Measuring the Effects of Fiscal Policy Shocks on U.S. Output in a Markov-Switching Bayesian VAR

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Prepared for the
2023 Midwest Econometrics Group Meetings
Hosted by the Federal Reserve Bank of Cleveland

October 13, 2023

Outline

Introduction

The Blanchard-Perotti Fiscal Policy Literature

- Blanchard and Perotti (QJE, 2002) estimate the effects of government spending and tax shocks on U.S. output in a SVAR.

- No consensus in the BP literature about size of fiscal multipliers.

  1. Different identification strategies.

     $\Longrightarrow$ See short-run restrictions of BP (QJE, 2002), sign restrictions of Mountford and Uhlig (JAE, 2009) and narrative approach of Ramey (QJE, 2011).

  2. State-dependent fiscal multipliers.

     $\Longrightarrow$ Auerbach and Gorodnichenko (AEJ:EP, 2012), Fazzari, Morley, and Panovska (SNDE, 2015, 2021) vs Ramey and Zubairy (JPE, 2018), Rossi, Inoue, and Wang (CEPR-WP, 2022).

  3. Fiscal foresight.

     $\Longrightarrow$ Leeper, Walker, and Yang (LWY) (Econometrica, 2013).

Contributions of this Paper

- **Goal:** Measure effects of fiscal policy shocks on U.S. output using Markov-switching Bayesian VARs (MS-BVARs).
- **Contribution 1:** Use MS-BVARs to address fiscal foresight identification problem.
- **Contribution 2:** Provide insights on whether fiscal multipliers depend on the fiscal or macro/financial regime in place.

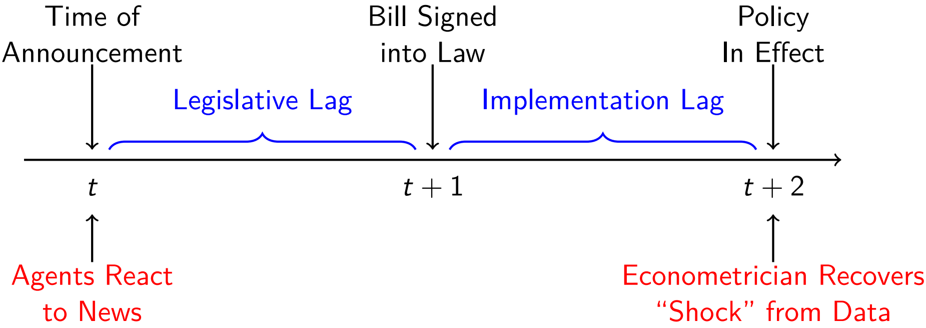
Key Findings

- GOV multipliers depend on state of U.S. business/financial cycle.
  - Near 1 during expansions.
  - Ranges from 1.5 to 2 during recessions.
- TAX multipliers are small and swamped with uncertainty.
  - Estimates fall between -0.1 and -0.4.
  - At odds with previous empirical estimates ranging from -2 to -3.
  - However, more consistent with those found by fiscal DSGE models.
- Estimated GOV multipliers $>$ TAX multipliers.
  - Consistent with traditional Keynesian prediction.

Identification Problem of Fiscal Foresight

Fiscal Foresight: An Illustration

- Fiscal foresight occurs when forward-looking agents preemptively react in anticipation of future policy changes.



Fiscal Foresight and Misidentification

- LWY (Econometrica, 2013) show fiscal foresight misaligns information sets of agents and econometrician.

  $\Longrightarrow$ Shocks of interest cannot be recovered from current and past observable data.

- **Result of Misidentification:** Foresight biases fiscal multiplier results obtained from conventional SVARs.

Analytical Example

Using MS-BVARs to Confront Fiscal Foresight

- Agents observe and anticipate fiscal policy regime changes.
- Agents assign probabilities to each possible and incorporate them when formulating expectations.
- Capturing these probabilities is key to address fiscal foresight.

  $\Longrightarrow$ An MS-BVAR captures these probabilities in estimation.

A Structural MS-BVAR

A Structural MS-BVAR

- The MS-BVAR of Sims and Zha (AER, 2006) and SWZ (JoE, 2008) is

$$y_t' A_0(s_t^c) = \sum_{j=1}^{p} y_{t-j}' A_j(s_t^c) + c + \varepsilon_t' \Xi^{-1}(s_t^{sv}), \quad \varepsilon_t \sim \mathcal{N}(0_{n\times 1}, I_n),$$

where

- s_t: Unobservable state variable driving regime switching.
- y_t: $n \times 1$ vector of endogenous variables,
- ε_t: $n \times 1$ vector of uncorrelated structural shocks,
- c: $1 \times n$ vector of intercept terms,
- $A_0(s_t)$ and $A_j(s_t)$: $n \times n$ matrices of structural coefficients,
- $\Xi(s_t)$: $n \times n$ diagonal matrix of factor loadings scaling SV of ε_t.

MS in an MS-BVAR | Bayesian Estimation

Data

- Define the information set y_t as

$$y_t \equiv \left[\underbrace{[GOV_t \;\; TAX_t]}_{\textit{Fiscal Policy}} \; \underbrace{[RGDP_t \;\; \pi_t \;\; R_{3m,t} \;\; R_{10yr,t}]}_{\textit{Macro \& Financial}} \right]',$$

  where
  - GOV_t: (Log of) Per capita real government spending.
  - TAX_t: (Log of) Per capita real net taxes.
  - $RGDP_t$: (Log of) Per capita real GDP.
  - π_t: GDP deflator inflation rate.
  - $R_{3m,t}$: Three-month U.S. Treasury bill rate.
  - $R_{10yr,t}$: Ten-year U.S. Treasury bond constant maturity yield.

- Sample period: 1960Q1 to 2019Q4, $T = 240$.

Model Space

- 15 MS-BVARs across three identifications and five MS specifications.
  1. 1c2v: Two SV regimes.
  2. 2c1v: Two structural coefficient regimes.
  3. 2c2v: Two structural coefficient regimes and two SV regimes.
  4. 2$\mathcal{FP}$c, 2v: Two Fiscal Policy block regimes and two SV regimes.
  5. 2$\mathcal{FP}$c, 2$\mathcal{MF}$c, 2v: Two Fiscal Policy block regimes, two Macro/Financial block regimes, and two SV regimes.

Identification Schemes Model Space

Results

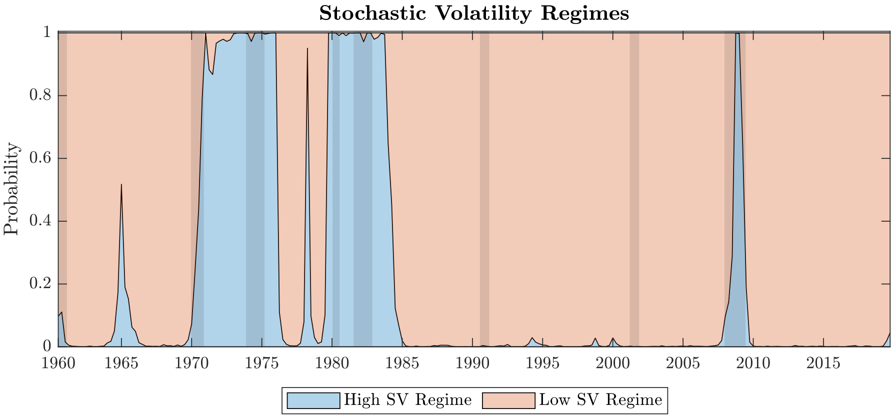
Best-Fit MS-BVAR

- MS-BVAR most favored by the data assumes

  1. a non-recursive Blanchard-Perotti identification scheme,
  2. two SV regimes,
  3. two Fiscal Policy block regimes, and
  4. two Macro/Financial block regimes.

Model Fit Results

SV Regime Probabilities, 1960Q1 to 2019Q4

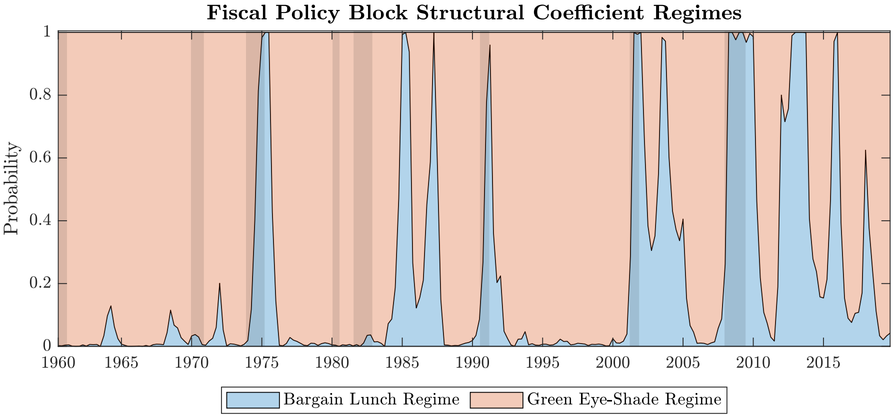


Notes: The shaded bars correspond to the NBER recession dates.

- High SV during most NBER recessions.

Estimates

Fiscal Policy Block Regime Probabilities, 1960Q1 to 2019Q4

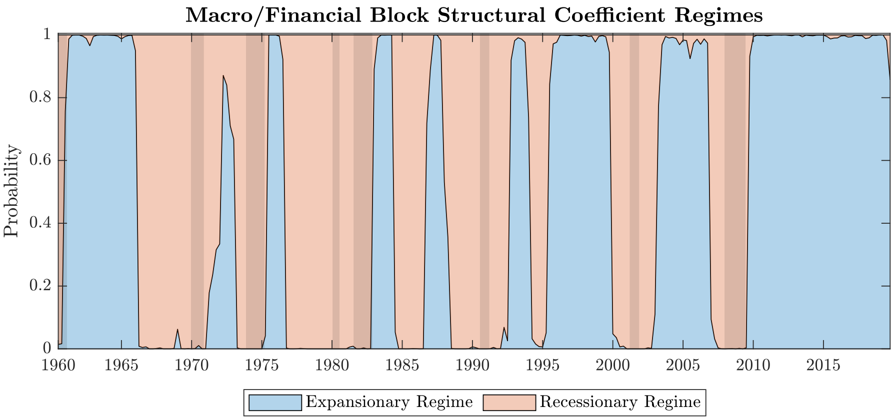


Notes: The shaded bars correspond to the NBER recession dates.

- "Bargain Lunch" regime: Historical episodes of increases in *GOV* and/or cuts in *TAX*.
- "Green Eye-Shade" regime: Periods outside fiscal expansions.

Estimates

Macro/Financial Block Regime Probabilities, 1960Q1 to 2019Q4

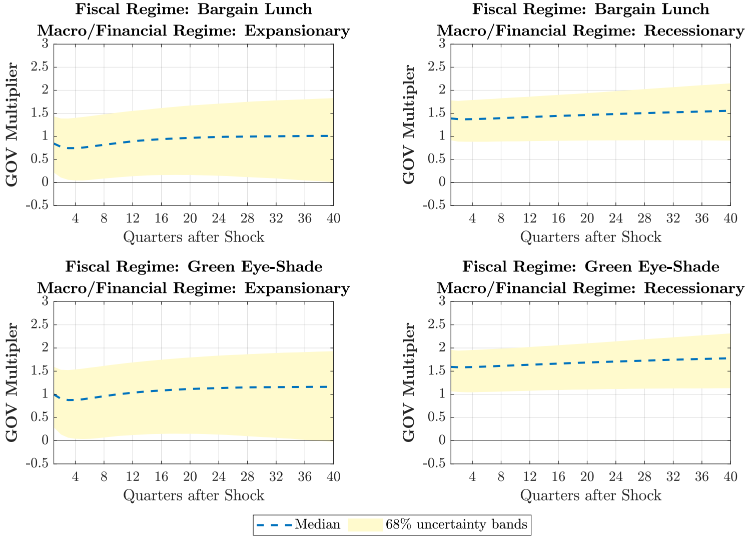


Notes: The shaded bars correspond to the NBER recession dates.

- *RGDP* response to *GOV* shocks > 2.5x during "Recessionary" regime.
- *RGDP* hardly responds to *TAX* shocks in either regime.

Estimates

Present-Value Government Spending Multipliers

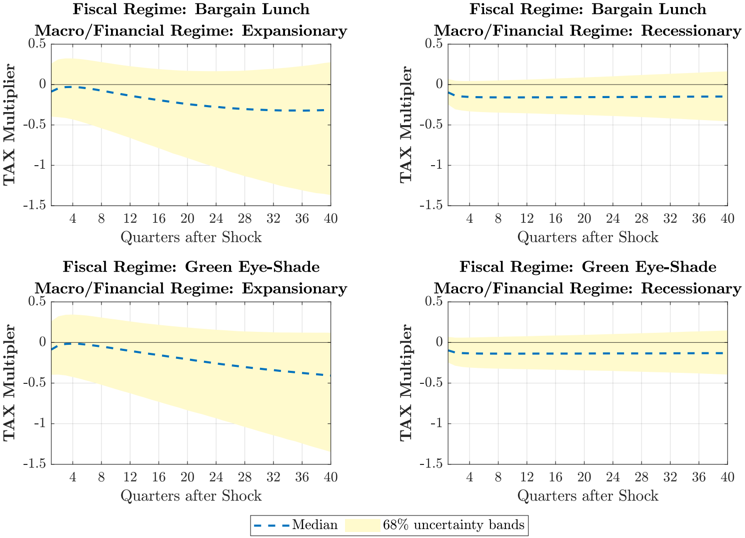


GIRFs

- GOV multipliers depend on state of business/financial cycle.

Estimates

Present-Value Tax Multipliers



- Uncertainty swamps TAX multipliers across all regimes.

GIRFs

Estimates

Conclusion

Conclusion

- Fiscal foresight complicates task of measuring fiscal multipliers.

  $\Longrightarrow$ MS-BVARs account for foresight by explicitly capturing agents' expectations of future regime change.

- GOV multipliers > 1 and larger in recessions.

- TAX multipliers are small and swamped with uncertainty.

- Estimated GOV multipliers $>$ TAX multipliers.

  $\Longrightarrow$ Consistent with traditional Keynesian macroeconomic theory.

Thank You.

Appendix

Analytical Example of Fiscal Foresight

- Consider a standard growth model with log preferences, inelastic labor supply, and complete depreciation of capital.

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \log(C_t)$$

$$\text{s.t.}$$

$$C_t + K_t + T_t \leq (1 - \tau_t) A_t K_{t-1}^{\alpha}$$

Equilibrium Condition and Solution for Capital

- Log-linearized equilibrium condition for capital

$$
\begin{aligned}
E_t k_{t+1} - \left(\theta^{-1} + \alpha\right) k_t + \alpha\theta^{-1} k_{t-1} \\
&= E_t \left[a_{t+1} - \theta^{-1} a_t\right] + \left\{\theta^{-1}(1-\theta)\left(\frac{\tau}{1-\tau}\right)\right\} E_t \hat{\tau}_{t+1}
\end{aligned}
$$

where $\theta = \alpha\beta(1-\tau) < 1$.

- Solution for capital

$$
k_t = \alpha k_{t-1} + a_t - (1-\theta)\left(\frac{\tau}{1-\tau}\right)\sum_{i=0}^{\infty} \theta^i E_t \hat{\tau}_{t+i+1}
$$

Tax Rule and Information Flows

- Assume agents at date t receive a signal that tells them exactly what tax rate they will face in period $t + q$.
- Log-linearized tax rule is

$$\hat{\tau}_t = \varepsilon_{\tau,t-q}$$

Case I: No Foresight

- Solution for capital with no foresight ($q = 0$)

$$k_t = \alpha k_{t-1} + \varepsilon_{A,t}$$

- Econometrician estimates the following VAR

$$\begin{bmatrix} \hat{\tau}_t \\ k_t \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & \alpha \end{bmatrix} \begin{bmatrix} \hat{\tau}_{t-1} \\ k_{t-1} \end{bmatrix} + \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{\tau,t} \\ \varepsilon_{A,t} \end{bmatrix}$$

$$\Longrightarrow \underbrace{\begin{bmatrix} \hat{\tau}_t \\ k_t \end{bmatrix}}_{y_t} = \underbrace{\begin{bmatrix} 1 & 0 \\ 0 & \frac{1}{1-\alpha L} \end{bmatrix}}_{C(L)} \underbrace{\begin{bmatrix} \varepsilon_{\tau,t} \\ \varepsilon_{A,t} \end{bmatrix}}_{\varepsilon_t}$$

- Knowledge of current and past y_t is equivalent to past and present ε_t.

  $\Longrightarrow$ **Result:** $\{\varepsilon_{t-j}\}_{j=0}^{\infty}$ are fundamental to $\{y_{t-j}\}_{j=0}^{\infty}$.

Case II: Two-Period Foresight

- Solution for capital with two-period foresight ($q = 2$)

$$k_t = \alpha k_{t-1} + \varepsilon_{A,t} - \kappa \{\varepsilon_{\tau,t-1} + \theta \varepsilon_{\tau,t}\}$$
$$\implies (1 - \alpha L) k_t = -\kappa (L + \theta) \varepsilon_{\tau,t}$$

where $\kappa = (1 - \theta) \left(\frac{\tau}{1-\tau} \right)$.

- Invertibility of stochastic process in current and past k_t requires $|\theta| > 1$,

$$\left[\frac{1 - \alpha L}{1 + \theta^{-1} L} \right] k_t = -\kappa \theta \varepsilon_{\tau,t}$$

- However, we know $\theta < 1$

$\implies$ Process is non-invertible in current and past capital!!!

Case II: Two-Period Foresight

- Wold representation for capital

$$(1-\alpha L)k_t = \underbrace{-\kappa(L+\theta)\left[\frac{1+\theta L}{L+\theta}\right]}_{-\kappa(1+\theta L)}\underbrace{\left[\frac{L+\theta}{1+\theta L}\right]\varepsilon_{\tau,t}}_{\varepsilon^*_{\tau,t}}$$

$$(1-\alpha L)k_t = -\kappa\left\{\theta\varepsilon^*_{\tau,t-1} + \varepsilon^*_{\tau,t}\right\}$$

- Recall solution for capital with two-period foresight

$$(1-\alpha L)k_t = -\kappa\left\{\varepsilon_{\tau,t-1} + \theta\varepsilon_{\tau,t}\right\}$$

- **Implication:** Econometrician recovers current and past $\varepsilon^*_{\tau,t}$, which are not news that agents observe, $\varepsilon_{\tau,t}$.

Case II: Two-Period Foresight

- Shocks recovered by econometrician turn out to be "old news" to agents

$$\varepsilon^*_{\tau,t} = \left[\frac{L+\theta}{1+\theta L}\right]\varepsilon_{\tau,t} = (L+\theta)\sum_{j=0}^{\infty} -\theta^j \varepsilon_{\tau,t-j}$$
$$= \theta\varepsilon_{\tau,t} + \left(1-\theta^2\right)\varepsilon_{\tau,t-1} - \theta\left(1-\theta^2\right)\varepsilon_{\tau,t-2} + \cdots$$

- Recovered shock is actually discounted sum of tax news observed by agents at date t and earlier!

  $\Longrightarrow$ Econometrician discounts tax innovations incorrectly!

- **Implication:** Information set of agents is strictly larger than econometrician's!

Case II: Two-Period Foresight

- Adding lagged taxes to VAR does not solve non-invertibility issue

$$\begin{bmatrix} \hat{\tau}_t \\ k_t \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & \alpha \end{bmatrix} \begin{bmatrix} \hat{\tau}_{t-1} \\ k_{t-1} \end{bmatrix} + \begin{bmatrix} L^2 & 0 \\ -\kappa(\theta + L) & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{\tau,t} \\ \varepsilon_{A,t} \end{bmatrix}$$

$$\Longrightarrow \underbrace{\begin{bmatrix} \hat{\tau}_t \\ k_t \end{bmatrix}}_{y_t} = \underbrace{\begin{bmatrix} L^2 & 0 \\ \frac{-\kappa(\theta+L)}{1-\alpha L} & \frac{1}{1-\alpha L} \end{bmatrix}}_{H(L)} \underbrace{\begin{bmatrix} \varepsilon_{\tau,t} \\ \varepsilon_{A,t} \end{bmatrix}}_{\varepsilon_t}$$

- **Ultimate Result:** $\{\varepsilon_{t-j}\}_{j=0}^{\infty}$ are NOT fundamental to $\{y_{t-j}\}_{j=0}^{\infty}$.

Back

MS in SWZ MS-BVAR

- MS may be imposed on
  1. structural (impact and lag) coefficients, $A_0(s_t)$ and $A_j(s_t)$,
  2. factor loadings in $\Xi(s_t)$, or
  3. both.
- MS is controlled by transition matrix $Q = [q_{ij}]$ for $i, j = 1, \ldots, H$.

  $\Longrightarrow$ q_{ij}: probability of switching from regime j to i.

Restricted Transition Matrices

- SWZ restrict Q to allow only for symmetric switching between adjacent regimes so that

$$Q = \begin{bmatrix} q_{11} & (1-q_{22})/2 & \cdots & 0 & 0 \\ 1-q_{11} & q_{22} & \ddots & \vdots & \vdots \\ 0 & (1-q_{22})/2 & \ddots & (1-q_{H-1,H-1})/2 & 0 \\ \vdots & \vdots & \ddots & q_{H-1,H-1} & 1-q_{H,H} \\ 0 & 0 & \cdots & (1-q_{H-1,H-1})/2 & q_{H,H} \end{bmatrix}.$$

A Structural MS-BVAR: The Likelihood Function

- The likelihood function of an MS-BVAR is

$$p\left(Y_T|\theta, Q\right) = \prod_{t=1}^{T}\left[\sum_{s_t \in H} p\left(y_t|Y_{t-1}, \theta, Q, s_t\right) p\left(s_t|Y_{t-1}, \theta, Q\right)\right],$$

where $Y_T \equiv \{y_1, \ldots, y_T\}$ and $\theta \equiv \{A_0, A_+, \Xi\}$.

- Evaluating the MS-BVAR likelihood function requires one to
    1. obtain the conditional likelihood function $p\left(y_t|Y_{t-1}, \theta, Q, s_t\right)$ at time t and
    2. recursively filter the sequence of transition probabilities in $p\left(s_t|Y_{t-1}, \theta, Q\right)$; see Appendix A of SWZ (JoE, 2008).

A Structural MS-BVAR: The Prior

- Posterior distribution of an MS-BVAR is constructed using a prior with two distinct elements.

  1. The Sims and Zha (IER, 1998) random walk prior.
     - Imposed on the impact and lag coefficients and the intercept terms.
     - Assumes y_t consists of n independent random walk processes.
     - Behavior of these random walk processes depends on six hyperparameters $\Longrightarrow \Lambda = [\lambda_0\ \lambda_1\ \lambda_3\ \lambda_4\ \mu_5\ \mu_6]$.
  2. A Dirichlet prior.
     - Imposed on the transition probabilities in Q.
     - Controls the average duration of regime $i \Longrightarrow \frac{1}{1-q_{ii}}$ periods.

A Structural MS-BVAR: The Posterior Distribution

- By Bayes' rule, the posterior distribution of an MS-BVAR is

$$\underbrace{p\left(\theta, Q | Y_T\right)}_{Posterior} \propto \underbrace{p\left(Y_T | \theta, Q\right)}_{Likelihood} \underbrace{p(\theta, Q)}_{Prior}.$$

- Model evaluation using MDDs relies on the MS-BVAR posterior.

  $\Longrightarrow$ Use modified harmonic mean (MHM) estimator of SWZ.

A Structural MS-BVAR: Estimation Tools

- MS-BVARs are estimated and evaluated in MATLAB using Dynare.
- Estimating MS-BVARs is computationally time-consuming.

  $\Longrightarrow$ High-performance computing resources are used.

A Structural MS-BVAR: Estimation and Evaluation

- Given the data and priors, the procedure for estimating a sequence of MS-BVARs and evaluating which of the competing model(s) is (are) favored by the data is sketched below.

Step 1. Estimate the posterior mode of θ and Q in $p(\theta, Q|Y_T)$ using SWZ's blockwise optimization algorithm,

Step 2. Initialize SWZ's Metropolis in Gibbs MCMC sampler at the posterior mode estimates of θ and Q,

Step 3. Employ SWZ's Metropolis in Gibbs sampling algorithm to simulate $K_1 + K_2$ MCMC draws from the proposal distribution,

Step 4. Discard the first K_1 MCMC draws as a burn-in sample and use remaining K_2 draws to construct the posterior distribution of the relevant MS-BVAR,

Step 5. Calculate the MDD using the posterior distribution of the previous step using either the modified harmonic mean (HMH) estimator of Gelfand and Dey (J. R. Stat. Soc., 1994) and Geweke (*Contemporary Bayesian Econometrics and Statistics*, 2005) or SWZ's truncated MHM estimator,

Step 6. Designate the MS-BVAR(s) with the highest MDD value(s) as the best-fit MS-BVAR(s), and

Step 7. Rerun the best-fit MS-BVAR(s) to verify the model(s) retains its most favored status.

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List of MS-BVAR Model Space

MS-BVAR	Specification	Identification
1	1c2v	Non-Recursive Impact Matrix: Extended Blanchard-Perotti
2	1c2v	Recursive Impact Matrix: Tax Rule
3	1c2v	Recursive Impact Matrix: Government Spending Rule
4	2c1v	Non-Recursive Impact Matrix: Extended Blanchard-Perotti
5	2c1v	Recursive Impact Matrix: Tax Rule
6	2c1v	Recursive Impact Matrix: Government Spending Rule
7	2c2v	Non-Recursive Impact Matrix: Extended Blanchard-Perotti
8	2c2v	Recursive Impact Matrix: Tax Rule
9	2c2v	Recursive Impact Matrix: Government Spending Rule
10	$2\mathcal{FP}$c,2v	Non-Recursive Impact Matrix: Extended Blanchard-Perotti
11	$2\mathcal{FP}$c,2v	Recursive Impact Matrix: Tax Rule
12	$2\mathcal{FP}$c,2v	Recursive Impact Matrix: Government Spending Rule
13	$2\mathcal{FP}$c,$2\mathcal{MF}$c,2v	Non-Recursive Impact Matrix: Extended Blanchard-Perotti
14	$2\mathcal{FP}$c,$2\mathcal{MF}$c,2v	Recursive Impact Matrix: Tax Rule
15	$2\mathcal{FP}$c,$2\mathcal{MF}$c,2v	Recursive Impact Matrix: Government Spending Rule

Notes: The MS-BVARs. The MS-BVAR-1 to -9 have one Markov chain on the structural (impact and lag) coefficients and another Markov chain on the SVs. The number of structural coefficient regimes is indicated by the label #c, while the number of SV regimes is specified by the label #v. This differs from MS-BVAR-10 to -12, which have one Markov chain on the structural coefficients of the $\mathcal{FP}$ block regressions and one Markov chain on the SVs. The MS-BVAR-13 to -15 assume one Markov chain on the $\mathcal{FP}$ block structural coefficients, another chain on the $\mathcal{MF}$ block structural coefficients, and a final chain on the SVs. The label $\#\mathcal{FP}$c ($\#\mathcal{MF}$c) indicates the number of $\mathcal{FP}$ ($\mathcal{MF}$) block structural coefficient regimes.

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Alternative Identification Schemes

- Consider three alternative identification schemes.
    1. Non-Recursive ordering with a tax rule.
    2. Recursive ordering with a tax rule.
    3. Recursive ordering and a government spending rule.

Non-Recursive Identification: Extended Blanchard-Perotti

- Identification draws from Blanchard and Perotti (QJE, 2002).
- Based on timing assumptions of tax, transfer, and spending programs.

1. *GOV* and *TAX* do not respond to each other's shock in same period.
2. *TAX* responds to *RGDP* shocks at impact.
3. Macro/Financial ($\mathcal{MF}$) block responds to Fiscal Policy ($\mathcal{FP}$) block shocks at impact.

Non-Recursive Identification Impact Matrix

Table: Non-Recursive Identifying Restrictions on the Impact Matrix $A_0(s_t)$

Variable \ Shock	Govt Spending	Tax Revenue	Aggregate Supply	Aggregate Demand	Debt Refinancing	Term Premium
GOV	X					
TAX		X	X			
$RGDP$	X	X	X			
π	X	X	X	X		
R_{3m}	X	X	X	X	X	
R_{10yr}	X	X	X	X	X	X

Notes: An "X" entry represents an unrestricted impact coefficient, while a blank space denotes a zero restriction.

Two Recursive Identifications

1. Recursive Ordering: Tax Rule

$$y_t \equiv \left[\underbrace{[GOV_t \quad TAX_t]}_{\text{Fiscal Policy}} \; \underbrace{[RGDP_t \quad \pi_t \quad R_{3m,t} \quad R_{10yr,t}]}_{\text{Macro \& Financial}}\right]'.$$

$\Longrightarrow$ *TAX* passively adjust to satisfy government budget constraint.

2. Recursive Ordering: Government Spending Rule

$$y_t \equiv \left[\underbrace{[TAX_t \quad GOV_t]}_{\text{Fiscal Policy}} \; \underbrace{[RGDP_t \quad \pi_t \quad R_{3m,t} \quad R_{10yr,t}]}_{\text{Macro \& Financial}}\right]'.$$

$\Longrightarrow$ *GOV* accommodates structural changes in tax policy.

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Model Fit Results

Table: Log Marginal Data Densities of the MS-BVARs

	Specification					
Identification	Constant Coefficient BVAR	Two SV Regimes	Two Coefficient Regimes	Two Coefficient and SV Regimes	Two $\mathcal{FP}$ Coefficient and SV Regimes	Two $\mathcal{FP}$ and $\mathcal{MF}$ Coefficient and SV Regimes
Non-Recursive Impact Matrix:	BVAR-1	MS-BVAR-1	MS-BVAR-4	MS-BVAR-7	MS-BVAR-10	**MS-BVAR-13**
Extended Blanchard-Perotti	-1772.60	-1629.91	-1648.83	-1578.62	-1583.31	**-1566.07**
Recursive Impact Matrix:	BVAR-2	MS-BVAR-2	MS-BVAR-5	MS-BVAR-8	MS-BVAR-11	MS-BVAR-14
Tax Rule	-1773.70	-1630.80	-1653.73	-1585.95	-1604.04	-1577.07
Recursive Impact Matrix:	BVAR-3	MS-BVAR-3	MS-BVAR-6	MS-BVAR-9	MS-BVAR-12	MS-BVAR-15
Government Spending Rule	-1773.70	-1629.93	-1653.34	-1610.76	-1596.42	-1573.95

Notes: The log marginal data densities (MDDs) of the constant coefficient BVARs (BVAR-1 to -3) are calculated with the modified harmonic mean (MHM) estimator of Geweke (*Contemporary Bayesian Econometrics and Statistics*, 2005). Sims, Waggoner, and Zha (JoE, 2008) develop a truncated MHM estimator suitable for MS-BVARs with multimodal posteriors. This estimator is employed to calculate the MDDs of the MS-BVARs (MS-BVAR-1 to -15). The results shown are based on 10 million MCMC draws and the 1960Q1 to 2019Q4 sample. The best-fit MS-BVAR and its estimated ln MDD are in bold.

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Estimates of SV Regime Transition Probabilities

- Estimated SV regime transition matrix $\hat{Q}^{sv}$ is

$$\widehat{Q}^{sv} = \begin{bmatrix} \underset{[0.822, 0.981]}{0.918} & \underset{[0.009, 0.073]}{0.033} \\ \underset{[0.019, 0.178]}{0.082} & \underset{[0.927, 0.991]}{0.967} \end{bmatrix}.$$

- SV regimes are quite persistent.

$\Longrightarrow \hat{p}^{sv}_{11} = 0.918 \longrightarrow$ First regime lasts over 12 quarters.

$\Longrightarrow \hat{p}^{sv}_{22} = 0.967 \longrightarrow$ Second regime is over 30 quarters.

Regime Dependent Scale Volatilities

- First SV regime coincides with most NBER recessions in sample.
    1. High SV in aggregate supply ($RGDP$), aggregate demand (π), and debt financing (R_{3m}) shocks.
    2. Large degree of uncertainty over scale of GOV, TAX, and term premium (R_{10yr}) shocks.
- Second SV regime occurs during economic expansions.

Estimates of SVs

Table: Regime Dependent Scale Volatilities of $\hat{\Xi}^{-1}(s_t^{sv})$, Best-Fit MS-BVAR

	GOV	TAX	RGDP	π	$\mathrm{R}_{3\mathrm{m}}$	$\mathrm{R}_{10\mathrm{yr}}$
$s_t^{sv} = 1$	1.000	1.000	1.000	1.000	1.000	1.000
$s_t^{sv} = 2$	0.655	0.516	0.280	0.342	0.122	0.731
	[0.391, 1.038]	[0.269, 0.919]	[0.181, 0.469]	[0.212, 0.553]	[0.084, 0.198]	[0.401, 2.697]

Notes: The regime dependent scale volatilities are the medians of the posterior of MS-BVAR-13. Ninety percent Bayesian credible sets (i.e., 5th and 95th quantiles) are in brackets. The results depend on 10 million MCMC draws.

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Fiscal Policy Block Regime Transition Probabilities

- Estimated Fiscal Policy block regime transition matrix $\hat{Q}^{\mathcal{FP}c}$ is

$$\widehat{Q}^{\mathcal{FP}c} = \begin{bmatrix} 0.823 & 0.061 \\ [0.701, 0.928] & [0.030, 0.106] \\ 0.177 & 0.939 \\ [0.073, 0.300] & [0.894, 0.970] \end{bmatrix}.$$

- One $\mathcal{FP}$ block coefficient regime is more persistent than the other.

$\Longrightarrow \hat{p}_{11}^{\mathcal{FP}c} = 0.823 \longrightarrow$ First regime expected duration is 6 quarters.

$\Longrightarrow \hat{p}_{22}^{\mathcal{FP}c} = 0.939 \longrightarrow$ Second regime lasts for 16 quarters.

Fiscal Policy Block Impact Coefficient Estimates

- First Fiscal Policy block regime covers several historical episodes of tax cuts and expansions in government spending.

  1. Own shock response for $GOV > 1$.
  2. TAX is only responsive to $RGDP$ shocks.

  $\Longrightarrow$ Label this as **"Bargain Lunch regime."**

- Second Fiscal Policy block regime occurs outside these fiscal expansions.

  1. GOV responds less than one-for-one to own shocks.
  2. TAX has a larger response to own and $RGDP$ shocks.

  $\Longrightarrow$ Label this as **"Green Eye-Shade regime."**

Estimates of Impact Matrices

Macro/Financial Block Regime Transition Probabilities

- Estimated Macro/Financial block regime transition matrix $\hat{Q}^{\mathcal{MF}c}$ is

$$\widehat{Q}^{\mathcal{MF}c} = \begin{bmatrix} 0.917 & 0.082 \\ [0.853, 0.960] & [0.039, 0.147] \\ 0.083 & 0.918 \\ [0.040, 0.147] & [0.853, 0.961] \end{bmatrix}.$$

- Macro/Financial block regime probabilities are almost identical.

  $\Longrightarrow$ Expected duration for either regime is around 12 quarters.

Macro/Financial Block Impact Coefficient Estimates

- Macro/Financial block regimes capture U.S. business and financial cycles.

  1. *GOV* shocks produce over 2.5 times larger response in *RGDP* under second regime.
  2. *RGDP* hardly responds to *TAX* shocks in any regime.

- First regime labeled as **"Expansionary regime."**
- Second regime labeled as **"Recessionary regime."**

Estimates of Impact Matrix $\widehat{A}_0'(s_t^{\mathcal{FP}c} = 1|s_t^{\mathcal{MF}c} = 1)$

Table: The Regime Conditional Impact Matrix $\widehat{A}_0'(s_t^{\mathcal{FP}c} = 1|s_t^{\mathcal{MF}c} = 1)$

Shock \ Variable	GOV	TAX	RGDP	π	R_{3m}	R_{10yr}
Government Spending	1.219 [0.921, 1.563]					
Tax		0.082 [0.061, 0.103]	-0.486 [-1.157, 0.450]			
Aggregate Supply	-0.174 [-0.345, 0.019]	0.008 [-0.064, 0.057]	0.897 [0.709, 1.106]			
Aggregate Demand	0.044 [-0.080, 0.181]	-0.046 [-0.075, -0.018]	0.024 [-0.155, 0.214]	2.435 [2.068, 2.830]		
Debt Financing	0.130 [0.038, 0.233]	0.001 [-0.019, 0.019]	-0.250 [-0.428, -0.114]	-0.554 [-0.911, -0.267]	0.890 [0.754, 1.035]	
Term Premium	0.055 [-0.120, 0.235]	0.006 [-0.028, 0.039]	-0.102 [-0.348, 0.109]	0.083 [-0.425, 0.643]	-1.077 [-1.399, -0.781]	2.820 [2.241, 3.509]

Notes: The elements of $\widehat{A}_0'(s_t^{\mathcal{FP}c} = 1|s_t^{\mathcal{MF}c} = 1)$ are at the median of the posterior of MS-BVAR-13. Each row represents a behavioral equation. The behavioral equations are labeled by their respective structural shock. The column labels indicate which variables enter each behavioral equation at impact. Ninety percent Bayesian credible sets (i.e., 5th and 95th quantiles) are in brackets.

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Estimates of Impact Matrix $\widehat{A}_0'(s_t^{\mathcal{FP}c} = 2 | s_t^{\mathcal{MF}c} = 2)$

Table: The Regime Conditional Impact Matrix $\widehat{A}_0'(s_t^{\mathcal{FP}c} = 2 | s_t^{\mathcal{MF}c} = 2)$

Shock \ Variable	GOV	TAX	RGDP	π	$\mathrm{R}_{3\mathrm{m}}$	$\mathrm{R}_{10\mathrm{yr}}$
Government Spending	0.908 [0.765, 1.070]					
Tax		0.340 [0.272, 0.406]	-0.675 [-0.935, -0.360]			
Aggregate Supply	-0.468 [-0.675, -0.239]	0.017 [-0.040, 0.054]	1.376 [1.072, 1.777]			
Aggregate Demand	-0.017 [-0.182, 0.143]	0.001 [-0.023, 0.025]	0.176 [-0.089, 0.454]	2.914 [2.195, 3.791]		
Debt Financing	-0.106 [-0.262, 0.082]	-0.001 [-0.019, 0.018]	-0.022 [-0.237, 0.198]	-0.445 [-0.847, -0.083]	2.494 [1.819, 3.443]	
Term Premium	-0.061 [-0.314, 0.160]	-0.008 [-0.053, 0.033]	-0.161 [-0.705, 0.286]	-0.960 [-1.793, -0.159]	-1.468 [-2.296, -0.667]	2.974 [2.106, 5.609]

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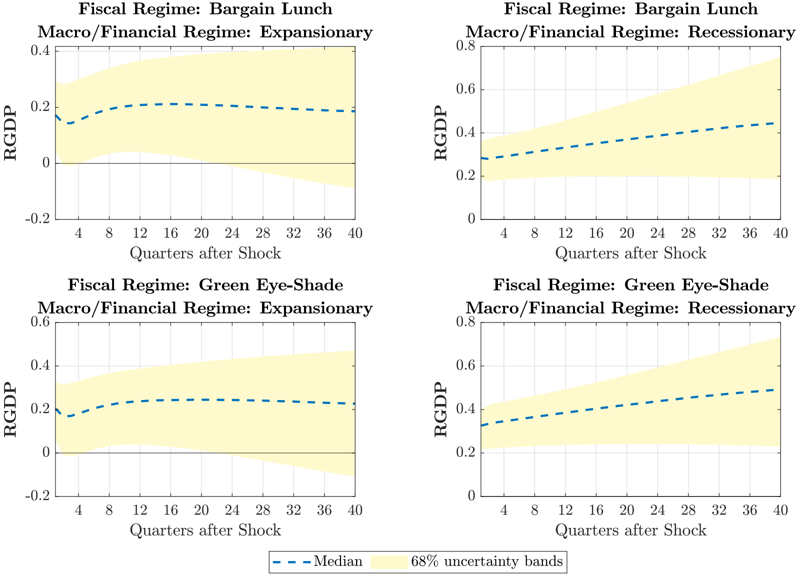
Computing GIRFs

- MS-BVARs are non-linear $\Longrightarrow$ compute GIRFs.
- GIRFs take into account possibility of future regime changes.
- Karame (JEDC, 2015) and Bianchi (JoE, 2016) provide an algorithm to compute GIRFs for an MS-BVAR.
- Conditional GIRFs are constructed under assumption that the regime is known with certainty at impact.

Conditional GIRFs of RGDP w/r/t GOV Shock



GIRFs of GOV
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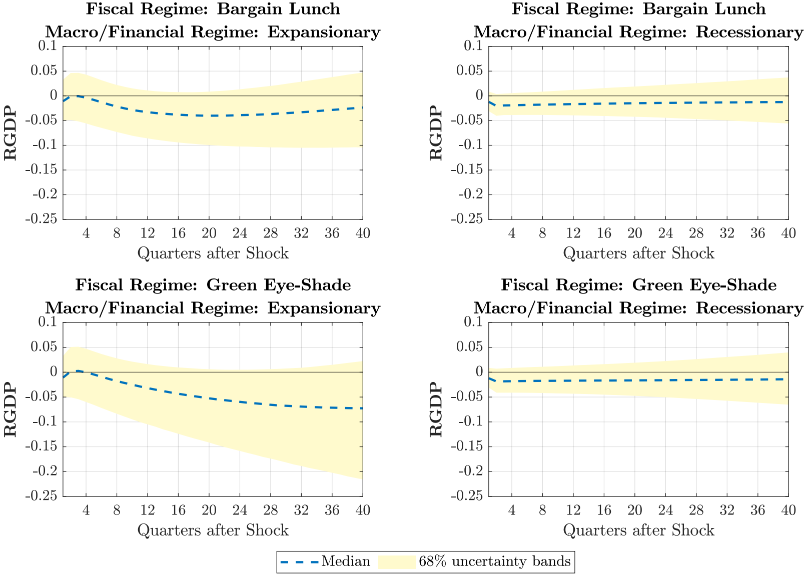
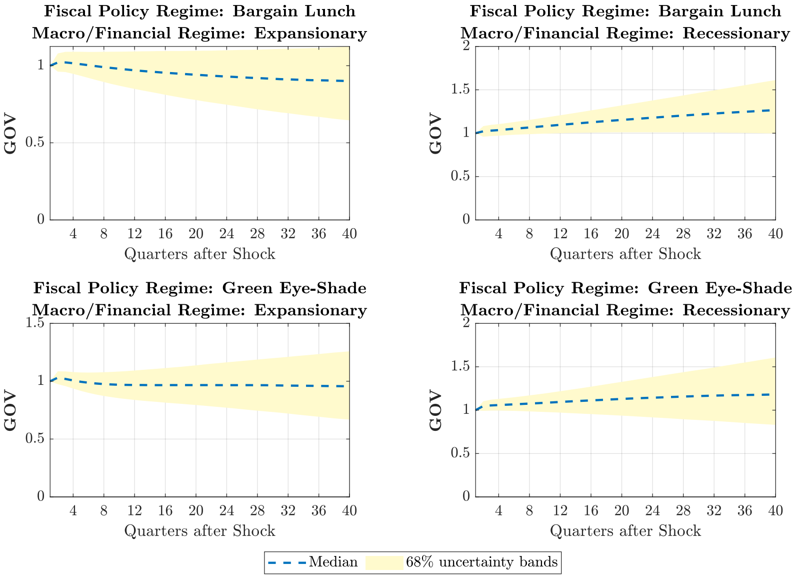
Conditional GIRFs of RGDP w/r/t TAX Shock



GIRFs of TAX Back

Conditional GIRFs of GOV w/r/t GOV Shock



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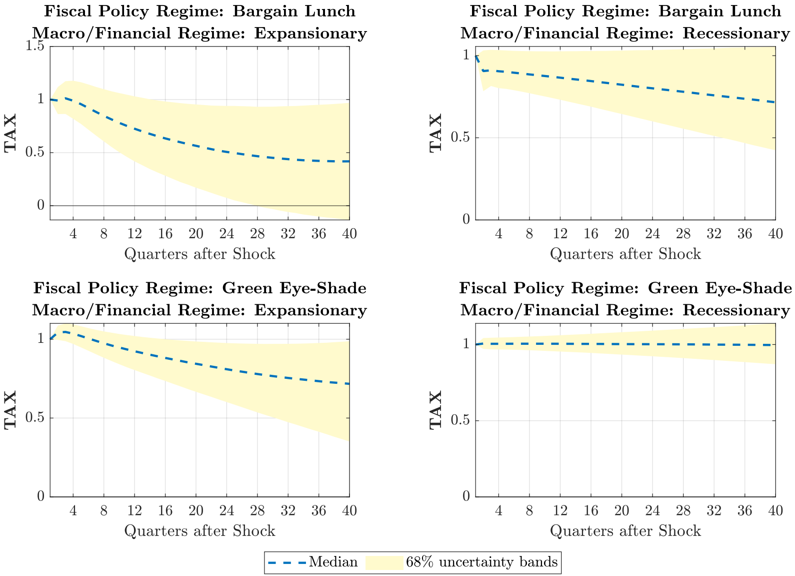
Conditional GIRFs of TAX w/r/t TAX Shock



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Formula to Calculate PV Fiscal Multipliers

- The k-period ahead present value fiscal multiplier is

$$\text{PV Fiscal Multiplier}(k) = \frac{E_t \sum_{j=0}^{k} \beta^j \Delta RGDP_{t+j}}{E_t \sum_{j=0}^{k} \beta^j \Delta FP_{t+j}},$$

  where β is the quarterly discount factor and FP is the fiscal policy variable (GOV or TAX).

- MS-BVARs are non-linear $\Longrightarrow$ compute GIRFs.

  $\Longrightarrow$ Constructed under assumption that the regime is known with certainty at impact.

  $\Longrightarrow$ Accounts for possibility of regime changes.

Present-Value Government Spending Multipliers

$$\text{PV GOV Multiplier}(k) = \frac{E_t \sum_{j=0}^{k} \beta^j \Delta RGDP_{t+j}}{E_t \sum_{j=0}^{k} \beta^j \Delta GOV_{t+j}}$$

Expansionary

	1 qrt	**4 qrts**	**10 qrts**	**20 qrts**	**40 qrts**
Bargain Lunch	0.84	0.75	0.86	0.97	1.01
	[0.21, 1.43]	[0.04, 1.40]	[0.11, 1.52]	[0.16, 1.67]	[0.01, 1.83]
Green Eye-Shade	1.00	0.88	1.00	1.12	1.16
	[0.29, 1.59]	[0.04, 1.54]	[0.10, 1.65]	[0.15, 1.80]	[-0.02, 1.93]

Recessionary

	1 qrt	**4 qrts**	**10 qrts**	**20 qrts**	**40 qrts**
Bargain Lunch	1.39	1.37	1.47	1.47	1.56
	[0.91, 1.78]	[0.88, 1.79]	[0.89, 1.84]	[0.91, 1.94]	[0.91, 2.15]
Green Eye-Shade	1.59	1.59	1.63	1.69	1.78
	[1.07, 1.96]	[1.04, 1.96]	[1.07, 2.00]	[1.10, 2.10]	[1.13, 2.31]

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Present-Value Tax Multipliers

$$\text{PV TAX Multiplier}(k) = \frac{E_t \sum_{j=0}^{k} \beta^j \Delta RGDP_{t+j}}{E_t \sum_{j=0}^{k} \beta^j \Delta TAX_{t+j}}$$

Expansionary

	1 qrt	**4 qrts**	**10 qrts**	**20 qrts**	**40 qrts**
Bargain Lunch	-0.09	-0.03	-0.11	-0.24	-0.31
	[-0.40, 0.26]	[-0.43, 0.32]	[-0.60, 0.25]	[-0.91, 0.17]	[-1.37, 0.28]
Green Eye-Shade	-0.09	-0.01	-0.08	-0.21	-0.41
	[-0.40, 0.26]	[-0.43, 0.34]	[-0.57, 0.28]	[-0.84, 0.19]	[-1.35, 0.12]

Recessionary

	1 qrt	**4 qrts**	**10 qrts**	**20 qrts**	**40 qrts**
Bargain Lunch	-0.10	-0.15	-0.16	-0.16	-0.15
	[-0.25, 0.07]	[-0.33, 0.04]	[-0.35, 0.06]	[-0.38, 0.09]	[-0.46, 0.16]
Green Eye-Shade	-0.10	-0.13	-0.14	-0.14	-0.13
	[-0.25, 0.07]	[-0.31, 0.06]	[-0.33, 0.07]	[-0.34, 0.09]	[-0.39, 0.15]

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