Instructions on the Replication Code for "Uncertainty and Business Cycles: Exogenous Impulse or Endogenous Response?"

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The replication files are written in MATLAB R2018a and were also tested in R2014b, R2018b, and R2019a. All files are written in Windows 10 OS and they are not tested under OS other than Windows 10. To run all programs more effectively, all codes are written in parallel ("parfor") and thus require MATLAB parallel computing toolbox. All codes, however, could still be operating without this toolbox but the runtime is significantly longer.

To replicate the figures and tables of the paper, run the MATLAB file for the corresponding figure and table. Throughout the paper, we fixed the 1.5-million random rotations and the seeds are saved in QQ_full.mat. All supporting codes needed for plots are in the "supporting_code" folder. Default output figures are saved in PDF format in "Figure" directory. These programs were last run in August 2019.

Data The data file "Replication_Data.xlsx" contains all data needed for replicating results in the paper.

- **Uncertainty Indexes.** For macro uncertainty U_{Mt}, we use the FRED-MD monthly *macro dataset* (May 2015 vintage), which we denote $\mathcal{X}_t^M$, consisting of 134 mostly macroeconomic time series. URL: `https://s3.amazonaws.com/files.fred.stlouisfed.org/fred-md/monthly/2015-05.csv`. This dataset is described in detail in McCracken and Ng (2016). For financial uncertainty U_{Ft}, we construct a *financial dataset* $\mathcal{X}_t^F$ consisting of 148 measures of monthly financial indicators. Both datasets were previously used in Ludvigson and Ng (2007) and JLN, but they are updated to the longer sample. Policy uncertainty data series are based on Baker, Bloom and Davis (2016).

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Both baseline EPU index (series name Baseline_overall_index) and news-based EPU index (series name News_Based_Policy_Uncert_Index) were downloaded from URL: `https://www.policyuncertainty.com/media/US_Policy_Uncertainty_Data.xlsx`. The series were downloaded in July 2017. In the data file, variable "Financial Uncertainty" is one-month ahead Financial Uncertainty, variable "Macro Uncertainty" is one-month ahead Macro Uncertainty, variable "Real Uncertainty" is one-month ahead Real Uncertainty. Variable "Um12" is one-year ahead Macro Uncertainty and variable "Uf12" is one-year ahead Financial Uncertainty.

- **Industrial Production**. Data for *ip* (series name "INDPRO") are from the FRED-MD dataset (2015-05 Vintage) URL: `https://s3.amazonaws.com/files.fred.stlouisfed.org/fred-md/monthly/2015-05.csv`. In the data file, variable "ip" is log of *ip* and variable "ipg" is the 12-month moving average of log *ip* growth.

- **CRSP** denotes Center for Research in Securities Prices value-weighted stock market index return. These data were retrieved from NYU CRSP data subscription file. The data were downloaded in February 2016.

- **Gold** denotes the real gold price level. These data were downloaded from Macrotrends, URL: `https://www.macrotrends.net/1333/historical-gold-prices-100-year-chart`. The data were downloaded in January 2018. Macrotrends produces the series by combining information from the London Bullion Market Association (LBMA) measure of daily auction prices of gold, and the Bureau of Labor Statistics.

- **EPU and EPU news**. Both baseline EPU (series name Baseline_overall_index) and news-based EPNnews (series name News_Based_Policy_Uncert_Index) were downloaded from URL `https://www.policyuncertainty.com/media/US_Policy_Uncertainty_Data.xlsx`. Both series were constructed by Baker, Bloom and Davis (2016). The series were downloaded in July 2017.

- **VIX** denotes CBOE Volatility Index. These data were downloaded from CBOE. The 1990-2003 data are from URL: `http://www.cboe.com/publish/scheduledtask/mktdata/datahouse/vixarchive.xls`. The post-2004 data are from URL: `http://www.cboe.com/publish/scheduledtask/mktdata/datahouse/vixcurrent.csv`. We convert the

daily observations to monthly frequency using the end-of-month "VIX Close". The data were downloaded in August 2018.

Figure 1 To replicate Figure 1, run gen_Figure1.m using MATLAB. It imports the spreadsheet data, loads pre-saved 1.5 million random rotations, and generates the plots "Figure1" in the Figure subfolder.

Figure 2 To replicate Figure 2, run gen_Figure2.m using MATLAB. It imports the spreadsheet data, loads pre-saved 1.5 million random rotations (and their corresponding IRF, stored in IRF_cov.mat). It generates the plots "Figure2" in the Figure subfolder.

Figure 3 To replicate Figure 3, run gen_Figure3.m using MATLAB. It imports the spreadsheet data, loads pre-saved 1.5 million random rotations. It generates the left panel of Figure 3 in the paper "Figure3_left" and the right panel of Figure 3 in the paper "Figure3_left" in the Figure subfolder.

Figure 4 To replicate Figure 4, run gen_Figure4.m using MATLAB. It imports the spreadsheet data, loads pre-saved 1.5 million random rotations (and their corresponding B, stored in B_store_hist.mat). It generates the plots "Figure4" in the Figure subfolder.

Figure 5 To replicate Figure 5, run gen_Figure5.m using MATLAB. It imports the spreadsheet data, loads pre-saved 1.5 million random rotations. It generates the left panel of Figure 5 in the paper "Figure5_left" and the right panel of Figure 5 in the paper "Figure5_left" in the Figure subfolder.

Figure 6 To replicate Figure 6, run gen_Figure6.m using MATLAB. It imports the spreadsheet data, loads pre-saved 1.5 million random rotations and 10,000 random replications (stored in MC_allsol.mat). It generates the plots "Figure6" in the Figure subfolder.

Figure 7 To replicate Figure 7, run gen_Figure7.m using MATLAB. It imports the spreadsheet data, loads pre-saved 1.5 million random rotations. It generates the left panel of Figure 7 in the paper "Figure7_left" and the right panel of Figure 7 in the paper "Figure7_left" in the Figure subfolder.

Figure 8 To replicate Figure 8, run gen_Figure8.m using MATLAB. It imports the spreadsheet data, loads pre-saved 1.5 million random rotations. It generates the left panel of Figure 8 in the paper "Figure8_left" and the right panel of Figure 8 in the paper "Figure8_left" in the Figure subfolder.

Figure A1 To replicate Figure A1, run gen_FigureA1.m using MATLAB. It imports the spreadsheet data, loads pre-saved 1.5 million random rotations. It generates the plots "FigureA1" in the Figure subfolder.

Table 1 To replicate Table 1, run both gen_Table1_Left_Panel and gen_Table1_Right_Panel using MATLAB. It imports the spreadsheet data, loads pre-saved 1.5 million random rotations. It produces the set of variance decomposition under $s = 1, 12, \infty$, and max.

In-text Numbers To replicate numbers on Page 10 line 12, and numbers on Page 22 line 11-14, run gen_intext.m. It imports the spreadsheet data, loads pre-saved 1.5 million random rotations.

Supporting codes

- ciplot_h.m: plot the set of impulse repones functions.
- gen_B.m: generate the matrix B for given rotations and $\bar{k}$ for the system (U_M, ip, U_F).
- gen_B_EPU.m: generate the matrix B for given rotations and $\bar{k}$ for the system (EPU, ip, U_F).
- gen_B_hist.m: generate the matrix B for given rotations and histogram specifications (Figure 4) for the system (U_M, ip, U_F).
- gen_B_minimal.m: generate the matrix B for given rotations and minimal specifications (Figure 2) for the system (U_M, ip, U_F).
- gen_lo_hi.m: generate impulse response set for given matrix B.
- plot_irf_fan_three_sign.m: plot impulse response set for three specifications (Figure 2).
- plot_ts_eshock.m: plot the time series of e (Figure 5).

- plot_irf_fan_CI.m: plot impulse response set with MC error bands (Figure 6).
- plot_irf_fan_two_EPU.m: plot impulse response set for two specifications (Figure 7).
- plot_irf_fan.m: plot impulse response set for one specification (Figure 8).
- rshade.m: add NBER recession bands to the plot.

References

Baker, Scott R, Nicholas Bloom, and Steven J Davis, "Measuring economic policy uncertainty," *The Quarterly Journal of Economics*, 2016, *131* (4), 1593–1636.

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