



ABSTRACT

This paper proposes a general statistical framework for systemic financial stress indexes rooted in standard definitions of systemic risk. We interpret systemic stress as materialised systemic risk. Our statistical framework defines systemic stress as a state of the financial system in which representative stress measures are extremely high and strongly co-dependent at the same time. The composite indicator results from a matrix association index that combines two matrices quantifying the extremeness and the co-dependence hypotheses. We demonstrate how several indicators from the financial stress and systemic risk literatures can be represented as special cases of our general framework.

We introduce a new daily variant of the ECB's composite indicator of systemic stress (CISS) for the US and the euro area. The CISS aggregates index components using their time-varying cross-correlations as co-dependence measures. The various design steps are geared towards delivering a homogenous and robust composite indicator. We develop a bootstrap algorithm to test, among other things, unusually high levels of the CISS.

Linear and Quantile-VARs estimated for euro area and US data confirm the CISS as a significant driver of economic activity. This predictive power is particularly strong in the lower tails of the growth distributions in line with the recent growth-at-risk literature. Conditional forecast exercises find a dominant role of financial stress in explaining the severe recession during the GFC in 2008/9, in contrast to the Covid-19 crisis dominated by aggregate output shocks.

1. Motivation

“Money is a veil, but when the veil flutters, real output sputters.” (Gurley, 1961)

- Financial systems prone to occasional systemic crises with severe output losses
- Lack of well-founded measures of crisis severity
- As such measure, we propose the concept of a *systemic* financial stress index (FSI) that combines notions of financial stress and systemic risk
- Systemic FSI aggregates several individual measures of observable stress symptoms (e.g., volatilities and risk premia) based on systemic risk weights

2. General statistical framework

- Systemic stress defined as state with index components being extremely high and strongly co-dependent, with co-dependence capturing the systemic stress dimension
- Let N -dimensional square matrices \mathcal{E}_t and \mathcal{C}_t measure the degree of extremeness and co-dependence, respectively, among the index components $z_{i,t}$ ($i=1, \dots, N$)
- Matrix association index S_t combines extremeness and co-dependence measures into a systemic FSI

$$S_t = \frac{1}{N^2} \sum_{i=1}^N \sum_{j=1}^N (\mathcal{E}_t)_{i,j} \cdot (\mathcal{C}_t)_{i,j} \quad (1)$$

- The scaling factor ($1/N^2$) represents standard assumption of equal weighting in the summation (could be relaxed)
- The design of many FSIs and systemic risk indicators from the literature can be represented as special cases of the general framework.

3. Composite Indicator of Systemic Stress (CISS)

- Daily variant of the original weekly CISS; euro area and US data (starting in Jan. 1980 and 1973, respectively)
- Composed of $N=15$ representative raw stress indicators $x_{i,t}$ (increasing in the level of stress)
- Applying probability integral transform (empirical CDF, relative ranks) delivers stress factors $z_{i,t}$
 - Stress factors are thus homogenised in terms of scale and distribution: $z_{i,t} \in (0,1]$ and $z_{i,t} \sim U(0,1)$
 - Recursive transformation as from Jan. 2002 avoids look-ahead bias and ex post event reclassification
 - Rank-based recursive transformation robust against outliers
- Extremeness quantified as cross product between all pairs of non-centred stress factors: $(\mathcal{E}_t)_{i,j} = (z_t z_t')_{i,j} \in (0,1]$
- Co-dependence measured by time-varying bilateral rank correlations (Spearman's ρ) collected in matrix R_t . Non-parametrically computed from autoregressive exponentially-weighted moving average (EWMA) conditional variance process H_t (Engle, 2002):

$$H_t = \lambda H_{t-1} + (1 - \lambda) \tilde{z}_t \tilde{z}_t' \quad (2)$$

$$(R_t)_{i,j} = (H_t)_{i,j} / \sqrt{(H_t)_{i,i} (H_t)_{j,j}} \quad (3)$$

with \tilde{z}_t the vector of centred stress factors.

- The CISS as an operationalisation of equation (1):

$$CISS_t = \frac{1}{N^2} \sum_{i=1}^N \sum_{j=1}^N (z_t z_t')_{i,j} \cdot (R_t)_{i,j} \quad (4)$$

Fig. 1: Euro area and US CISS
(daily data; 3 Jan. 1973 to 28 Dec. 2021)

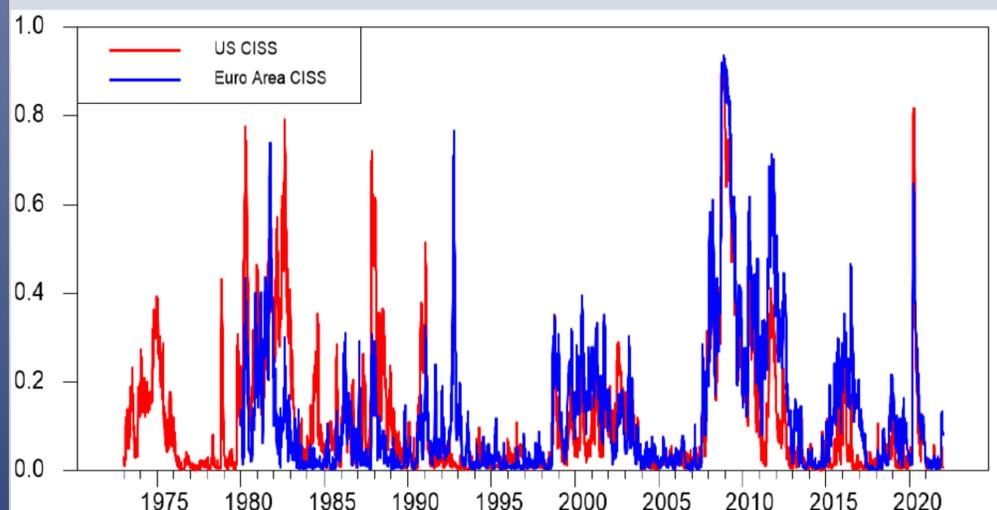




Fig. 2: Realisations of $z_t z_t'$ and R_t around GFC

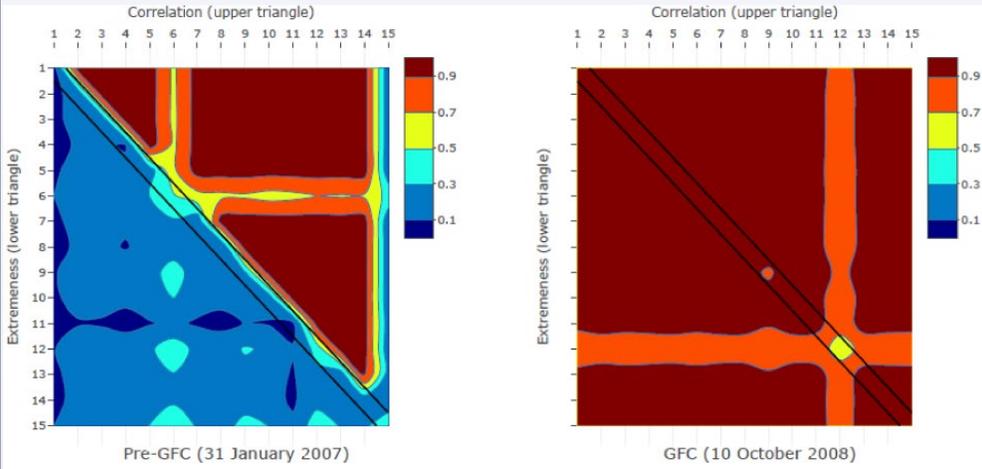
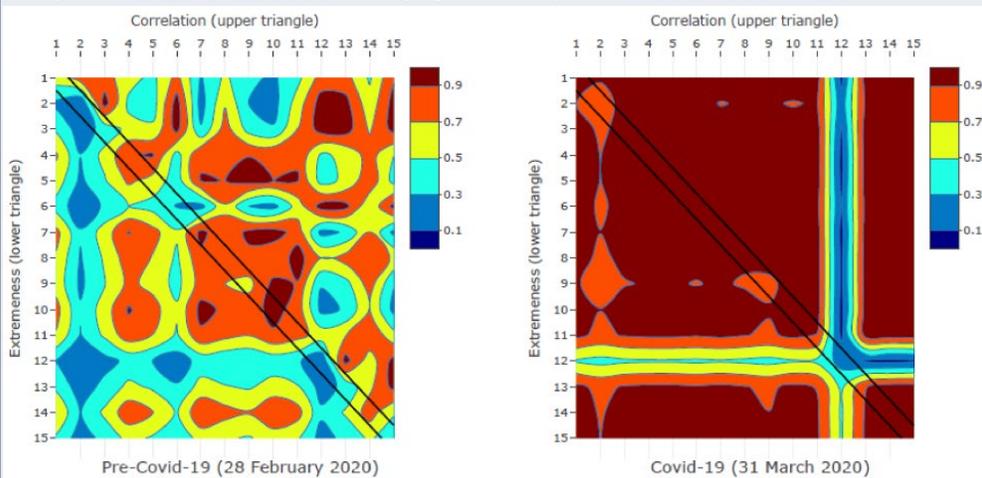


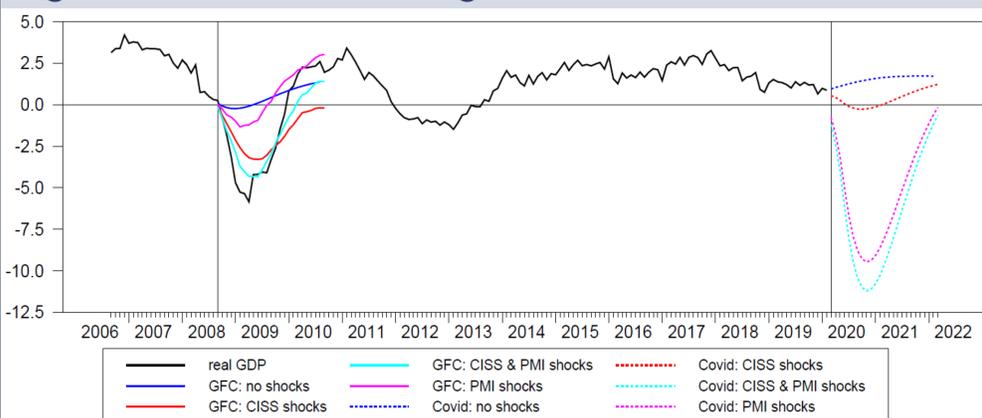
Fig. 3: Realisations of $z_t z_t'$ and R_t around Covid-19 crisis



4. Real growth effects of systemic financial stress

- Systemic financial crises entail severe losses in output and employment. We replicate this stylised fact within linear and Quantile-VARs on the CISS, the Purchasing Managers' Index (PMI) and annual real GDP growth for euro area and US data, respectively.
- Results confirm the CISS as an important driver of economic activity. We find systemic stress to be the major force behind the deep GFC recession, while playing a minor role only in the Covid-19 crisis.
- The QVAR (Chavleishvili and Manganelli, 2019) finds amplified effects of the CISS on economic activity in the lower tails of the growth distribution. This macro-financial asymmetry is in line with the general findings of the recent growth at risk literature.

Fig. 4: Simulated real GDP growth from linear VAR



Notes: Fig. 4 plots up to 2-year real GDP growth forecasts from the linear VAR for the GFC (origin: Aug. 2008) and the Covid-19 crisis (origin: Feb. 2020). GFC forecasts are conditional on the estimated shocks of the CISS, the PMI, or both from Sept. 2008 to August 2010). The Covid-19 forecasts are conditional on CISS and/or PMI shocks in Mar. and Apr. 2020.

Fig. 5: Impulse-response functions from Quantile-VAR (responses to CISS, PMI and GDP shocks in the first, second and third column, respectively; responses of the CISS, PMI and GDP in the first, second and third row, accordingly)

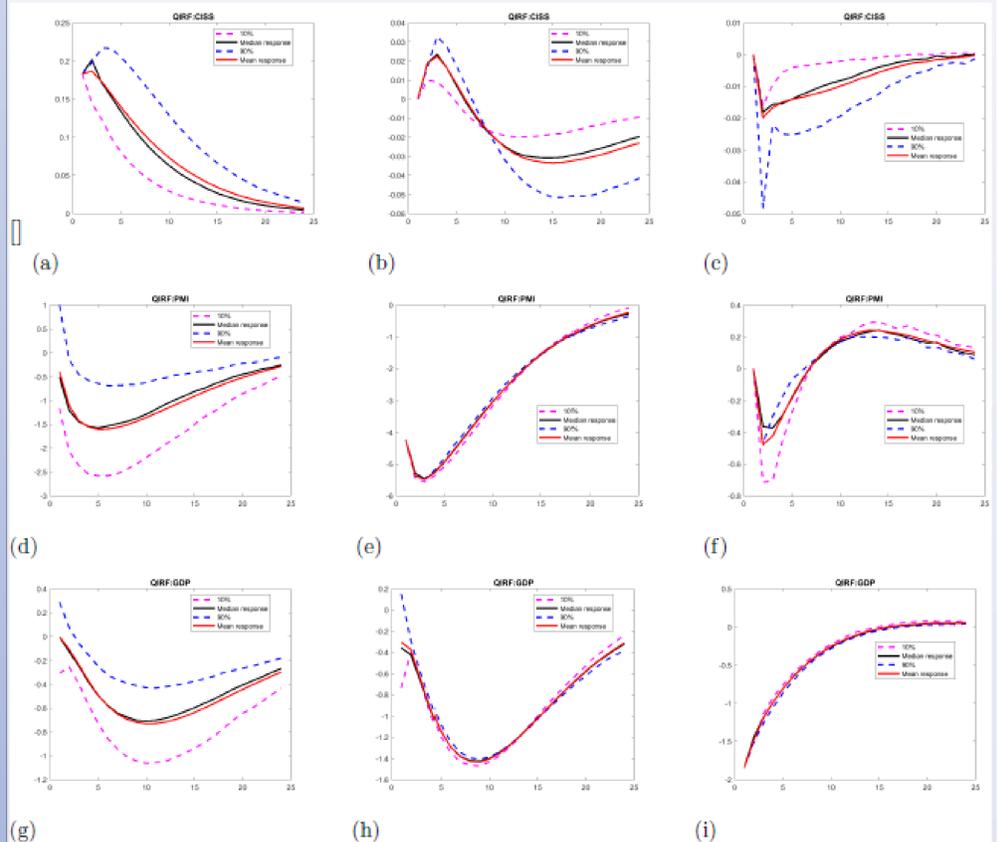
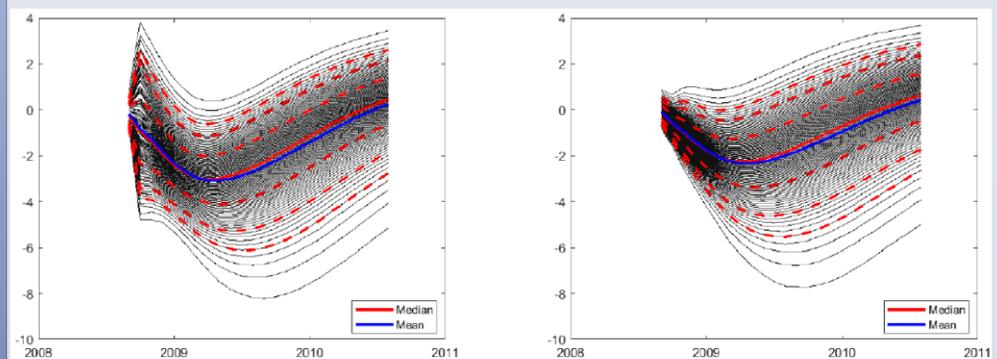
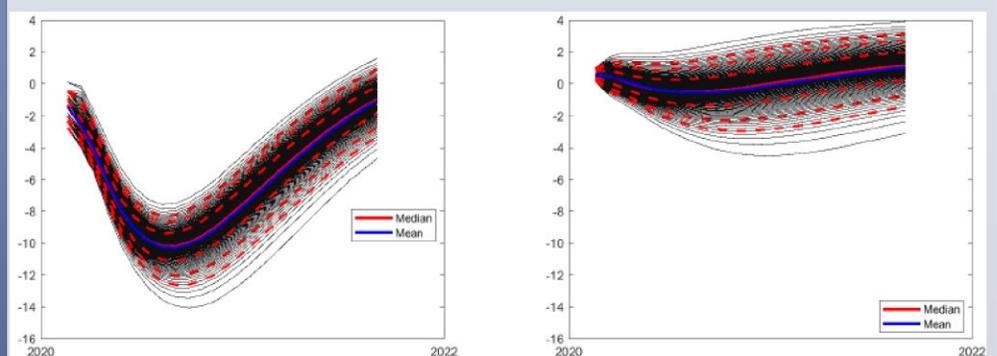


Fig. 6: Simulated crisis densities for real GDP growth

(1) Global Financial Crisis (2008/9)



(2) Covid-19 crisis (2020/1)



Notes: Fig. 6 plots density forecasts from the QVAR of real GDP growth over a 2-year horizon, with forecast origin in Aug. 2008 for the GFC (panel 1) and Feb. 2020 for the Covid-19 crisis (panel 2). Density forecasts are conditional on realisations of the CISS and the PMI in Sept. and Oct 2008 (for GFC) and in Mar. and Apr. 2020 (for Covid-19 crisis). Solid black lines correspond to empirical percentiles from 1% to 99% with a step size of 1%. Dashed red lines highlight empirical percentiles from 5% to 95% with a step size of 5%. The left panels show density forecasts conditional on both the CISS and the PMI, while the forecast densities in the right panel are conditional only on the CISS.