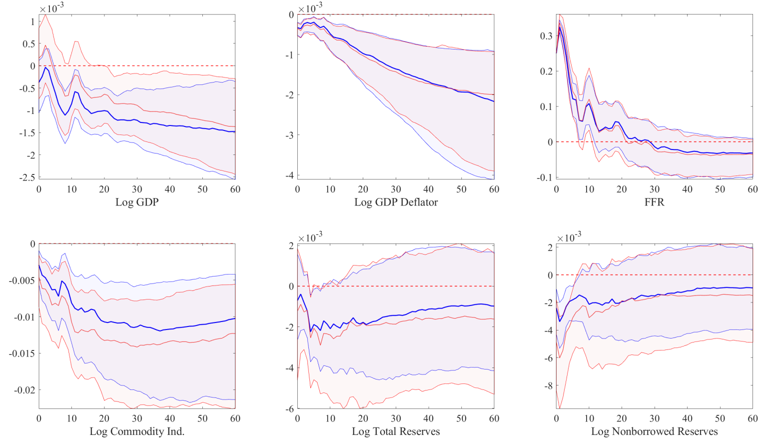


Figure A.6: Responses to contractionary ε_t^m formed from $A \in \mathcal{P}^*_{99th}$ (in blue) and under narrative sign restrictions (in red)
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Comparison with restrictions on the monetary policy equation

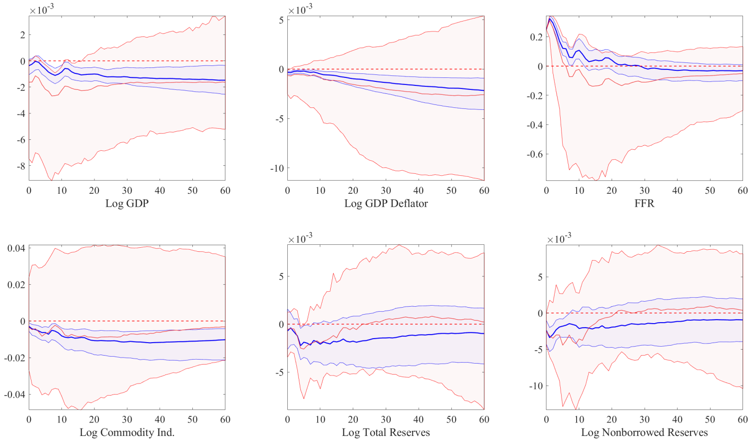


Figure A.7: Responses to contractionary ε_t^m formed from $A \in \mathcal{P}^*_{99th}$ (in blue) and under Taylor-rule restrictions (in red)
Notes: The shaded bands are the 68% equal-tailed point-wise posterior probability bands.

Am I controlling for the central bank information channel? (1)

- I now evaluate whether the use of Restriction SR and ER succeeds in controlling for the central bank information channel.
- The logic behind the tests I perform is that 'true' contractionary monetary policy shocks should be associated with a drop in the stock market (e.g. Jarociński and Karadi 2020).
- The comovement should instead be positive if the increase in the federal funds rate is related to the disclosure of good news from the Fed about future economic conditions.

Am I controlling for the central bank information channel? (2)

- First, I compute the correlation coefficients ρ_s between the monetary policy shocks ε_t^m formed from $SQ \in \mathcal{P}^*_{99th}$ and the stock market surprises SPI_t^{hf}.
- The latter are measured as the changes in the S&P 500 over a 30-minute window around each FOMC announcement.

ρ_s	**SR**	**SR+NR1+NR2**	**TR1+TR2**	**SR+ER**
< 0	45.7%	81.2%	85.6%	100.0%
> 0	54.3%	18.8%	14.4%	0%

Table A.3: Percentages of shocks whose correlation with S&P 500 surprises is < 0 and > 0, 1990:M1-2007:M11.

Am I controlling for the central bank information channel? (3)

- Second, I use local projections to derive the IRFs of US stock prices to contractionary monetary policy shocks.
- Denoting by $\varepsilon_t^{m,i}$, for $i = 1, \dots, 227$, the i-th shock formed from $SQ \in \mathcal{P}^*_{99th}$, I run the following regression at the monthly frequency:

$$SPI_{t+h} = \gamma_i^{(h)} + \sum_{l=1}^{2} \alpha_{l,i}^{(h)} SPI_{t-l} + \sum_{j=0}^{5} \beta_{j,i}^{(h)} \varepsilon_{t-j}^{m,i} + u_{t+h,i} \tag{9}$$

  where $h = 0, \dots, 48$ and SPI_t is the log of the US share price index calculated by the OECD as the average of daily closing data.
- For each horizon h, I compute the median response and the 68% credibility interval by calculating the appropriate percentiles of the set of impulse responses $\{\hat{\beta}_{0,1}^{(h)}, \dots, \hat{\beta}_{0,227}^{(h)}\}$.

Am I controlling for the central bank information channel? (4)

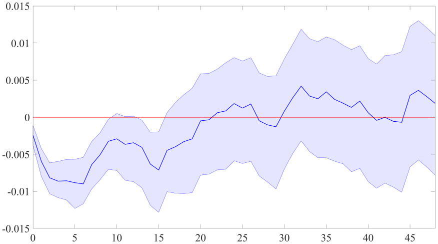


Figure A.8: Response of SPI_t to contractionary monetary policy shocks formed from $\mathcal{P}^*_{99th}$.
Notes: The shaded bands are the 68% equal-tailed point-wise posterior probability bands.

- The response is negative on impact and reaches its minimum after a few months.
- These findings seem to be consistent with the propagation of 'true' contractionary monetary policy shocks, rather than with the disclosure of Fed's private information.

Imposing Restriction SR and ER on a different model specification (1)

- I use the same external information as Miranda-Agrippino and Ricco (2021), who use Greenbook forecast and monetary surprises in a SVAR-IV framework.
- Thus, I check if my method gives analogous results when applied to the their model, that includes US monthly variables over the sample 1979:01-2014:12.

$$Y_t' = \begin{bmatrix} ip_t & pi_t & ebp_t & ci_t & u_t & ff_t \end{bmatrix} \tag{10}$$

  - ip_t and pi_t are the log of industrial production and consumer price index.
  - ebp_t is the excess bond premium and ci_t is the log of a commodity price index.
  - u_t is the unemployment rate and ff_t is the federal funds rate.

Imposing Restriction SR and ER on a different model specification (2)

Restriction SR. A monetary policy shock ε_t^m leads to a negative response of pi_t and ci_t and to a positive response of ff_t at horizons $h = 0, \ldots, 5$.

Restriction ER. Over the period 1990:M1-2014:M12, a monetary policy shock ε_t^m satisfies the following external variable constraints:

$$corr(\varepsilon_t^m, FF4_t) > k \tag{11}$$

$$corr(\varepsilon_t^m, FI_t) = 0 \tag{12}$$

where $FF4_t$ are the high-frequency monetary surprises and FI_t is the Fed's information set about current and future economic conditions, as summarized by Greenbook forecasts.

Imposing Restriction SR and ER on a different model specification (3)

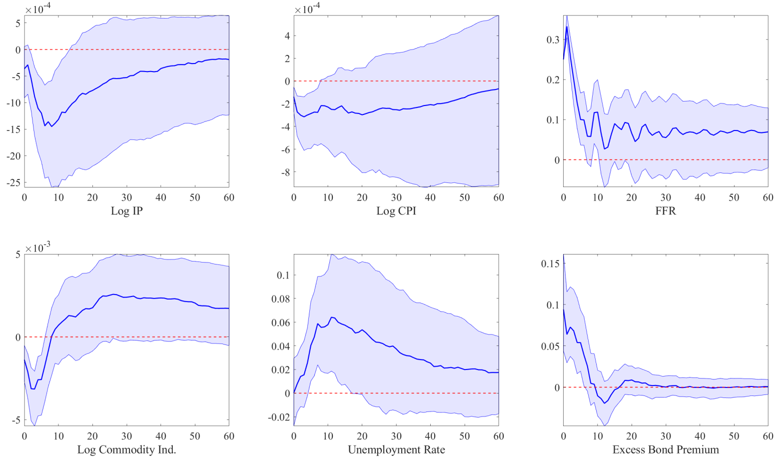


Figure A.9: Responses to contractionary ε_t^m formed from $A \in \mathcal{P}^*_{99th}$ using Miranda-Agrippino and Ricco's (2021) model. Notes: The shaded bands are the 68% equal-tailed point-wise posterior probability bands.

Robust Bayesian inference (1)

- As standard in the literature on set-identified SVARs, the marginal prior distribution for the rotation matrices $Q \in \mathcal{Q}$ has been so far assumed to be uniform.
- However, as pointed out by Baumesteir and Hamilton (2015), this implies a nonuniform distribution for the elements of Q.
- Since the impulse responses to a monetary policy shock are a weighted average of the elements in q_1, the uniform prior for Q is therefore informative for them.
- To address this issue, I compute the infimum and supremum over all admissible rotation matrices and I derive an identified set that does not depend on specific priors for Q.

Robust Bayesian inference (2)

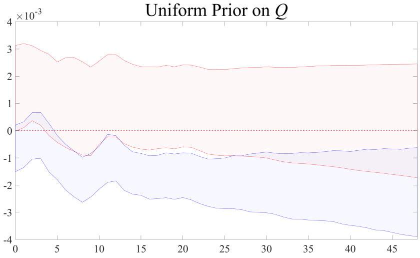
1. Draw $\phi = (B, \Sigma_e)$ from the posterior distribution of the reduced-form VAR.
2. Check if the following optimization problems have solutions q_1^* at any horizon h:

$$\min_{q_1} \text{ and } \max_{q_1} \; d'_{ih}(\phi)q_1 \quad \text{s.t.} \quad \begin{aligned} &(i)\ S_1(\phi)q_1 \geq 0 \\ &(ii)\ corr(\varepsilon_t^m(SQ), FF4_t) > k \\ &(iii)\ corr(\varepsilon_t^m, FI_t) = 0 \\ &(iv)\ ||q_1|| = 1 \end{aligned}$$

   where $d'_{ih}(\phi)$ is the i-th row vector of $D_h = C_h S$ and $S_1(\phi)q_1 \geq 0$ denotes *Restriction SR*.
3. If Step 2 is satisfied, store the impulse response functions computed using the solutions q_1^* in the sets $IRF_{i,h}^{min}$ and $IRF_{i,h}^{max}$. Otherwise, go back to Step 1.
4. Repeat Steps 1-3 M times. In the baseline case, I set $M = 1000$.

Output response under robust Bayesian inference

Sign restrictions and external variable constraints



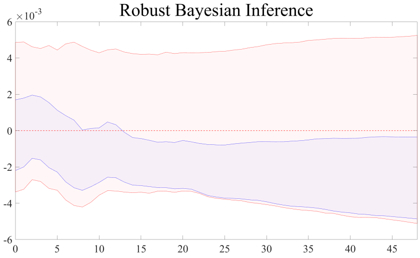


Figure A.10: 68% equal-tailed credibility interval for output response using Restriction SR and ER (in blue) and using Restriction SR (in red), with $k = 0.2$.

Output response under robust Bayesian inference

Narrative sign restrictions

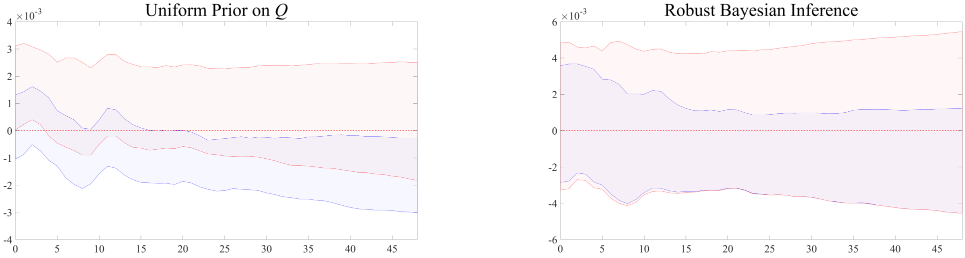


Figure A.11:68% equal-tailed credibility interval for output response using Restriction SR, NR1 and NR2 (in blue) and using Restriction SR (in red).

Output response under robust Bayesian inference

Taylor-rule restrictions

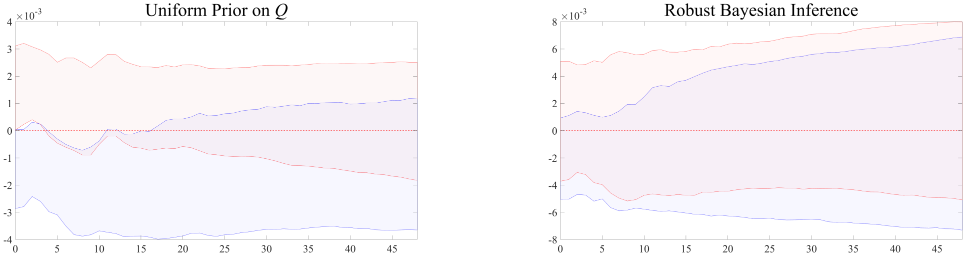


Figure A.12: 68% equal-tailed credibility interval for output response using Restriction TR1 and TR2 (in blue) and using Restriction SR (in red).

Details on historical consistency of monetary policy shocks

- A close scrutiny of Greenbook forecasts and FOMC meetings minutes suggests that the episodes occurred in December 1988 and February 1994 may not be really exogenous.
- The monetary tightening in December 1988 is in fact paired with upward revisions in the nowcast and one-quarter ahead Greenbook forecast for output growth.
- The minutes of the FOMC meeting held in February 1994 state instead that the policy tightening was motivated by the confidential access to ‘optimistic’ employment data.

Back