

Supplementary Information

Epicenter or bystander? Currency connectedness around the 2024 yen carry unwind

A Supplementary methods and results

A.1 TVP-VAR estimation

We estimate the TVP-VAR using the forgetting-factor Kalman filter in Antonakakis et al. (2020). Returns are centred before estimation, and the coefficient state follows a random walk. If $\tilde{\mathbf{u}}_t$ denotes the one-step prediction error, the innovation covariance is updated as

$$\tilde{\mathbf{u}}_t = \mathbf{y}_t - \mathbf{Z}_t \boldsymbol{\beta}_{t|t-1}, \quad (\text{S1})$$

$$\mathbf{H}_t = \lambda_H \mathbf{H}_{t-1} + (1 - \lambda_H) \tilde{\mathbf{u}}_t \tilde{\mathbf{u}}_t'. \quad (\text{S2})$$

The updated $\mathbf{H}_t$ enters the current Kalman gain and coefficient update. In the baseline specification, the initial coefficient mean and innovation covariance come from a full-sample OLS estimate, with the associated OLS covariance used for the initial coefficient uncertainty. The resulting historical paths are therefore filtered rather than real-time estimates. The Minnesota and uninformative priors in Table 6 do not use the full-sample OLS fit. If an update produces an unstable companion matrix, the coefficient state is shrunk toward its preceding stable value; this fallback was not required in the baseline estimation.

A.2 Properties of TVP-VAR- R^2 connectedness

Positive definiteness implies $0 \leq R_{i,t}^2 \leq 1$, and Equation (9) is a sum of squared terms. The Genizi contributions therefore satisfy

$$0 \leq g_{ij,t} \leq R_{i,t}^2 \leq 1, \quad \sum_{j \neq i} g_{ij,t} = R_{i,t}^2. \quad (\text{S3})$$

The own and cross-currency components consequently sum to one without an additional row normalization.

If a permutation matrix $\mathbf{P}$ reorders the $N - 1$ sources for target i , then $\mathbf{R}_{x,i,t}$ becomes $\mathbf{P} \mathbf{R}_{x,i,t} \mathbf{P}'$ and $\mathbf{r}_{i,t}$ becomes $\mathbf{P} \mathbf{r}_{i,t}$. The symmetric principal root and its inverse transform accordingly, so Equation (9) returns $\mathbf{P} \mathbf{g}_{i,t}$. Reordering thus relabels the contributions without changing the total connectedness index (TCI) or the directional measures.

If $\mathbf{B}_t = \mathbf{B}$ and $\mathbf{H}_t = \mathbf{H}$ for all t , Equation (2) is constant and the measure reduces to a fixed-parameter VAR decomposition of R^2 among the H -step forecast errors. When $H = 1$, $\boldsymbol{\Omega}_t(1) = \mathbf{H}_t$ and the measure becomes a Genizi decomposition of the multiple R^2 among standardized contemporaneous innovations. At longer horizons, the forecast-error correlations also incorporate propagation through the current VAR coefficients.

A.3 Connectedness measures and comparison statistics

Supplementary Table A1 defines the connectedness measures and the statistics used to compare them. Section 3.5 gives the mathematical definitions.

Supplementary Table A1. Connectedness measures and comparison statistics.

Measure	Notation	Interpretation and direction	Unit
<i>Panel A. Connectedness measures</i>			
Diebold–Yilmaz connectedness	DY	Row-normalised generalized forecast-error variance shares	Percent
Genizi-based R^2 connectedness	R^2	Share of a target forecast-error variance jointly explained by the other forecast errors, allocated using the Genizi decomposition	Percent
Total connectedness index	TCI	Average of the off-diagonal connectedness received across the currencies in the system	Percent
Total directional connectedness FROM others	FROM	Sum of the contributions received by a target currency from all other currencies	Percent
Total directional connectedness TO others	TO	Sum of a currency's contributions to all other target equations	Percent
Net total directional connectedness	NET	TO minus FROM; positive values identify net contributors	Percentage points
Net pairwise directional connectedness	NPDC	Contribution from the first currency to the second minus the reverse contribution; it is a directional difference, not the sum of the two entries	Percentage points
<i>Panel B. Comparison statistics for DY and R^2</i>			
Months with the same sign	—	Share of monthly DY and R^2 NET or NPDC estimates with the same sign	Percent
Correlation of monthly estimates	—	Time-series correlation between DY and R^2 estimates of the same measure	Range $[-1, 1]$
Average absolute NPDC	$\text{mean}_t \text{NPDC}_{ij,t} $	Sample average of absolute monthly NPDC, used to rank currency pairs	Percentage points

Notes: In a connectedness table, rows are targets and columns are sources. DY and R^2 contributions use the same target–source orientation. The baseline empirical results use a 12-month forecast horizon. Panel B is calculated from unsmoothed monthly estimates.

A.4 Full-sample connectedness matrices

Supplementary Table A2. Full-sample connectedness matrices.

Panel A. TVP-VAR-DY					
Target/source	EUR	GBP	JPY	CHF	FROM
EUR	41.94	18.43	9.81	29.81	58.06
GBP	23.88	50.80	6.61	18.72	49.20
JPY	13.12	7.54	62.42	16.92	37.58
CHF	30.34	15.21	12.31	42.13	57.87
TO	67.34	41.19	28.74	65.45	TCI ^{DY} = 50.68
NET	9.28	−8.01	−8.85	7.58	
Panel B. TVP-VAR-R ²					
Target/source	EUR	GBP	JPY	CHF	FROM
EUR	20.91	24.23	10.24	44.63	79.09
GBP	26.59	49.02	6.47	17.92	50.98
JPY	11.24	6.80	64.61	17.34	35.39
CHF	45.01	17.19	14.71	23.09	76.91
TO	82.84	48.22	31.42	79.90	TCI ^{R²} = 60.59
NET	3.75	−2.77	−3.97	2.99	

Notes: Entries are full-sample averages in percent; rows are targets and columns are sources. In Panel A, cell (i, j) is currency j 's row-normalised GFEVD share in target i . In Panel B, it is currency j 's contribution to the target forecast error's jointly explained variation under the Genizi decomposition. The diagonal is the own component. FROM and TO are total directional connectedness from and to others and exclude the diagonal; NET is TO minus FROM. The TO-row entry in the FROM column is the total connectedness index (TCI), the mean of the four TO (equivalently FROM) values.

The diagonal entries report the own components of the full-sample decomposition. The EUR diagonal falls from 41.94 percent under DY to 20.91 percent under R^2 , and the CHF diagonal falls from 42.13 to 23.09 percent. The corresponding EUR–CHF entries increase from 29.81 to 44.63 and from 30.34 to 45.01, respectively.

EUR–JPY has the same sign under the two measures in 89.22 percent of months, but the correlation between its monthly estimates is -0.122 ; GBP–JPY has the lowest same-sign share at 72.39 percent. For CHF, the monthly NET estimates have a correlation of 0.680 and the same sign in 81.54 percent of months.

A.5 Inference on the aggregate difference

Statistical uncertainty around the sample-average TCI difference is evaluated with a heteroskedasticity- and autocorrelation-consistent standard error and two block-bootstrap confidence intervals, because both TCIs are strongly autocorrelated.

Let $d_t = \text{TCI}_t^{R^2} - \text{TCI}_t^{\text{DY}}$ denote the monthly difference. Regressing d_t on a constant over the 612 months gives a mean of 9.92 percentage points with a Newey–West standard error of 0.43, a t statistic of 22.91, and a p value below 0.001 (Newey and West, 1987). The lag length follows the conventional rule $\lfloor 4(n/100)^{2/9} \rfloor$, which equals five at this sample size, without prewhitening (Andrews, 1991). A moving-block bootstrap with a block length of twelve months and 1,000 replications gives a 95 percent confidence interval of $[8.83, 11.15]$; a block wild bootstrap with the same block length, 2,000 replications, and Rademacher multipliers gives $[8.81, 11.06]$. Both intervals exclude zero.

The confidence intervals quantify uncertainty around the average TCI difference; currency-level rankings, bilateral rankings, and individual monthly networks are separate estimates.

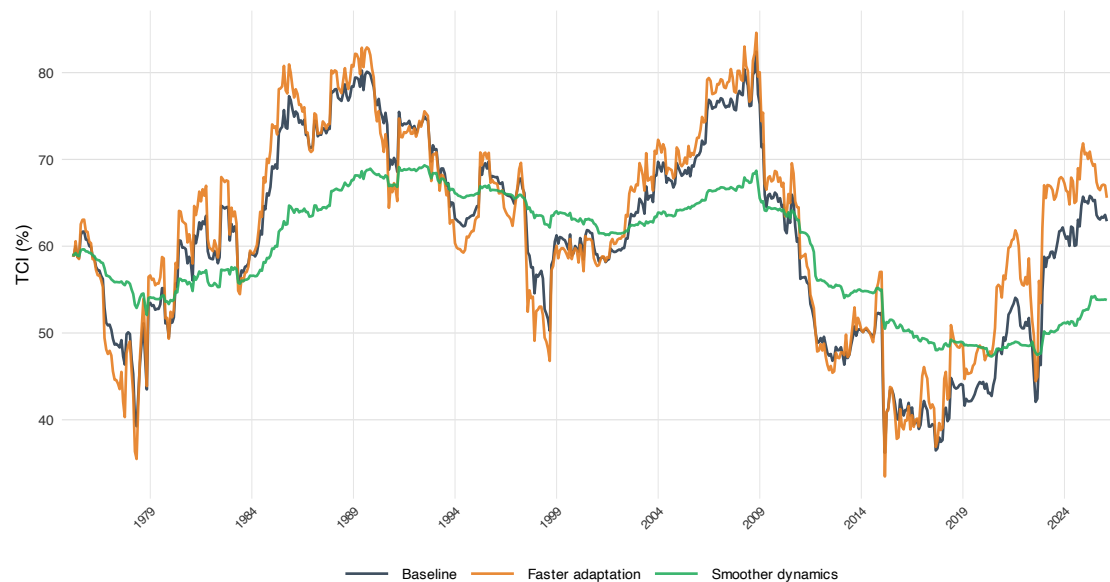
A.6 Dynamic-specification robustness

The estimates are unchanged to two decimal places at forecast horizons of 6, 12, and 24 months because the forecast-error covariance converges rapidly in the baseline monthly VAR(1). The R^2 connectedness path is also similar across lag orders of one, two, and three (Supplementary Fig. A1). Alternative forgetting factors and priors mainly affect local smoothness (Supplementary Figs. A2 and A3).



Supplementary Fig. A1. Lag-order robustness.

Notes: Lines report monthly TVP-VAR- R^2 total connectedness (percent) for lag orders of one, two, and three at a 12-month forecast horizon.



Supplementary Fig. A2. Forgetting-factor robustness.

Notes: Lines report monthly TVP-VAR- R^2 total connectedness (percent) for coefficient/covariance forgetting factors of (0.99, 0.96), (0.97, 0.94), and (0.99, 0.99).



Supplementary Fig. A3. Prior robustness.

Notes: Lines report monthly TVP-VAR- R^2 total connectedness (percent) under the OLS-based, Minnesota, and uninformative priors.

Supplementary Fig. A4 shows DY and R^2 connectedness for the baseline TVP-VAR and a rolling 60-month fixed VAR. Each pair of measures is constructed from the forecast-error system implied by the corresponding estimator.



Supplementary Fig. A4. Rolling-VAR and TVP-VAR connectedness under DY and R^2 .

Notes: Lines report monthly total connectedness (percent) for the baseline TVP-VAR and a fixed VAR estimated in 60-month rolling windows.

A.7 Monte Carlo design and finite-sample performance

The Monte Carlo experiments evaluate how accurately TVP-VAR- R^2 recovers a known population network when connectedness is constant, changes gradually, or reverses direction. This comparison is unavailable in the currency data, where the population network is not observed. The first design measures precision under stable parameters. The second shows how closely the estimators follow a changing total-connectedness path, and the third measures their response to a change in the sign of net pairwise directional connectedness. Rolling-window VARs provide the conventional benchmark for dynamic connectedness (Diebold and Yilmaz, 2009). Windows of 36, 60, and 120 monthly observations span three, five, and ten years and therefore range from faster adjustment to greater sampling precision.

Each experiment uses 500 samples of 300 observations after a 100-observation burn-in. Following Antonakakis et al. (2020), the time-varying estimator is initialized with 60 observations and uses coefficient and covariance forgetting factors of 0.99 and 0.96; these forgetting factors are the benchmark values in Koop and Korobilis (2014). Population and estimated connectedness are computed at the 12-month horizon used in the empirical analysis. Performance is evaluated over $t = 120, \dots, 300$, the 181 observations available to all four estimators after allowing for the longest rolling window.

The simulated data follow the four-variable Gaussian VAR(1)

$$\mathbf{y}_t = \mathbf{B}_t \mathbf{y}_{t-1} + \boldsymbol{\varepsilon}_t, \quad \boldsymbol{\varepsilon}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Sigma}_t). \quad (\text{S4})$$

The experiments differ in how the coefficients and innovation covariance evolve. Both remain fixed in the stable experiment. In the smooth-drift experiment, selected cross-lag coefficients and covariance terms move linearly from weak to strong dependence. In the directional-reversal experiment, the relative strength of the first two variables' cross-lags switches and the innovation covariance changes halfway through the sample. This changes the sign of their net pairwise relation while leaving total connectedness broadly similar before and after the break.

Each replication is scored against the population connectedness path, which is computed directly from the known $\mathbf{B}_t$ and $\boldsymbol{\Sigma}_t$ rather than estimated from data. For the stable experiment the population TCI is the constant reported in Supplementary Table A3; in the changing experiments it varies with the parameters. With $\widehat{\text{TCI}}_t^{(r)}$ the estimate from replication r and $\text{TCI}_t^{\text{pop}}$ the population value, the root mean squared error of that replication over the evaluation sample is

$$\text{RMSE}^{(r)} = \left[\frac{1}{181} \sum_{t=120}^{300} \left(\widehat{\text{TCI}}_t^{(r)} - \text{TCI}_t^{\text{pop}} \right)^2 \right]^{1/2}, \quad (\text{S5})$$

and the entries in Supplementary Table A4 average $\text{RMSE}^{(r)}$ over the 500 replications. The remaining statistics use the same evaluation sample: the reported standard deviation is the time-series standard deviation of $\widehat{\text{TCI}}_t^{(r)}$ within a replication, peak bias is the largest estimated TCI minus the largest population TCI, sign accuracy is the share of the 181 monthly NPDC_{1,2} estimates with the correct sign, and detection delay counts the months from the break to the first of three consecutive correctly signed estimates. In the stable experiment, for example, a single replication compares each monthly TVP-VAR- R^2 estimate with the constant population TCI, averages the squared deviations over the 181 evaluation months, and takes the square root; the reported TCI RMSE is the average of this quantity over the 500 replications, each generated with a different innovation sequence.

Supplementary Table A3 summarises the population paths generated by the three designs. The designs are stylised rather than calibrated to the currency sample and compare estimator performance under stability, gradual change, and a reversal in direction. All coefficient matrices are stable, and all

innovation-covariance matrices are positive definite. The replication files report the complete parameter paths.

Supplementary Table A3. Monte Carlo data-generating processes.

Experiment	Parameter path	Population TCI	Population NPDC _{1,2}	Evaluation focus
Stable	Coefficients and innovation covariance remain fixed.	13.064	0.348	Precision when the population network is constant.
Smooth drift	Coefficients and innovation covariance evolve linearly.	2.595 to 68.833	0.000 to 14.681	Tracking a gradually changing population path.
Directional reversal	Cross-lag and covariance relations switch at $t = 151$.	70.847 to 68.046	16.031 to -13.071	Adjustment after a change in direction.

Notes: Population values are computed from the known $\mathbf{B}_t$ and Σ_t at a 12-month forecast horizon. TCI is the total connectedness index, and NPDC_{1,2} is net pairwise directional connectedness from variable 1 to variable 2. Entries for the changing experiments report the initial and final values. In the smooth-drift experiment, TCI first falls from 2.595 to 2.134 and then rises to 68.833; NPDC_{1,2} rises from approximately zero to 14.681. The reversal occurs between observations 150 and 151. The burn-in is generated at the initial parameter values.

Supplementary Table A4. Finite-sample performance of the dynamic and rolling estimators.

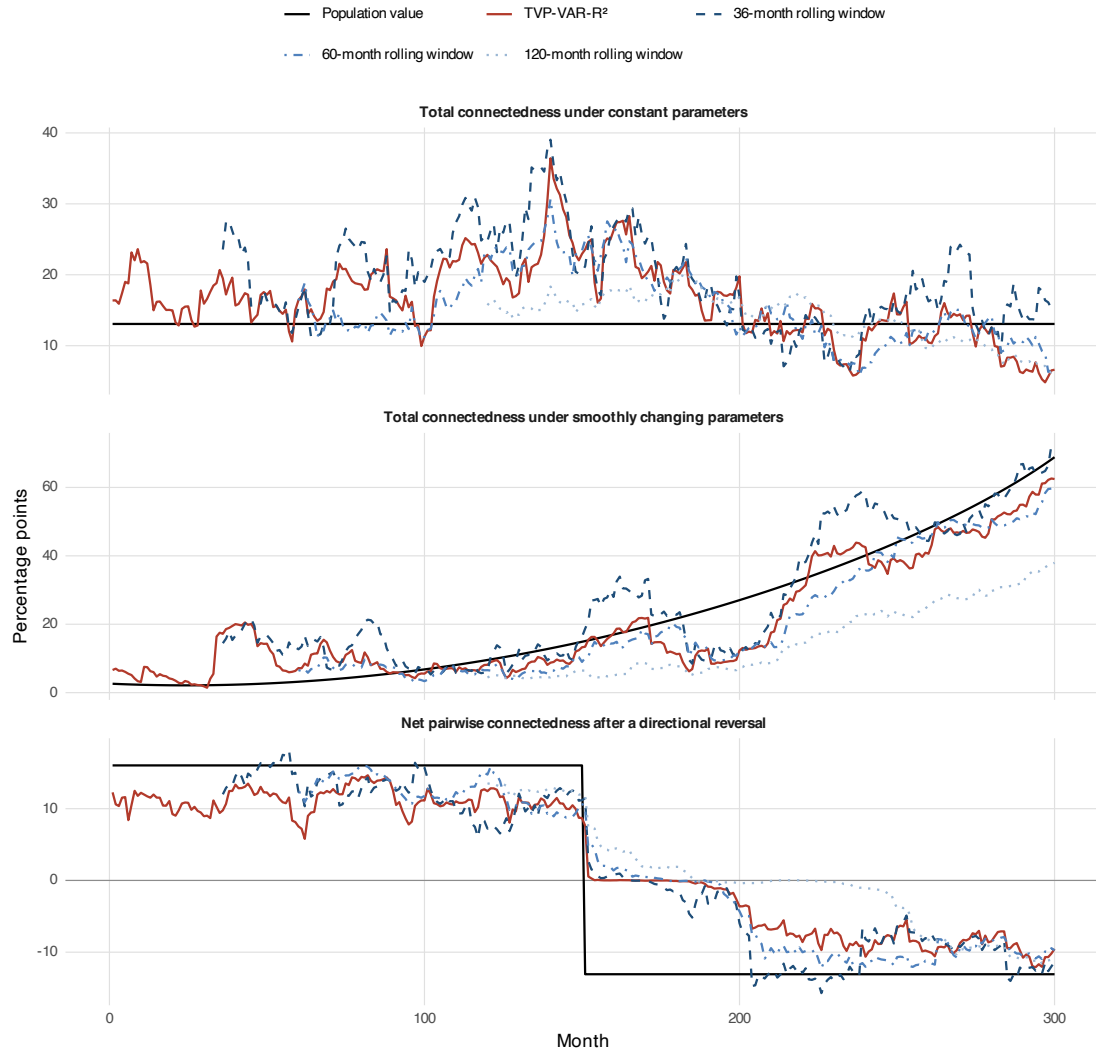
Method	Stable design		Smooth-drift design		Directional-reversal design	
	TCI RMSE	TCI std. dev.	TCI RMSE	Peak bias	Sign accuracy (%)	Delay
TVP-VAR- R^2	7.23	5.22	8.13	-11.76	91.06	15.59
Rolling window (36)	10.49	7.12	8.58	-3.71	91.18	14.97
Rolling window (60)	6.99	4.95	8.45	-12.88	86.15	24.60
Rolling window (120)	4.29	2.81	15.21	-26.88	72.35	49.27

Notes: Entries are averages over 500 replications and use the common evaluation sample $t = 120, \dots, 300$ (181 months, the span available to all four estimators once the 120-month window is filled). TCI RMSE is the square root of the mean squared deviation between estimated and population TCI over these months within a replication, averaged over the 500 replications; see Equation (S5). Root mean squared error (RMSE), standard deviation, and peak bias are in percentage points; detection delay is in months. The reported standard deviation is the time-series standard deviation of estimated TCI within a replication. Peak bias is the estimated peak TCI minus its population value, so negative entries indicate attenuation. Sign accuracy is the percentage of monthly NPDC_{1,2} estimates with the correct sign over the evaluation sample. Detection delay is the number of months from the break to the first of three consecutive correctly signed estimates. It therefore measures the time to statistical confirmation of a sign change, not the first response of the point estimate, which begins adjusting in the month of the break.

Supplementary Table A4 shows that performance varies systematically with the parameter path. Under constant parameters, the 120-month window has the lowest TCI RMSE, at 4.29 percentage points. Under smooth drift, its RMSE increases to 15.21 points, while TVP-VAR- R^2 has the lowest RMSE, at 8.13 points. Following the directional reversal, TVP-VAR- R^2 and the 36-month window have similar sign accuracy and detection delay; the 60- and 120-month windows retain the pre-break direction for longer. Longer windows reduce sampling variation when parameters are fixed but adjust more slowly to drift or reversal. Recursive discounting sacrifices some precision under stability and responds more quickly when the population relations change.

Known population paths permit an assessment of estimator tracking, but they do not establish the empirical attribution for a particular currency pair. The simulations show that the recursive estimator tracks a changing population network more promptly than long rolling windows. The persistent difference between the two TCIs reflects the two allocations: DY attributes forecast variation to individual innovations, whereas R^2 allocates jointly explained forecast variation.

Supplementary Fig. A5 reports the median-performing replication from each design. Replications are ranked by the TVP-VAR- R^2 RMSE in the stable and smooth-drift experiments and by sign accuracy in the directional-reversal experiment.



Supplementary Fig. A5. Representative paths from the Monte Carlo designs.

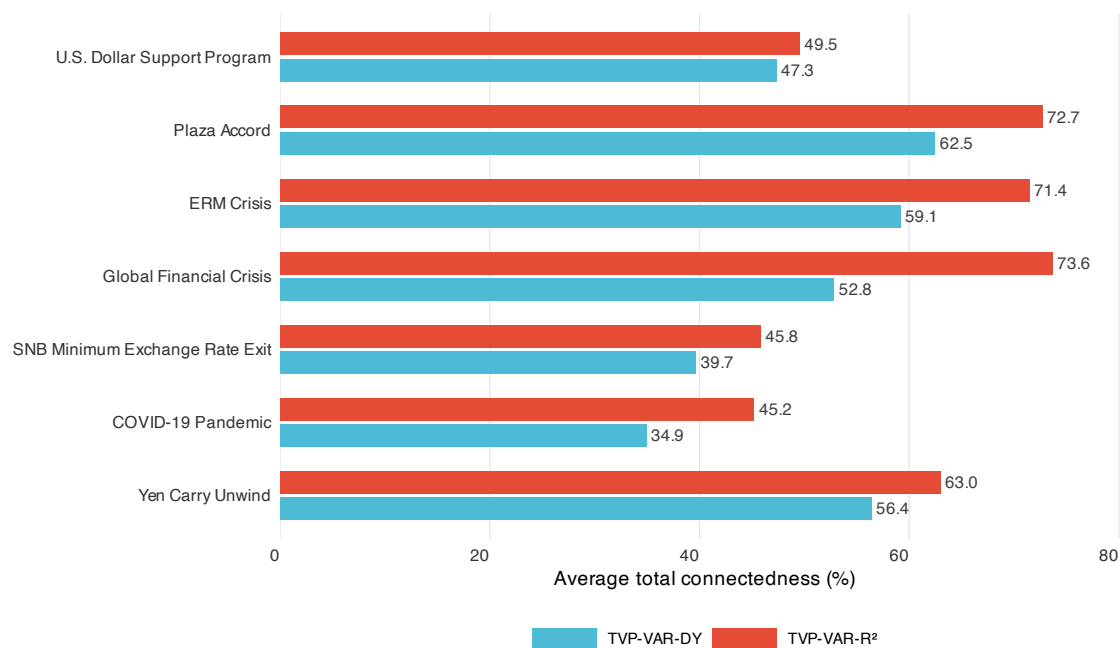
Notes: Lines show the population value, the TVP-VAR- R^2 estimate, and estimates from fixed-parameter VARs using 36-, 60-, and 120-month rolling windows. Each panel uses the median-performing replication, ranked by TVP-VAR- R^2 RMSE in the stable and smooth-drift designs and by sign accuracy in the directional-reversal design.

A.8 Selected episodes

Supplementary Table A5. Episodes used for descriptive comparison.

Episode	Reference month	Institutional event
U.S. Dollar Support Program	October 1978	U.S. measures announced to support the dollar (Federal Open Market Committee, 1978).
Plaza Accord	September 1985	Group of Five (G5) agreement on exchange rates (Finance Ministers and Central Bank Governors, 1985).
ERM Crisis	September 1992	Sterling's withdrawal from the Exchange Rate Mechanism (Bank of England, 1992).
Global Financial Crisis	October 2008	Group of Seven (G7) plan to stabilize financial markets and restore credit flows (G-7 Finance Ministers and Central Bank Governors, 2008).
SNB Minimum Exchange Rate Exit	January 2015	SNB discontinuation of the CHF 1.20 per euro minimum exchange rate (Swiss National Bank, 2015).
COVID-19 Pandemic	March 2020	World Health Organization (WHO) characterization of COVID-19 as a pandemic (World Health Organization, 2020).
Yen Carry Unwind	August 2024	Bank of Japan (BoJ) change in the guideline for money market operations, raising the uncollateralized overnight call rate to around 0.25 percent on 31 July 2024 (Bank of Japan, 2024).

Notes: Each window includes the reference month and the preceding and following 12 months. Reference dates follow the institutional sources listed in the table.



Supplementary Fig. A6. Connectedness in selected episodes.

Notes: Bars report average total connectedness (percent) under DY and R^2 for 25-month windows centred on each reference month in Supplementary Table A5.

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