Shocks or Shifts?
Identifying Macroeconomic Impulse Responses with Instruments

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SVAR:

$$
\begin{aligned}
\boldsymbol{A}(L)\boldsymbol{y}_t &= \boldsymbol{u}_t && \text{reduced-form VAR} \\
\boldsymbol{u}_t &= \boldsymbol{\Theta}_0 \boldsymbol{w}_t && \text{innovations spanned by shocks} \\
\boldsymbol{y}_t &= \boldsymbol{\Theta}(L)\boldsymbol{w}_t && \text{SVMA representation} \\
\mathbb{E}[\boldsymbol{w}_t \boldsymbol{w}_t'] &= \operatorname{diag}(\sigma_{w_1}^2, \dots, \sigma_{w_K}^2) && \text{orthogonality}
\end{aligned}
$$

Instrument:

$$
\begin{aligned}
\mathbb{E}[z_t w_{j,t}] &= \alpha \neq 0 && \text{relevance} \\
\mathbb{E}[z_t \boldsymbol{w}_{-j,t}'] &= \boldsymbol{0} && \text{exogeneity}
\end{aligned}
$$

Moment condition: $\mathbb{E}[z_t \boldsymbol{u}_t] = \alpha \boldsymbol{\Theta}_0 \boldsymbol{e}_j = \alpha \boldsymbol{\theta}$,

$$\implies \text{IRFs to } w_{j,t} \quad \boldsymbol{\Theta}(L)\boldsymbol{e}_j = \boldsymbol{A}(L)^{-1}\boldsymbol{\theta} \quad \text{identified up to scale.}$$

Standard approach: recover the impact vector using the SVAR-IV estimator of Stock and Watson (2018).

Motivating Example

Colombo and Toni (2025) construct an external instrument for a natural gas supply shock.

If we instrument gas **price**, we obtain:

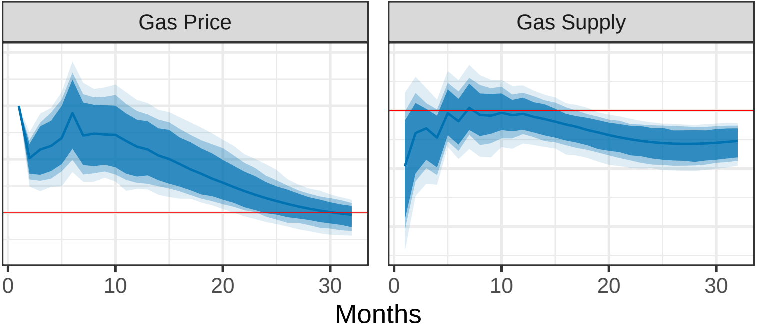

Figure: Responses of gas prices and quantities. Other variables omitted. Robust $\boldsymbol{F = 12.92}$.

Motivating Example

Colombo and Toni (2025) construct an external instrument for a natural gas supply shock.

If we instrument gas **quantity**, we obtain:

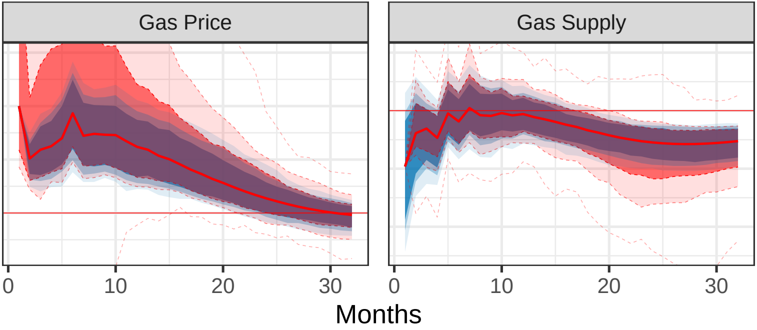

Figure: Responses of gas prices and quantities. Other variables omitted. Robust $\boldsymbol{F = 1.32}$.

Different Normalizations Define Different Estimands

Price anchor p

$$\boldsymbol{\theta}^{\mathrm{UI}(p)} = \frac{\mathbb{E}[z_t \boldsymbol{u}_t]}{\mathbb{E}[z_t u_{p,t}]}.$$

Quantity anchor q

$$\boldsymbol{\theta}^{\mathrm{UI}(q)} = \frac{\mathbb{E}[z_t \boldsymbol{u}_t]}{\mathbb{E}[z_t u_{q,t}]}.$$

Plug-in estimators

$$\widehat{\boldsymbol{\theta}}^{\mathrm{UI}(p)} = \frac{\sum_{t=1}^{T} z_t \widehat{\boldsymbol{u}}_t}{\sum_{t=1}^{T} z_t \widehat{u}_{p,t}}.$$

$$\widehat{\boldsymbol{\theta}}^{\mathrm{UI}(q)} = \frac{\sum_{t=1}^{T} z_t \widehat{\boldsymbol{u}}_t}{\sum_{t=1}^{T} z_t \widehat{u}_{q,t}}.$$

Different estimands. Price and quantity normalization are distinct random ratio estimators. Normalize every bootstrap draw; do not rescale IRFs or confidence bands ex post.

Anchor-specific weak IV. The price and quantity denominators can each be small. F_p and F_q therefore diagnose different weak-IV problems.

The Same Estimand and Estimator Arise Without Structural Shocks

Common reduced form

$$\boldsymbol{A}(L)\boldsymbol{y}_t = \boldsymbol{u}_t.$$

Structural-shock assumptions

$$\boldsymbol{u}_t = \boldsymbol{\Theta}_0 \boldsymbol{w}_t, \qquad \Theta_{0,jj} \neq 0$$

$$\mathbb{E}[z_t w_{j,t}] \neq 0, \quad \mathbb{E}[z_t \boldsymbol{w}'_{-j,t}] = \boldsymbol{0} \implies$$

Economic object: effects of a one-unit impact movement in $y_{j,t}$ induced by latent shock $w_{j,t}$.

Observed-shift IV assumptions

$$\boldsymbol{u}_t = \boldsymbol{b} u_{j,t} + \boldsymbol{v}_t^{(j)}$$

$$\mathbb{E}[z_t u_{j,t}] \neq 0, \quad \mathbb{E}[z_t \boldsymbol{v}_{-j,t}^{(j)}] = \boldsymbol{0}$$

Economic object: effects of a one-unit exogenous impact shift in $y_{j,t}$.

$$\frac{\mathbb{E}[z_t \boldsymbol{u}_t]}{\mathbb{E}[z_t u_{j,t}]}.$$

▸ Same result in LP-IV

One-Standard-Deviation Normalization

Under $\boldsymbol{u}_t = \boldsymbol{\Theta}_0 \boldsymbol{w}_t$ with orthogonal shocks, $\boldsymbol{\Sigma}_u = \boldsymbol{\Theta}_0 \boldsymbol{\Sigma}_w \boldsymbol{\Theta}_0'$. Together with the moment condition $\mathbb{E}[z_t \boldsymbol{u}_t] = \alpha \boldsymbol{\theta}$, this implies:

$$\boldsymbol{\theta} \sigma_{w_j} = \operatorname{sgn}(\alpha) \frac{\boldsymbol{\theta}}{\left(\boldsymbol{\theta}' \boldsymbol{\Sigma}_u^{-1} \boldsymbol{\theta}\right)^{1/2}}.$$

$$\widehat{\boldsymbol{\theta}}^{\,\mathrm{UV}} = \pm \frac{\sum_{t=1}^T z_t \widehat{\boldsymbol{u}}_t}{\left[\left(\sum_{t=1}^T z_t \widehat{\boldsymbol{u}}_t\right)' \widehat{\boldsymbol{\Sigma}}_u^{-1} \left(\sum_{t=1}^T z_t \widehat{\boldsymbol{u}}_t\right)\right]^{1/2}} \qquad \Longrightarrow \qquad \operatorname{Var}\left(w_{j,t}^{\mathrm{UV}}\right) = 1.$$

No anchor variable. No need to select an anchor response or require its true impact to be nonzero.

Limits weak-anchor problems. Uses the full covariance between the instrument and innovation vector.

Natural shock scale. Delivers the shock series and objects used for variance and historical decompositions.

Example: What Is a Monetary Policy Shock?

(Quasi)-random policy-rate shift (Jordà et al., 2020)

Instrument: observe coin flips used by central bank to randomly move policy rate beyond systematic rule.

- Channel: **only through the interest rate**
- Natural object: **impact-normalized IRF**
- Example: response to a 25bp increase in the policy rate
- Rate moves by construction, **no impact confidence band for normalized variable**; uncertainty concerns the responses of other variables.
- F: $u_{r,t} \sim z_t$, targets $\mathbb{E}[z_t u_{r,t}]$.

Latent policy shock (Jarociński & Karadi, 2020)

Instrument: observe imperfect measure of shift in expectations, communication, reaction function...

- Channel: **latent shift**, not only the interest rate
- Natural object: **one-SD structural-shock IRF**
- Same 25bp move may reflect different underlying shocks
- No variable is fixed by normalization on impact, **uncertainty applies to all variables**, including the policy rate.
- Relevant F: **?**

A Shock-Based Weak-IV Diagnostic

Recall the model's relevance condition:

$$\mathbb{E}[z_t w_{j,t}] \neq 0.$$

Since

$$w_{j,t} = \text{Proj}(z_t \mid \boldsymbol{u}_t) = \boldsymbol{\theta}' \boldsymbol{\Sigma}_u^{-1} \boldsymbol{u}_t,$$

I propose the following shock-based diagnostic:

1. Estimate the reduced-form VAR and obtain $\widehat{\boldsymbol{u}}_t$ and $\widehat{\boldsymbol{\Sigma}}_u$.
2. Estimate the impact direction $\widehat{\boldsymbol{\theta}}$, up to scale.
3. Recover the shock index:

$$\widehat{w}_{j,t} = \widehat{\boldsymbol{\theta}}' \widehat{\boldsymbol{\Sigma}}_u^{-1} \widehat{\boldsymbol{u}}_t.$$

4. Regress $\widehat{w}_{j,t}$ on z_t and report the associated first-stage F-statistic.

Note that $F_{\text{shock}} \geq F_{\text{anchor}}(j) \qquad \forall j.$

Standard-Deviation Normalization

Colombo and Toni (2025) with SD normalization:

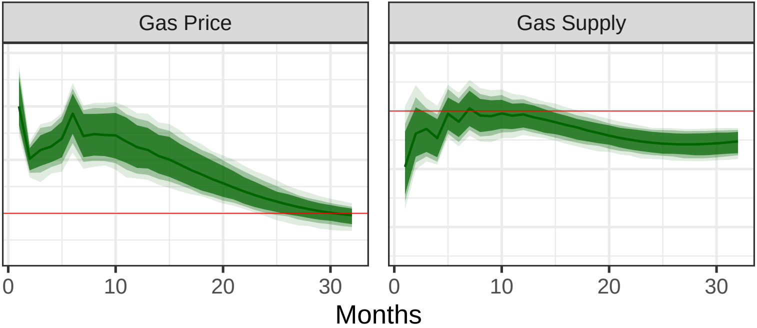

Figure: Responses of gas prices and quantities. Other variables omitted. Robust $\boldsymbol{F = 14.37}$.

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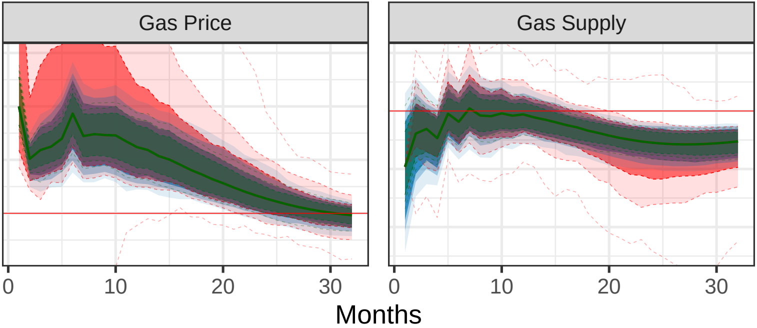


Figure: Responses of gas prices and quantities. Other variables omitted. Robust $\boldsymbol{F = 14.37}$.

Monte Carlo Design

Design

- Same stable trivariate VAR in all DGPs.
- The instrument is generated as

$$z_t = \bar{m} + \psi_T \varepsilon_{1,t} + v_t, \qquad v_t \sim N(0,1).$$

- Four calibrated proxy strengths span strong to weak relevance; for $T = 3600$, use the local-to-zero scaling $\psi_T = \psi_{360}\sqrt{360/T}$.

Simulation objects

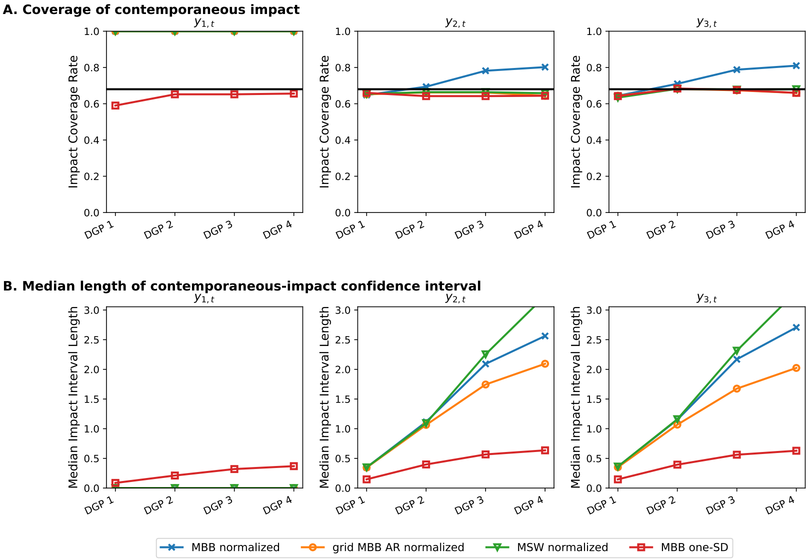
For each DGP, report impact coverage and median interval length:

1. MBB percentile, impact-normalized (bootstrap, non-robust);
2. grid-MBB Anderson–Rubin, impact-normalized (bootstrap, weak-IV robust);
3. MSW analytical, impact-normalized (analytical, weak-IV robust);
4. MBB percentile, one-standard-deviation (bootstrap, non-robust).

$\Longrightarrow$ AR/MSW intervals can be unbounded when the anchor normalization is weak.

Full Monte Carlo design

Impact coverage and length, 68%, $T = 360$



▸ Full IRF coverage and length

Rejection Rates of First-Stage Diagnostics

DGP	ψ_T	$F_{\text{iv}} > 10$	$F_{\text{shock}} > 10$	$F_{\text{SW2012}} > 10$
1	1.000	100.0%	100.0%	100.0%
2	0.076	51.2%	92.8%	23.6%
3	0.044	9.0%	41.8%	0.0%
4	0.035	4.4%	26.8%	0.0%

Table: Share of simulations in which the first-stage statistic exceeds 10, $T = 3600$.

Simulation takeaways

- **Impact-normalized inference** is sensitive to the normalization equation: a weak anchor yields wide or unbounded AR/MSW intervals.
- **One-standard-deviation IRFs** deliver shorter MBB intervals and are less exposed to weak-anchor problems.
- Anchor-based diagnostics can understate relevance for one-SD IRFs; $\boldsymbol{F_{\text{shock}}}$ remains informative about the latent shock.

Conclusions

What is the economic object of interest: an observed shift or a latent shock?

- **Observed shift.** Reduced-form IV may be enough. Imposing a full structural-shock model may add unnecessary assumptions (e.g. invertibility) without changing the estimand.
- **Latent shock.** Structural assumptions are doing substantive work. One-SD normalization is then natural: it avoids choosing an anchor variable and puts the recovered shock on a meaningful scale.
- **Inference.** Normalization is part of the estimator. One-SD normalization limits exposure to a weak anchor equation; in the simulations, it maintains coverage better and yields shorter intervals as relevance declines.
- **Diagnostic.** I propose a relevance diagnostic based on the first-stage relationship between the instrument and the recovered shock index, targeting the latent shock rather than an arbitrarily chosen anchor.

References I

Stock, J. H., & Watson, M. W. (2018). Identification and estimation of dynamic causal effects in macroeconomics using external instruments. *The Economic Journal*, *128*(610), 917–948.

Jarociński, M., & Karadi, P. (2020). Deconstructing monetary policy surprises—the role of information shocks. *American Economic Journal: Macroeconomics*, *12*(2), 1–43.

Jordà, Ò., Schularick, M., & Taylor, A. M. (2020). The effects of quasi-random monetary experiments. *Journal of Monetary Economics*, *112*, 22–40.

Colombo, D., & Toni, F. (2025). Gas prices and the macroeconomy. *Available at SSRN 5237587*.

Appendix: LP-IV

LP:

$$
\begin{aligned}
\boldsymbol{y}_{t+h} &= \boldsymbol{\theta}_h w_{1,t} + \boldsymbol{u}_{t+h} && \text{horizon-}h\text{ LP equation} \\
\boldsymbol{y}_t &= \boldsymbol{\Theta}(L)\boldsymbol{w}_t && \text{SVMA representation} \\
\mathbb{E}[\boldsymbol{w}_t \boldsymbol{w}_t'] &= \operatorname{diag}(\sigma^2_{w_1}, \dots, \sigma^2_{w_K}) && \text{orthogonality}
\end{aligned}
$$

Instrument:

$$
\begin{aligned}
\mathbb{E}[z_t w_{1,t}] &= \alpha \neq 0 && \text{relevance} \\
\mathbb{E}[z_t w_{k,t+\tau}] &= 0, \quad (k,\tau) \neq (1,0),\ \tau \leq h && \text{lead-lag exogeneity}
\end{aligned}
$$

$$
\Longrightarrow \quad \mathbb{E}[z_t \boldsymbol{u}_{t+h}] = \boldsymbol{0}.
$$

Thus the instrument is valid for the horizon-h LP written in terms of the latent target shock. However, $w_{1,t}$ is unobserved, so regression cannot be estimated directly. Identification also requires that the shock be normalized wrt an observed impact variable, say $y_{j,t} = \boldsymbol{e}_j' \boldsymbol{y}_t$.

▸ Back to structural comparison

LP-IV: Impact Normalization

To obtain an estimable equation, express the target shock in units of an observed impact variable:

$$w_{1,t}^{(j)} = \gamma_j w_{1,t}, \qquad y_{j,t} := \boldsymbol{e}_j' \boldsymbol{y}_t = w_{1,t}^{(j)} + r_{j,t} = \gamma_j w_{1,t} + r_{j,t}.$$

$r_{j,t}$ is the part of $y_{j,t}$ not due to the target shock: systematic movements, measurement error, and other shocks. Under the SVMA,

$$r_{j,t} = \sum_{(\ell,k)\neq(0,1)} \boldsymbol{e}_j' \boldsymbol{\Theta}_\ell \boldsymbol{e}_k \, w_{k,t-\ell}.$$

Since $w_{1,t} = (y_{j,t} - r_{j,t})/\gamma_j$, the horizon-$h$ LP becomes

$$\boldsymbol{y}_{t+h} = \boldsymbol{\theta}_h^{(j)} y_{j,t} + \boldsymbol{u}_{t+h}^{IV,(j)}, \qquad \boldsymbol{\theta}_h^{(j)} = \frac{\boldsymbol{\theta}_h}{\gamma_j}, \quad \boldsymbol{u}_{t+h}^{IV,(j)} = \boldsymbol{u}_{t+h} - \boldsymbol{\theta}_h^{(j)} r_{j,t}.$$

The shock-level restrictions imply $\mathbb{E}[z_t r_{j,t}] = 0$, hence

$$\mathbb{E}[z_t y_{j,t}] = \gamma_j \mathbb{E}[z_t w_{1,t}] \neq 0, \qquad \mathbb{E}[z_t \boldsymbol{u}_{t+h}^{IV,(j)}] = \boldsymbol{0}.$$

Therefore,

$$\boldsymbol{\theta}_h^{(j)} = \frac{\mathbb{E}[z_t \boldsymbol{y}_{t+h}]}{\mathbb{E}[z_t y_{j,t}]}, \qquad \widehat{\boldsymbol{\theta}}_h^{IV,(j)} = \frac{\sum_t z_t \boldsymbol{y}_{t+h}}{\sum_t z_t y_{j,t}}.$$

▸ Back to structural comparison

Again... the Same Estimand/Estimator Arise Without Structural Shocks

$$\boldsymbol{y}_{t+h}(y) = \boldsymbol{a}_h + \boldsymbol{\tau}_h^{(j)} y + \boldsymbol{v}_{t+h}^{(j)}.$$

Assume that z_t shifts $y_{j,t}$, but affects $\boldsymbol{y}_{t+h}$ only through that shift:

$$\mathbb{E}[z_t y_{j,t}] \neq 0, \qquad \mathbb{E}[z_t \boldsymbol{v}_{t+h}^{(j)}] = \mathbf{0}, \qquad \boldsymbol{y}_{t+h}(z, y) = \boldsymbol{y}_{t+h}(y).$$

Using consistency, $\boldsymbol{y}_{t+h} = \boldsymbol{y}_{t+h}(y_{j,t})$, and centering z_t,

$$\mathbb{E}\left[z_t \left(\boldsymbol{y}_{t+h} - \boldsymbol{\tau}_h^{(j)} y_{j,t}\right)\right] = \mathbf{0} \quad \Longrightarrow \quad \boldsymbol{\tau}_h^{(j)} = \frac{\mathbb{E}[z_t \boldsymbol{y}_{t+h}]}{\mathbb{E}[z_t y_{j,t}]}.$$

Therefore,

$$\boldsymbol{\tau}_h^{(j)} = \frac{\mathbb{E}[z_t \boldsymbol{y}_{t+h}]}{\mathbb{E}[z_t y_{j,t}]}, \qquad \widehat{\boldsymbol{\tau}}_h^{IV,(j)} = \frac{\sum_{t=1}^T z_t \boldsymbol{y}_{t+h}}{\sum_{t=1}^T z_t y_{j,t}}.$$

$$\Longrightarrow \ \widehat{\boldsymbol{\tau}}_h^{IV,(j)} = \widehat{\boldsymbol{\theta}}_h^{IV,(j)},$$

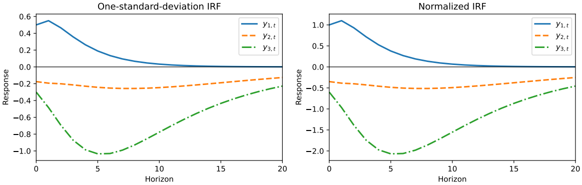
so that the same ratio estimator has two readings: an impact-normalized structural-shock IRF, or a causal effect of an observed exogenous movement in $y_{j,t}$.

This is not surprising: with the same lags, controls, and normalization, the LP-IV and SVAR-IV estimators coincide at impact, $h = 0$.

▸ Back to structural comparison

Appendix: Monte Carlo Design

- Same stable trivariate VAR in all DGPs:



- The instrument is generated as

$$z_t = \bar{m} + \psi_T \varepsilon_{1,t} + v_t, \qquad v_t \sim N(0,1).$$

- Instrument strengths are calibrated at sample size $T = 360$ (30 years of monthly data). Chosen so that the normalized-IRF first-stage diagnostic $F_{iv} > 10$ rejects in $100\%, 50\%, 10\%$, and 5% of simulations:

$$\psi_{360} \in \{1,\ 0.24,\ 0.14,\ 0.11\}.$$

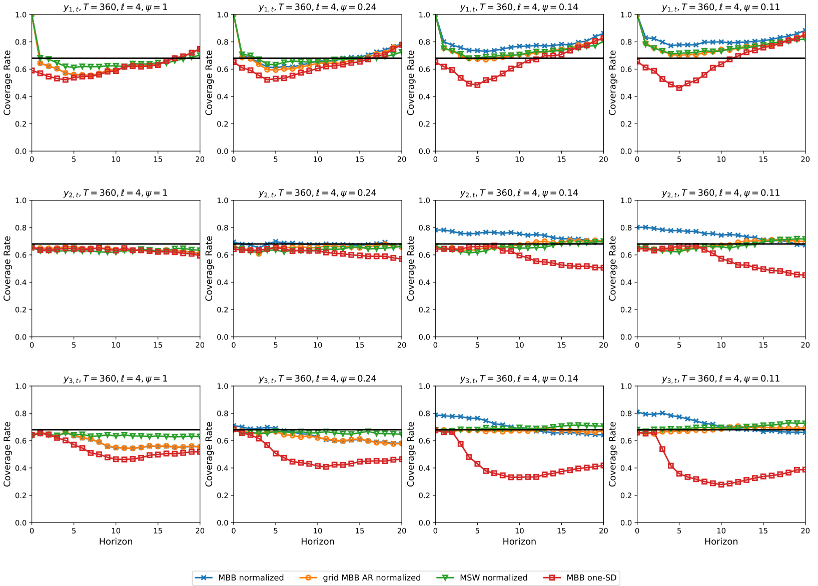
- For the large-sample design, $T = 3600$, use local-to-zero scaling,

$$\psi_T = \psi_{360}\sqrt{360/T},$$

so that $\sqrt{T}\psi_T$ is held fixed across sample sizes.

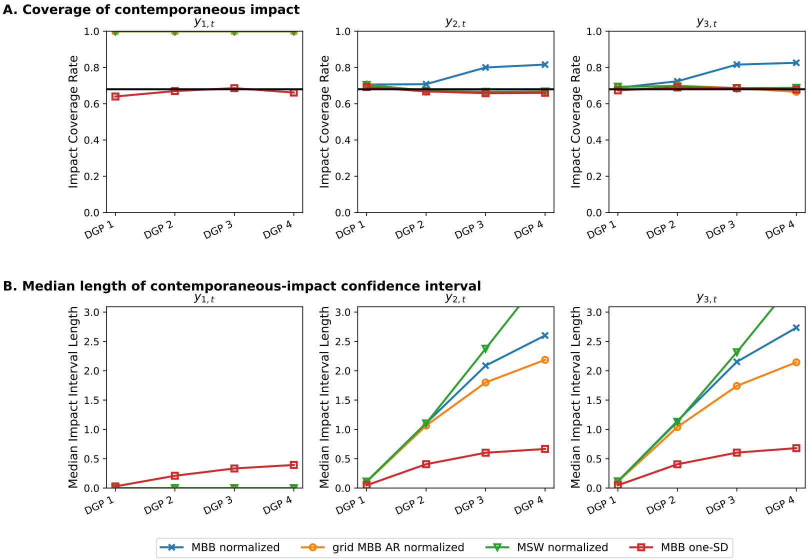
▸ Back to Monte Carlo design

Appendix: Full-IRF Coverage, 68%, $T = 360$



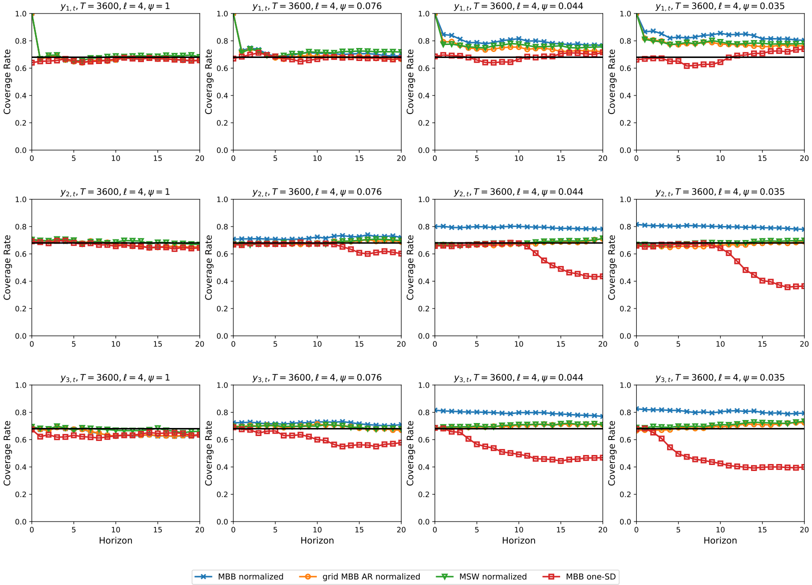
Back to main results

Impact coverage and length, 68%, $T = 3600$



Back to main results

Appendix: Full-IRF Coverage, 68%, $T = 3600$



Back to main results