Identifying High-Frequency Shocks with a Bayesian Mixed Frequency VAR Approach

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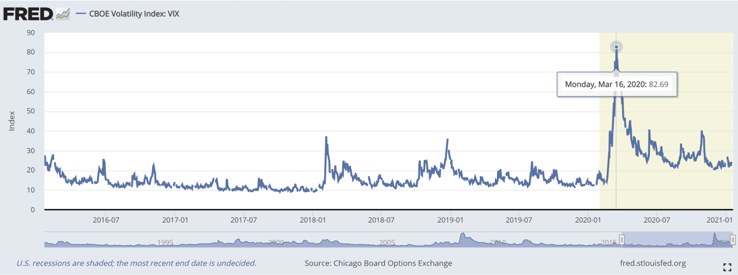
*The views expressed in this paper are those of the authors and do not necessarily reflect the views of the Bank of Lithuania or the ESCB.

Motivation

- Uncertainty induced by COVID-19 has a huge impact on business cycle.
- Financial Uncertainty (VIX) is high-frequency and business cycle variables are low-frequency.



- **How can we identify a high-frequency uncertainty shock on US macroeconomic variables?**

Contribution

- Research question: "**How can we identify a high-frequency shock on low-frequency variables?**"
- What we do: We assess the propagation mechanism of VIX uncertainty shock in U.S. over 1990M1-2019M12, using data sampled at a different frequency.
- We introduce a new **High-Frequency Identification Approach**.
- We study **Temporal Aggregation Bias** induced by relying on a standard (common low-frequency) VAR.
- How we do it: We estimate a Mixed-frequency VAR (Ghysels, 2016 JOE) by adopting Bayesian techniques.

  We use a Normal-Inverse Wishart prior for mixed-frequency VARs (Götz et al., 2016 JOE) for shock identification.
- Spoiler: Mixed-Frequency matters!

Data and empirical strategy

- Baseline MF-VARs (estimated over 1990M1 – 2019M12) fitted to:
  1. VIX (weekly) and U.S. macro variables (monthly). weekly VIX series
  2. VIX (daily) and U.S. macro variables (monthly): each month has 20 observations as in Götz et al. (2016).
- The set of U.S. business cycle variables includes:
  - Consumer price index - CPI (Δln)
  - Industrial production index - IP (Δln)
  - Real personal consumption expenditures - PCE (Δln)
  - Effective federal funds rate - FFR
- Lag length is set to 3 (Akaike criterion). Robustness check: 6 and 12 lags.
- Cholesky decomposition with VIX ordered first (publication lags) as in Ferrara and Guérin (2018).
- Size of the COVID-19 uncertainty shock calibrated as in Caggiano et al., (2020): 5σ of VIX shock identified over 1990M1-2019M12

Weekly IRF - MF-VAR(3) Priors

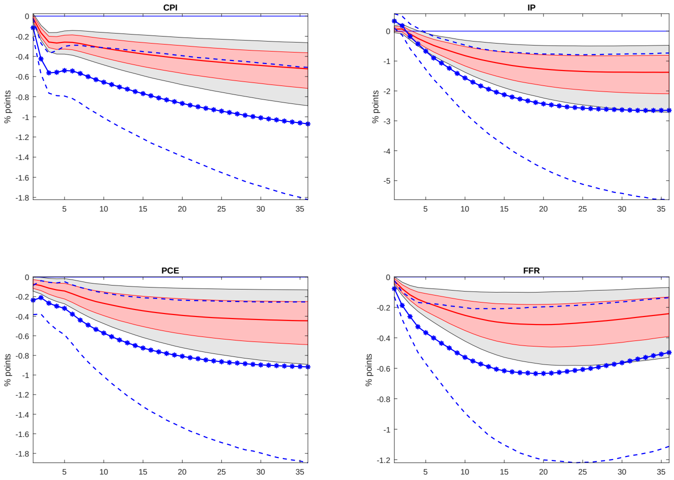


Figure 1: Aggregated weekly responses. Median response (red line) with 68% (red shading) and 90% (gray shading) CI. IRFs from standard VAR(3) are reported (blue lines).

Daily IRF - MF-VAR(3) Priors

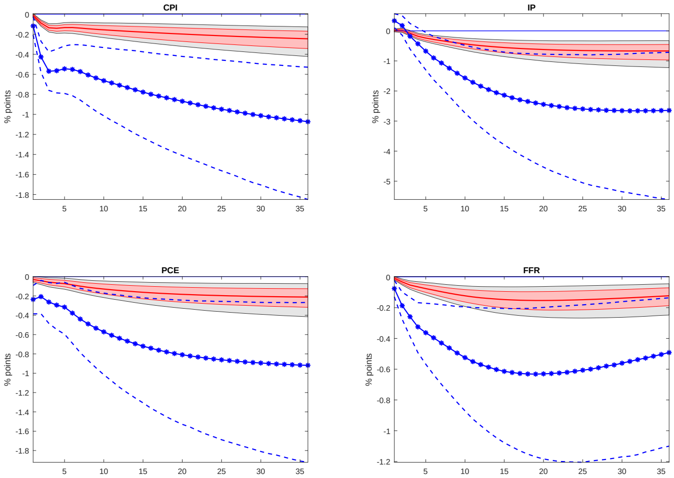


Figure 2: Aggregated daily responses. Median response (red line) with 68% (red shading) and 90% (gray shading) CI. IRFs from standard VAR(3) are reported (blue lines).

Robustness checks

- We perform several robustness checks.
  - Number of Lags. 6 and 12 lags
  - Extended set of macroeconomic variables. More variables Shadow short rate
  - VIX ordered last. IRF
  - Excluding Global Financial Crisis. IRF
  - Pre-treatment of High-Frequency Variable. IRF
- The Current COVID-19-induced Uncertainty: 1990M1-2020M11 time span.
  - Weekly vs. monthly. Aggregated IRF
  - Daily vs. monthly. Daily IRF Aggregated daily IRF

Wrapping Up

- This paper investigates the effects of a high-frequency shock on low-frequency variables using mixed-frequency data.
- We introduce a **novel Bayesian Mixed-Frequency VAR model** applied to structural analysis.
- We identify the VIX shock on US macro variables as illustrative example.
- **General Main Result**: Detrimental effect of uncertainty on real economic activity (i.e. Bloom, 2009; Caldara et al., 2016; Caggiano et al., 2017) in both common and mixed-frequency.
- **Particular Main Result**: Moderate evidence of temporal aggregation bias, more pronounced in case of large differences in sampling frequencies (HFvsLF).
- **Policy Implications**: Temporal Aggregation Bias and the timing of the shocks matter in the response of low frequency variables (Ferrara and Guérin, 2018).

Questions Time

Appendix

Appendix: Weekly series of VIX I Back

- Following Ferrara and Guérin (2018), we construct a weekly series of VIX such that each month contains 4 weeks.
- Given the number of traded days (D_t) within a month, the weekly observations can be computed as follows:
  - First week extends from day 1 to $D_t - 15$.
  - Second week extends from $D_t - 14$ to $D_t - 10$.
  - Third week extends from $D_t - 9$ to $D_t - 5$.
  - Fourth week extends from $D_t - 4$ to D_t.
- We use the last observation for each week to construct the weekly series of VIX.

Appendix: Weekly series of VIX II

Back

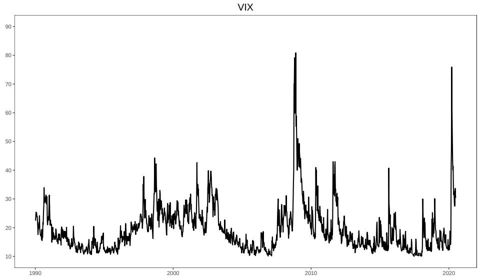


Figure A.1: VIX (weekly frequency). 1990M1 – 2020M6.

Appendix: N-IW prior for MF-VAR Back

- Let us write the model in (1) as follows:

$$Z = \underline{Z}B + U \tag{A.1}$$

where $Z = (Z_1, \ldots, Z_T)'$, $\underline{Z} = (\underline{Z}_1, \ldots, \underline{Z}_T)'$, with $\underline{Z}_t = (\underline{Z}'_{t-1}, \ldots, \underline{Z}'_{t-\ell}, 1')$, $U = (u_1, \ldots, u_t)'$ and $B = (A_1, \ldots, A_\ell, c)'$.

- Normal-Inverse Wishart prior obtained by using artificial observations (Y_d, X_d):

$$Z^* = \underline{Z}^* B + U^* \tag{A.2}$$

where $Z^* = (Z', Y_d')'$ and $\underline{Z}^* = (\underline{Z}', X_d')'$.

Appendix: Dummy observations for RHS variables

- Dummy observations for lagged variables in MF-VAR are set as in Bańbura et al. (2010):

$$\underset{[(Kp+1)+K]\times(Kp+1)}{X_d} = \begin{pmatrix} J_P \otimes diag(\sigma_{1,H}, \dots, \sigma_{m-1,H}, \sigma_{m,H}, \sigma_L)/\lambda & \mathbf{0}_{Kp\times 1} \\ \cdots & \cdots \\ \mathbf{0}_{K\times Kp} & \mathbf{0}_{K\times 1} \\ \cdots & \cdots \\ \mathbf{0}_{1\times Kp} & \varepsilon \end{pmatrix} \tag{A.3}$$

where $J_p = \text{diag}(1, 2, \dots, p)$, ε controls the prior for the intercept and $K = (Kh \times m) + Kl$. Back

Appendix: Conditional posterior

Back

- Conditional posterior of the MF-VAR parameters (B, Σ):

$$B|\Sigma, Y \sim \mathcal{N}\Big(B^*,\ \Sigma \otimes (\underline{Z}^{*'}\underline{Z}^*)^{-1}\Big) \tag{A.4}$$
$$\Sigma|B, Y \sim \mathcal{IW}\Big(S^*,\ v^*\Big)$$

with:

$$B^* = (\underline{Z}^{*'}\underline{Z}^*)^{-1}\underline{Z}^{*'}Z^* \tag{A.5}$$
$$S^* = (Z^* - \underline{Z}^*\tilde{B})'(Z^* - \underline{Z}^*\tilde{B})$$

where B^* is the OLS estimate of the augmented regression in (A.2) and $\tilde{B}$ is a draw of the MF-VAR coefficients.

- Gibbs sampler to simulate the posterior distribution of the MF-VAR coefficients. 15000 iterations, using the last 5000 for inference.

Appendix: Convergence - MFVAR(3) (weekly VIX)

Back

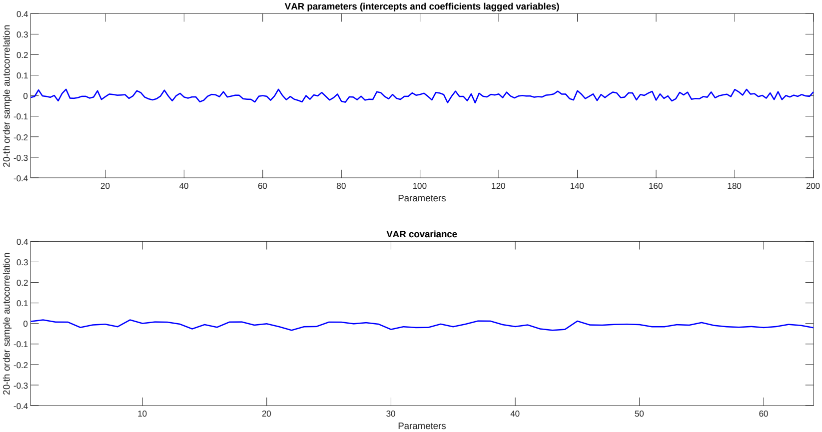


Figure A.2: 20th-order sample autocorrelation of the retained draws computed for the VAR parameters (intercepts and coefficients associated to lagged variables) (upper panel) and for the VAR covariances (lower panel).

Appendix: Convergence - MFVAR(3) (daily VIX)

Back

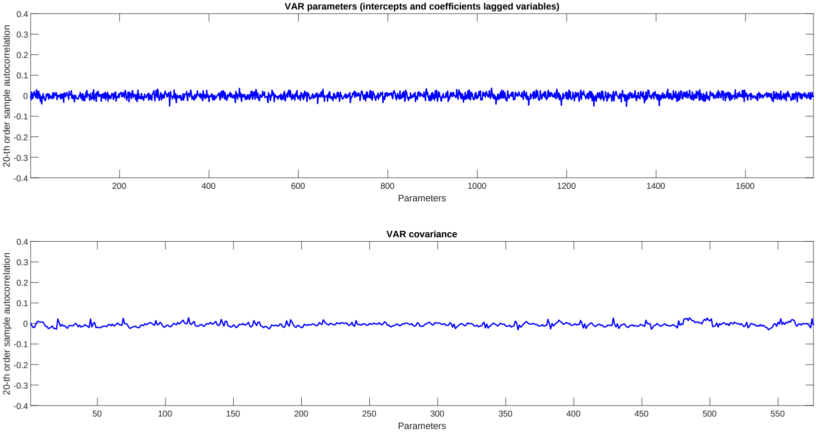
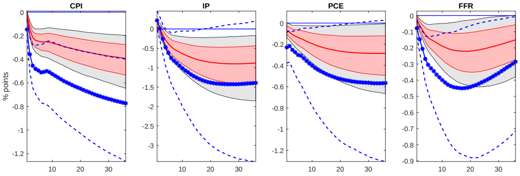


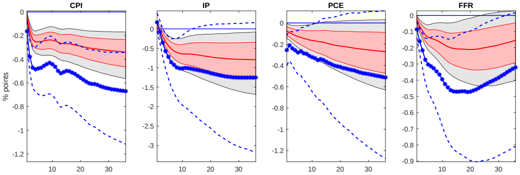
Figure A.3: 20th-order sample autocorrelation of the retained draws computed for the VAR parameters (intercepts and coefficients associated to lagged variables) (upper panel) and for the VAR covariances (lower panel).

Appendix: Different number of lags

Back



(a) Mixed-Frequency VAR with 6 lags.



(b) Mixed-Frequency VAR with 12 lags.

Figure A.4: Aggregated weekly responses. Median response (red line) with 68% (red shading) and 90% (gray shading) CI. IRFs from standard VAR(3) are reported (blue lines).

Appendix: Extended set of variables I

Back

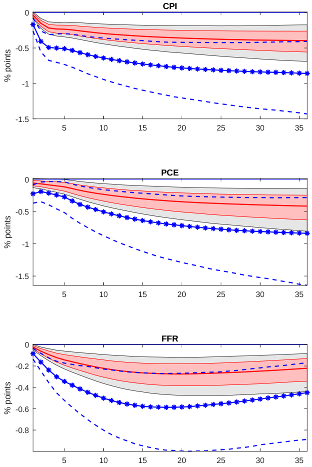


Figure A.5: Aggregated weekly responses. Median response (red line) with 68% (red shading) and 90% (gray shading) CI. IRFs from standard VAR(3) are reported (blue lines).

Appendix: Extended set of variables II

Back

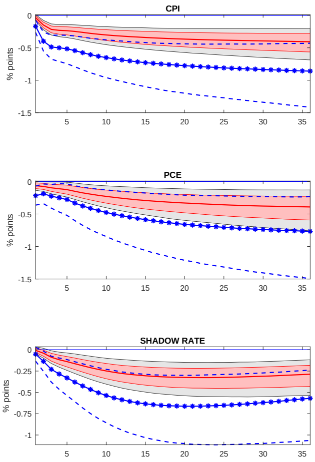


Figure A.6: Aggregated weekly responses. Median response (red line) with 68% (red shading) and 90% (gray shading) CI. IRFs from standard VAR(3) are reported (blue lines).

Appendix: VIX ordered last

Back

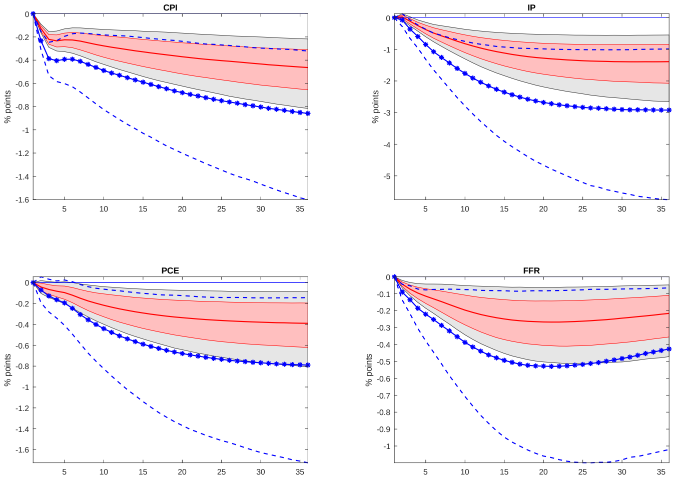


Figure A.7: Aggregated weekly responses. Median response (red line) with 68% (red shading) and 90% (gray shading) CB. IRFs from standard VAR(3) are reported (blue lines).

Appendix: IRF weekly (including COVID-19)

Back

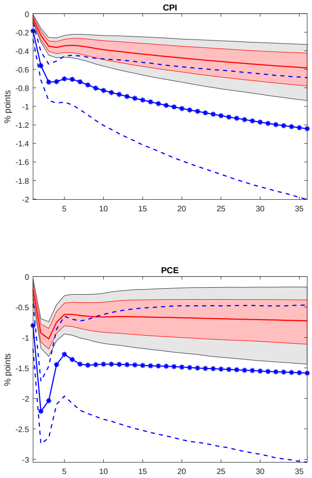


Figure A.8: Aggregated weekly responses. Median response (red line) with 68% (red shading) and 90% (gray shading) CB. IRFs from standard VAR(3) are reported (blue lines).

Appendix: IRF daily (including COVID-19) I

Back

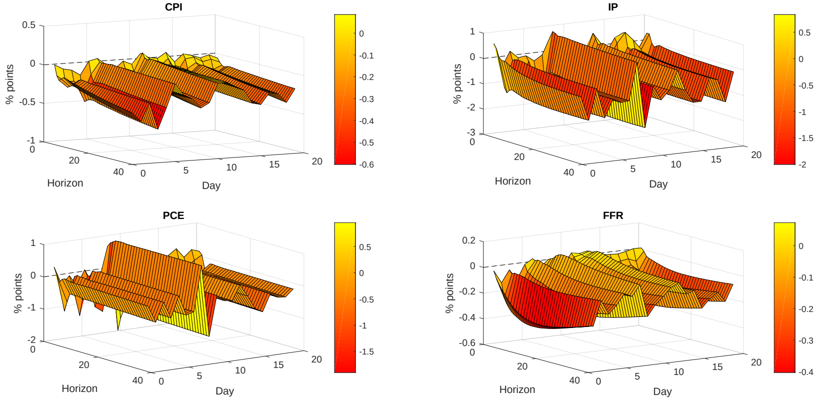


Figure A.9: Median responses of macroeconomic variables.

Appendix: IRF daily (including COVID-19) II

Back

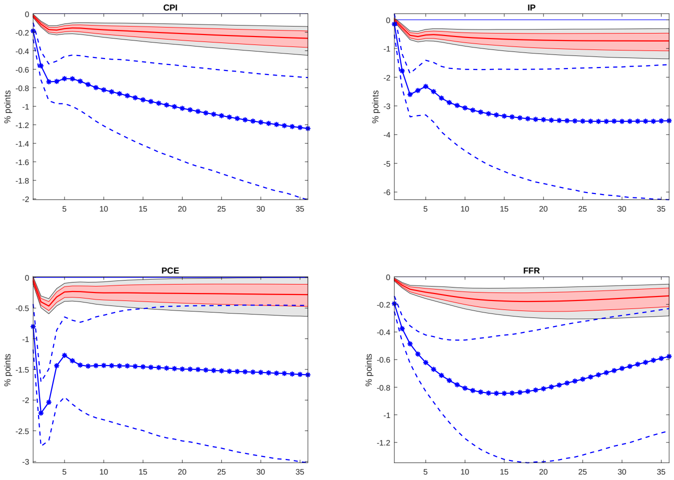


Figure A.10: Aggregated daily responses. Median response (red line) with 68% (red shading) and 90% (gray shading) CB. IRFs from standard VAR(3) are reported (blue lines).

Appendix: IRF weekly (before Global Financial Crisis)

Back

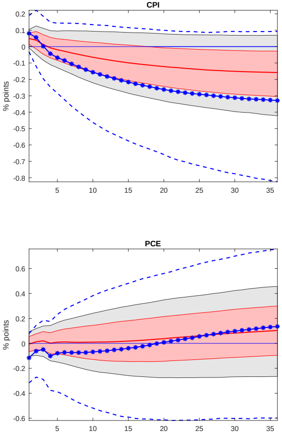


Figure A.11: Aggregated weekly responses. Median response (red line) with 68% (red shading) and 90% (gray shading) CB. IRFs from standard VAR(3) are reported (blue lines).

Different Priors

Back

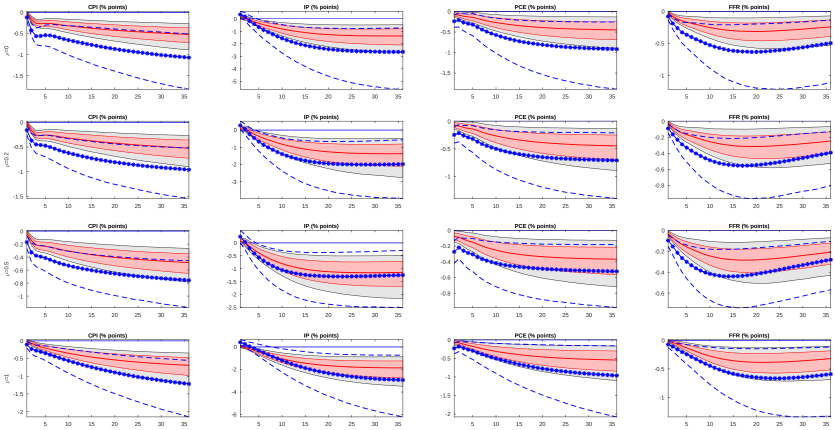


Figure A.12: Aggregated weekly responses. Median response (red line) with 68% (red shading) and 90% (gray shading) CB. IRFs from standard VAR(3) are reported (blue lines).

Different Priors

Back

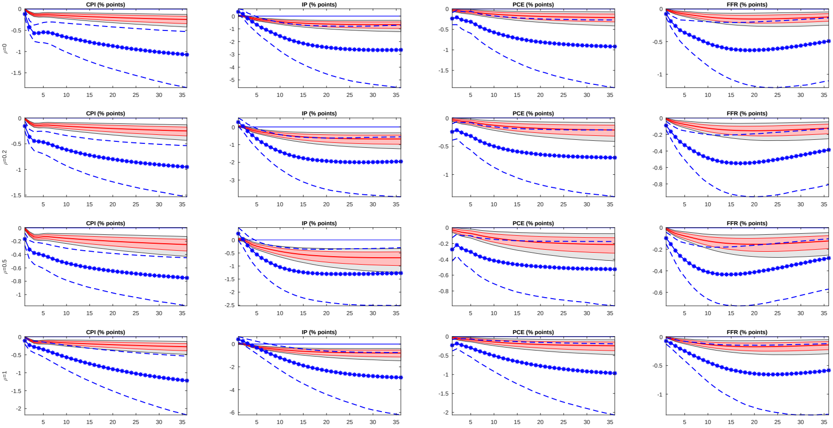


Figure A.13: Aggregated daily responses. Median response (red line) with 68% (red shading) and 90% (gray shading) CB. IRFs from standard VAR(3) are reported (blue lines).

Pre-Treatment Weekly

Back

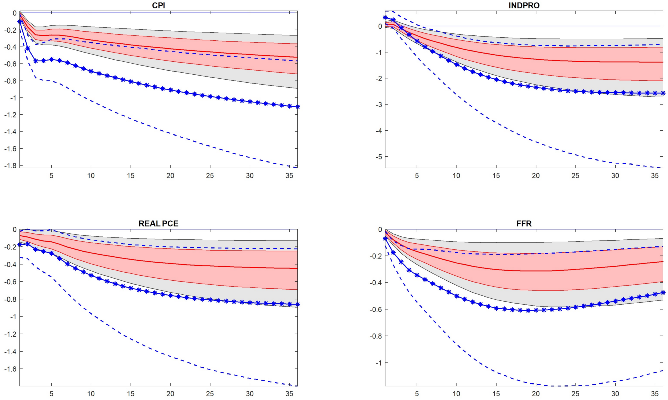


Figure A.14: Aggregated weekly responses. Median response (red line) with 68% (red shading) and 90% (gray shading) CB. IRFs from standard VAR(3) are reported (blue lines).

Pre-Treatment daily

Back

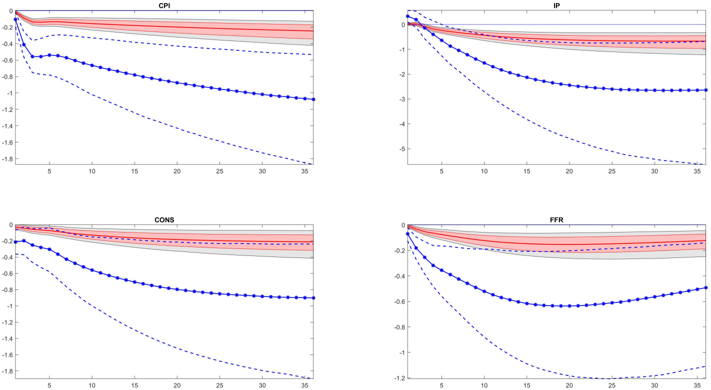


Figure A.15: Aggregated daily responses. Median response (red line) with 68% (red shading) and 90% (gray shading) CB. IRFs from standard VAR(3) are reported (blue lines).

Pre-Treatment Daily

Back

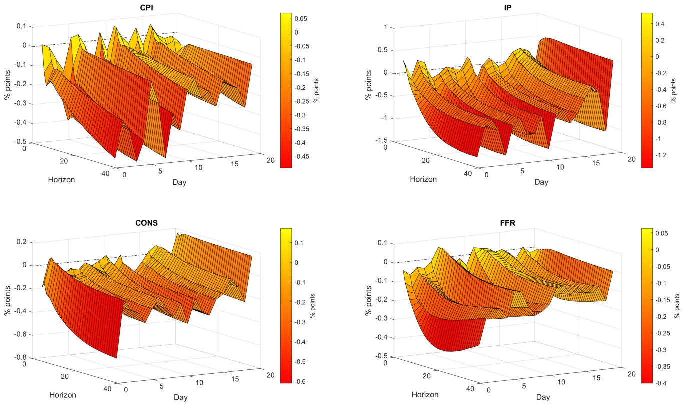


Figure A.16: Median responses of macroeconomic variables.