CISS – A Portfolio-Theoretic Framework for the Construction of Financial Stress Indices

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Outline

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2. Statistical indicator design
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   b) Raw stress indicators
   c) Transformation and aggregation
3. Presenting the CISS
4. Evaluation
5. Preliminary US CISS
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1. Motivation

- **What is the CISS about?**
  - CISS stands for "Composite Indicator of Systemic Stress";
  - CISS is a novel "financial stress index" (FSI), i.e. a composite indicator quantifying the current state of instability in the financial system by aggregating a number of individual stress indicators into a single statistic;
  - CISS aims to measure systemic financial stress: measures systemic risk ex post

    ⇒ "thermometer", no "barometer".

- **Recent contributions to growing literature:**
  - Canada: Illing and Liu (JFS, 2006)
  - USA: Nelson and Perli (Board of Governors, 2005), Hakkio and Keeton (FRB Kansas City, 2009), Oet et al. (FRB Cleveland, 2011), Brave and Butters (FRB Chicago, 2011), Carlson, Lewis and Nelson (Board of Governors, 2012), Kliesen, Owyang and Vermann (FRB St. Louis, 2012)
  - Euro area: Blix Grimmaldi (ECB, 2010; Riksbank, 2011), Hollo, Kremer and Lo Duca (ECB, 2012)
  - Germany: van Roye (IfW Kiel, 2011)
  - Multi-country: Caldarelli et al. (IMF, 2009).

1. Motivation (cont'd)

- **What's our contribution to the literature?**
  - **We propose a systemic FSI that**
    - **is explicitly designed along the notion of systemic risk *(main conceptual innovation)***

      Systemic risk can be defined as the risk that instability becomes so widespread within the financial system ('horizontal view') that it impairs its functioning to the point where economic growth and welfare suffer materially ('vertical view').
      (de Bandt and Hartmann, 2000)

    - **operationalises the idea of systemic instability by applying basic portfolio theory to the aggregation of individual financial stress indicators *(main statistical innovation)*.**
  - **We propose a simple econometric framework to**
    - **endogenously identify different financial stress regimes; and**
    - **assess the real costs of systemic crises (empirical literature on macro-financial linkages).**

2. a) Basic statistical setup

- **Real-world financial system is an opaque, complex and interdependent network of financial markets, intermediaries and infrastructures;**
- **Ideally, CISS should capture strains in each part of the financial system, weighted by its systemic importance**
  $\Rightarrow$ obviously impossible;
- **We propose 3-tier aggregation framework to reduce complexity and cope with opaqueness (each tier featuring certain *characteristics of systemic risk*):**
  - **intermediate tier: identify 5 aggregated financial system segments covering the main flows of financial funds (*systemic importance: size, substitutability*)**
  - **lower tier: identify 3 raw stress indicators per segment covering typical *stress/crisis symptoms***
  - **top tier: compute segment-specific stress subindexes and aggregate them into the CISS based on portfolio-theoretic principles (*widespread instability; systemic importance: interconnectedness, size; real costs*).**

2. b) Raw stress indicators (cont'd)

- **Raw stress indicators (mostly standard price-based indicators) grouped into five market segments:**
  - **Money market (MM):** realised volatility of 3 month Euribor; spread Euribor/T-bill (3 month maturity); recourse to the marginal lending facility at the ECB.
  - **Bond market, sovereign and non-financials (BM):** realised volatility of 10y Bund; spread corporate AAA versus government bonds; 10y interest rate swap spread.
  - **Equity market, non-financials (EM):** realised volatility of equity returns; CMAX; stock-bond correlation
  - **Financial intermediaries (FI):** realised volatility of idiosyncratic returns of the banking index; spread A rated financials/non-financials; CMAX interacted with book-price ratio for the financial sector equity index.
  - **Foreign exchange (FX):** realised volatility of US/EUR, JPY/EUR, GBP/EUR.

2. c) Transformation of raw indicators and computation of stress subindexes

- **Raw stress indicators standardised on the basis of order statistics (resp. CDF) to improve robustness:**
  - replace each value of the raw indicator x_t by its ranking number r in the ordered sample of size n, scaled by the sample size: r/n

$$z_t = F_n(x_t) := \begin{cases} \frac{r}{n} \text{ for } x_{[r]} \leq x_t < x_{[r+1]}, \quad r = 1,2,\ldots,n-1 \\ 1 \text{ for } x_t \geq x_{[n]} \end{cases}$$

  - Recursively computed over expanding samples to preserve "real-time" character
  - trades off likely gains in statistical robustness against loss of information contained in original cardinal measures.
- **Segment-specific subindexes $s_{i,t}$ (i = MM, BM, EM, FIN, FX):**

$$s_{i,t} = \tfrac{1}{3} \sum_{j=1}^{3} z_{i,j,t}$$

2. c) Portfolio-theoretic aggregation framework

- **Application of portfolio theory to aggregate subindexes into composite indicator:**
  - **Compute system-wide stress in an analogous way to the risk of a portfolio of assets:**
    - "covariances/correlations matter"
  - **Offers two avenues to introduce systemic risk characteristics:**
    - time-varying cross-correlations (between subindexes) collected in correlation matrix C_t
      $\Rightarrow$ widespread instability, interconnectedness
    - subindex-specific "market shares" $w_{i,t}$ in the "portfolio" of subindexes
      $\Rightarrow$ systemic importance (size, real economy, …).

2. c) Portfolio-theoretic aggregation framework: The formula

$$CISS_t = (w_t \circ s_t)\Sigma_t(w_t \circ s_t)' \in (0,1]$$

$$\begin{aligned} w &= \left(w_{MM,t}, w_{BM,t}, w_{EM,t}, w_{FI,t}, w_{FX,t}\right) \\ &= \left(\overline{w}_{MM}, \overline{w}_{BM}, \overline{w}_{EM}, \overline{w}_{FI}, \overline{w}_{FX}\right) = (0.19, 0.22, 0.14, 0.25, 0.20) \end{aligned}$$

$$s_t = \left(s_{MM,t}, s_{BM,t}, s_{EM,t}, s_{FI,t}, s_{FX,t}\right)$$

$$\Sigma_t = \begin{pmatrix} 1 & \rho_{12,t} & \rho_{13,t} & \rho_{14,t} & \rho_{15,t} \\ \rho_{12,t} & 1 & \rho_{23,t} & \rho_{24,t} & \rho_{25,t} \\ \rho_{13,t} & \rho_{23,t} & 1 & \rho_{34,t} & \rho_{35,t} \\ \rho_{14,t} & \rho_{24,t} & \rho_{34,t} & 1 & \rho_{45,t} \\ \rho_{15,t} & \rho_{25,t} & \rho_{35,t} & \rho_{45,t} & 1 \end{pmatrix}$$

2. c) Time-varying cross-correlations

- **Time-varying cross-correlations (covariances and variances) computed as exponentially weighted moving averages (EWMA):**

$$\tilde{s}_{i,t} = (s_{i,t} - 0.5)$$

$$\lambda = 0.93$$

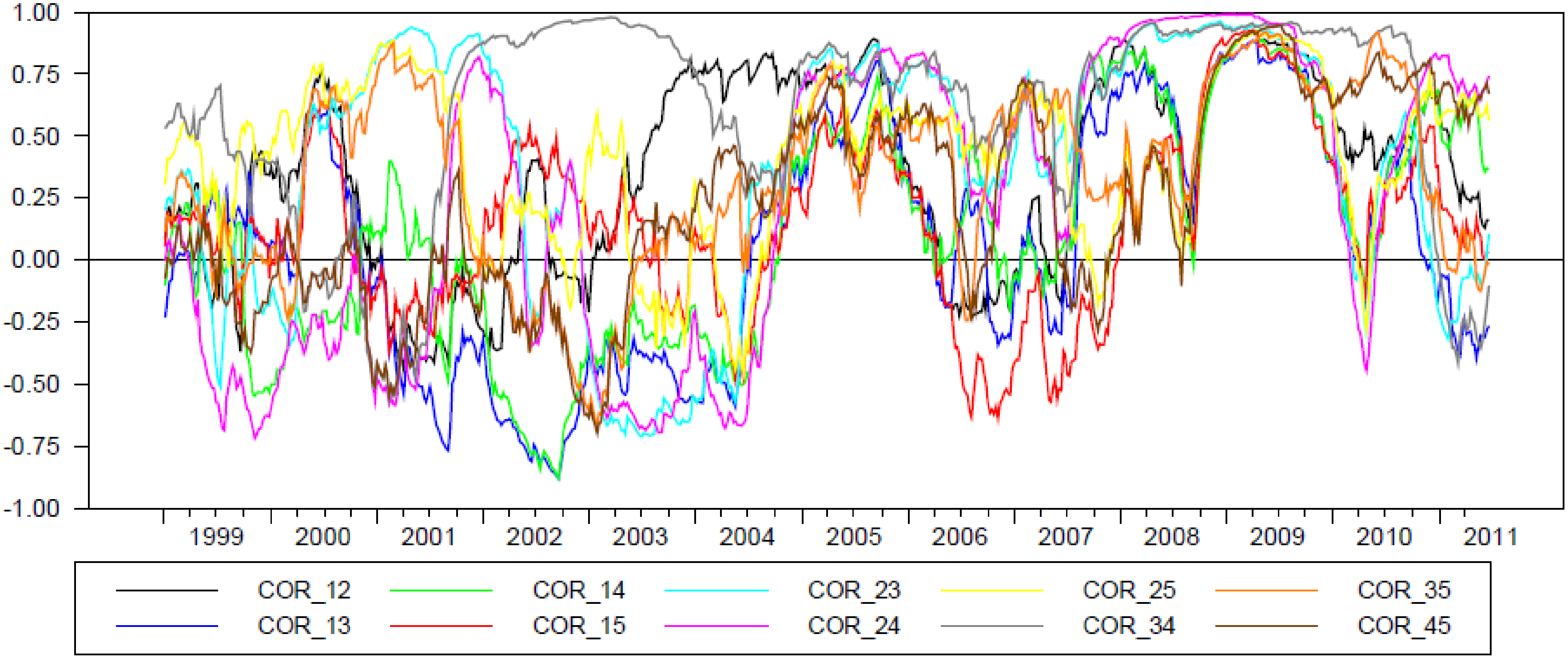
$$\sigma_{ij,t} = \lambda \sigma_{ij,t-1} + (1-\lambda)\tilde{s}_{i,t}\tilde{s}_{j,t}$$

$$\sigma_{i,t}^2 = \lambda \sigma_{i,t-1}^2 + (1-\lambda)\tilde{s}_{i,t}^2$$

$$\rho_{ij,t} = \sigma_{ij,t} / \sigma_{i,t}\sigma_{j,t}$$

2. c) Time-varying cross-correlations (cont'd)

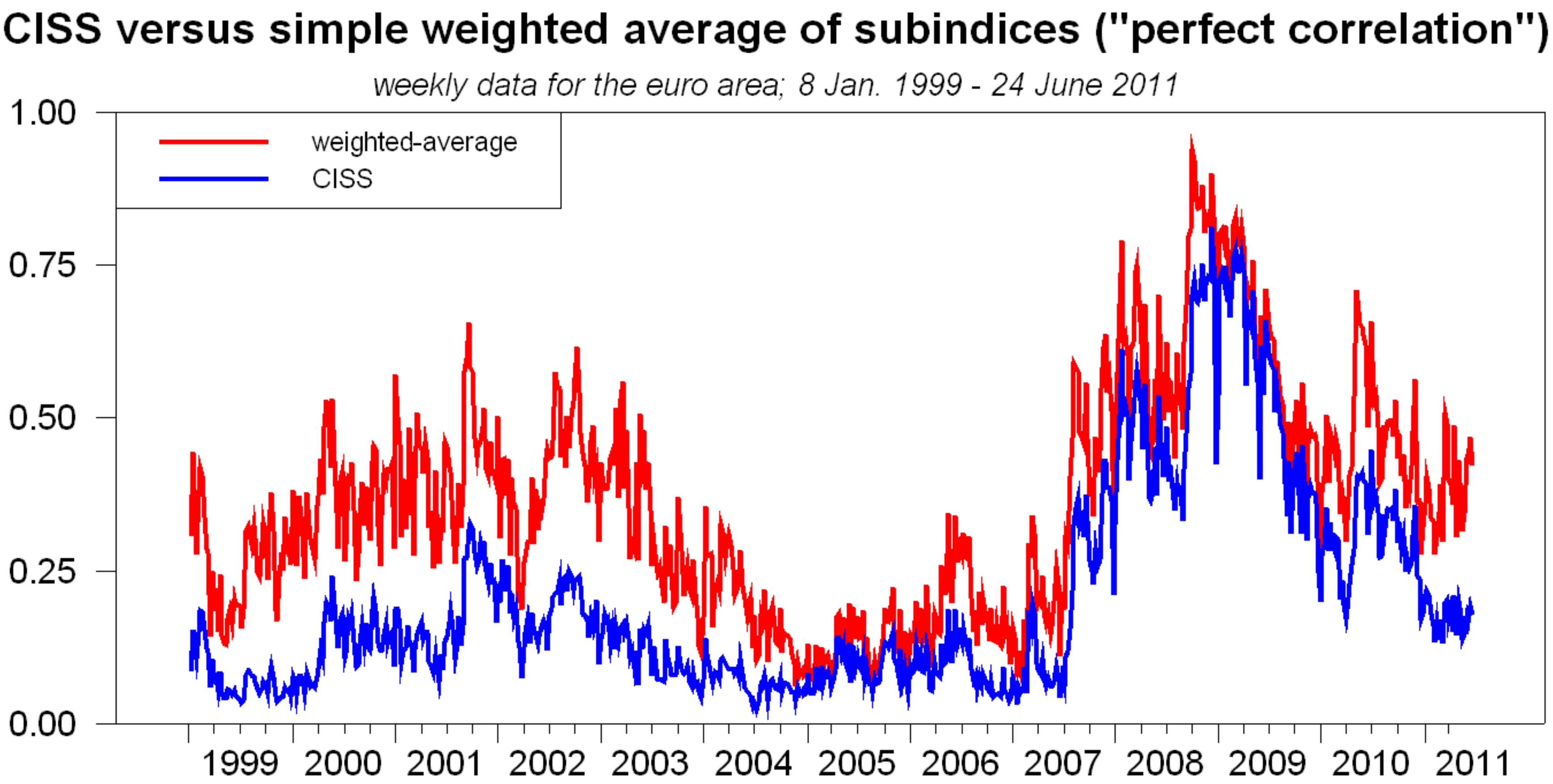
Fig. 2. Cross-correlations between subindices



Notes: Correlation pairs are computed as exponentially-weighted moving averages with smoothing parameter λ=0.93. The cross-correlations are labelled as follows: 1 – money market, 2 – bond market, 3 – equity market, 4 – financial intermediaries, 5 – foreign exchange market. Weekly euro area data from 8 Jan. 1999 to 24 June 2011.

3. Presenting the CISS: correlation impact

CISS equals (square of) weighted average of subindexes if all elements of the matrix Σ_t take the value 1, i.e. if all subindexes are perfectly correlated (special case, upper bound).

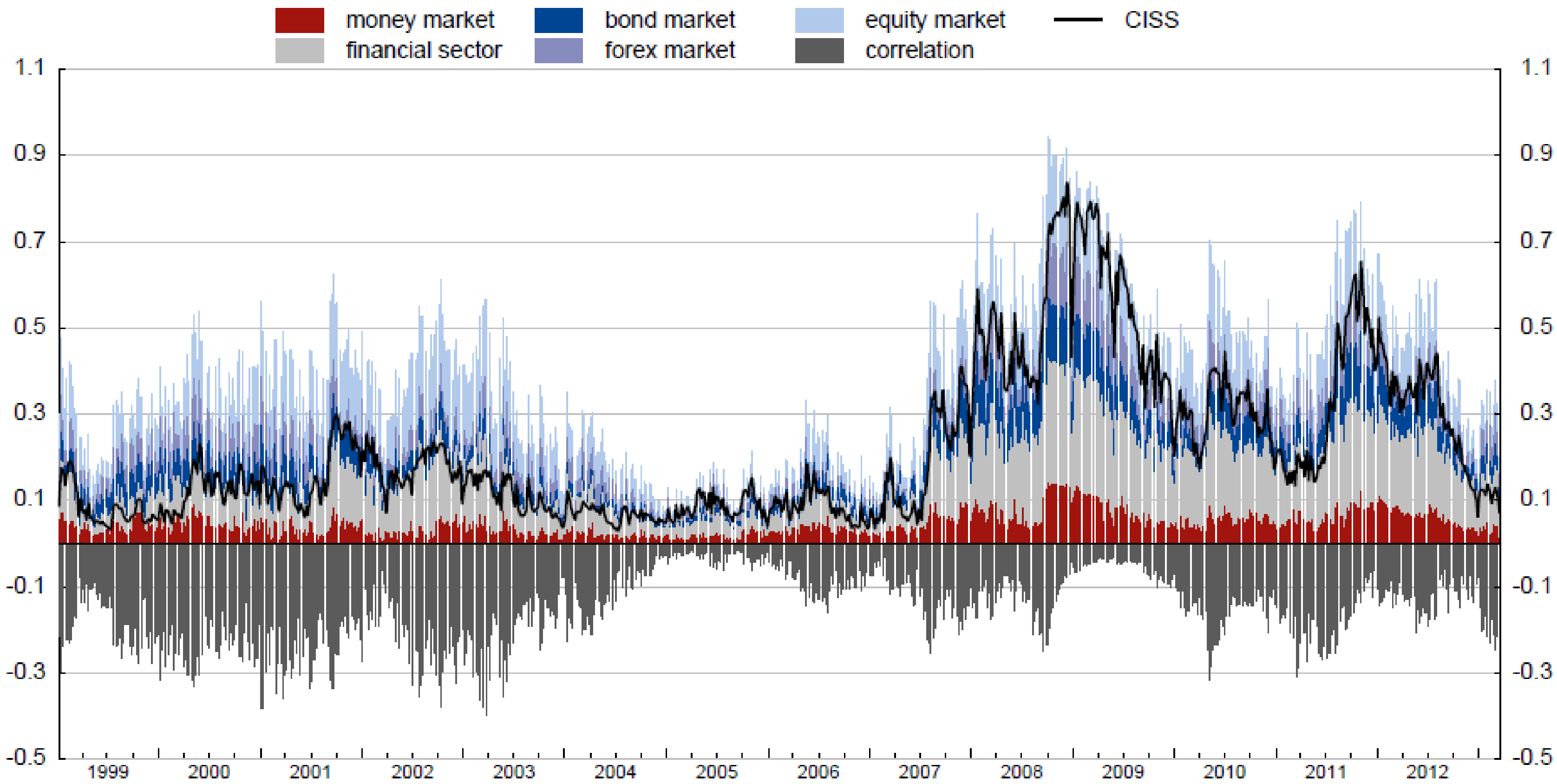


3. Presenting the CISS: Decomposition chart

1. Interlinkages and composite measures of systemic risk

1.1 Composite indicator of systemic stress (CISS)

(8 Jan. 1999 - 15 Mar. 2013)



Sources: Thomson Reuters, ECB and ECB calculations.

4. Evaluation: General observations

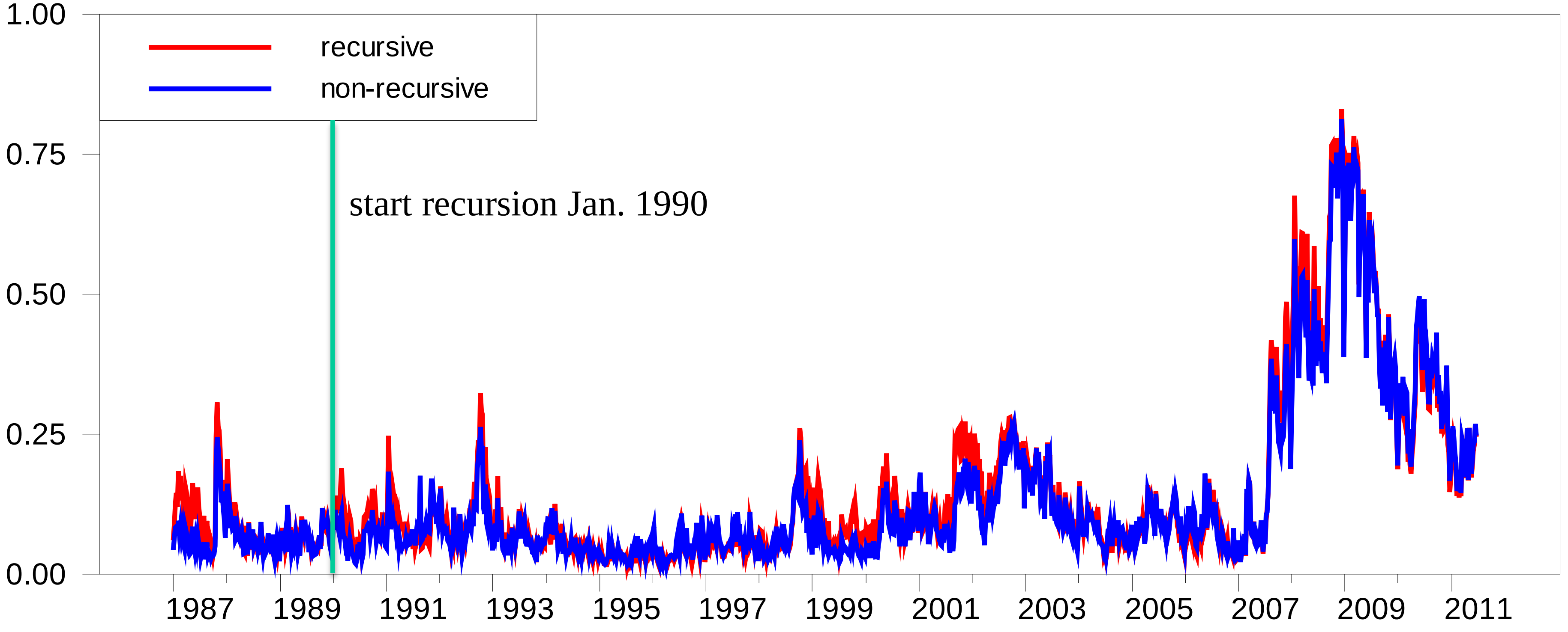
- **Difficult to assess whether an FSI performs well both in absolute terms (What is a good indicator?) and in relative terms (Which indicator is better?)**
  - Systemic risk is an elusive and complex phenomenon
  - Many degrees of freedom in constructing composite stress indicators
  - Severe data constraints limiting the reliability of empirical analysis (crises are "rare events", lack of statistical degrees of freedom in "horse races")

- **Assess the CISS's performance in absolute terms:**
  - Statistical stability and …
  - … economic plausibility of its information content

4. Evaluation: Statistical robustness

- **Historical signals of the CISS very robust to the arrival of new information (no "event re-classification problem")**
- **Example for backward-extended proxy CISS, with recursion starting in Jan. 1990**

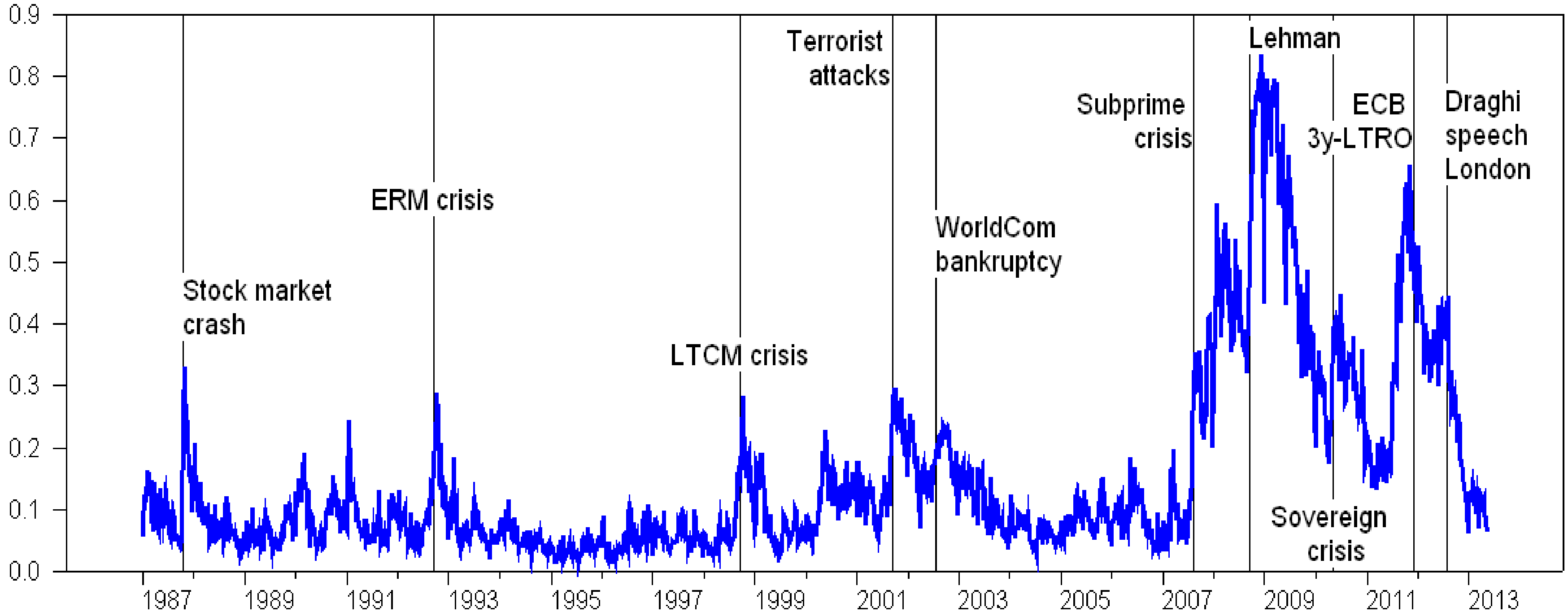
Recursive versus full-sample computation of the backward-extended CISS



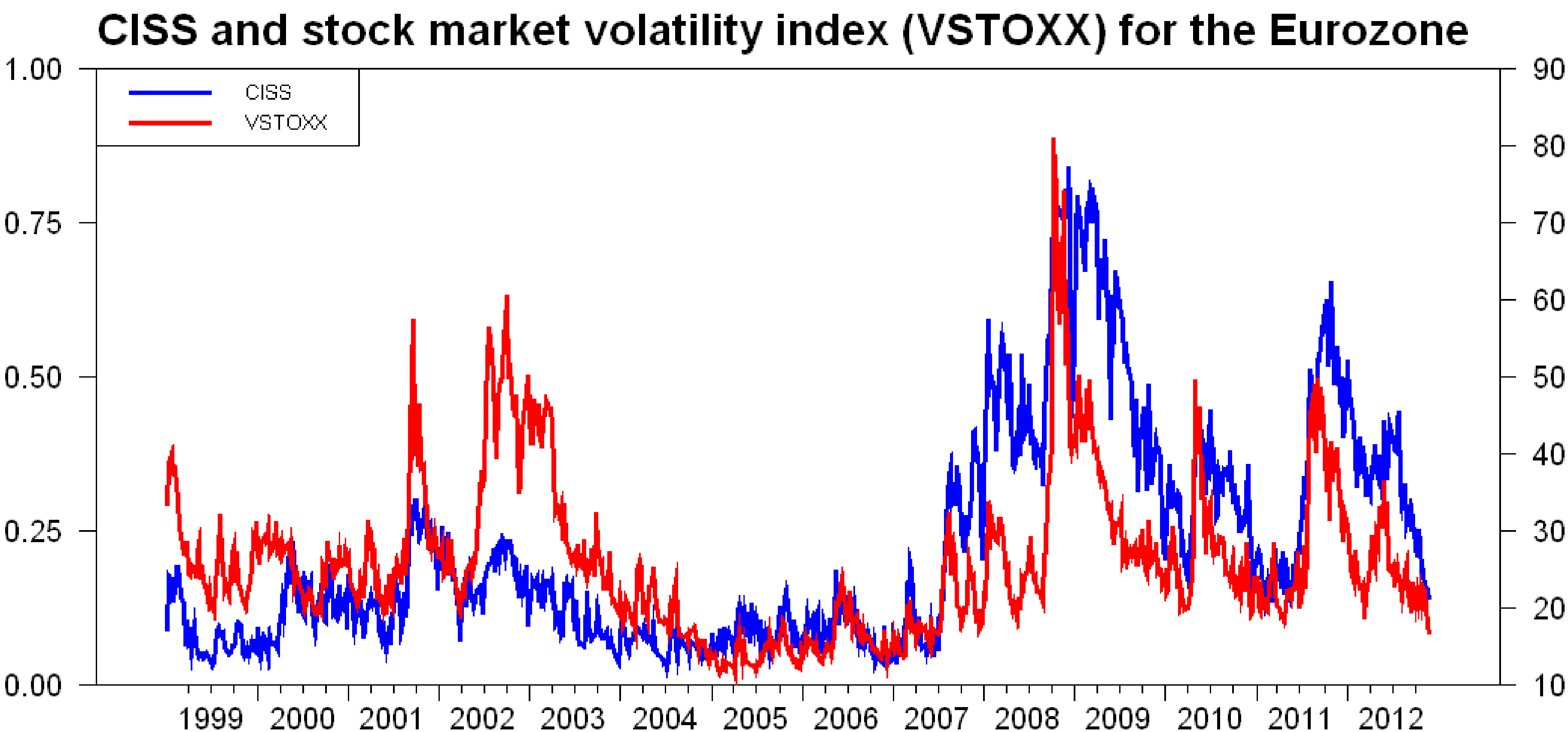
4. Evaluation: Identification of crisis events

Euro area CISS and major financial stress events

(weekly data; 2 Jan. 1987 – 13 May 2013)



4. Evaluation: Value added?



Notes: Weekly data. Last observation: 30 November 2012.

4. Evaluation: Bivariate Threshold-VAR

$$x_t = c^H + \Phi_1^H x_{t-1} + \Phi_2^H x_{t-2} + e_t^H \qquad \text{if} \qquad z_{t-d} > \tau \qquad \text{(high-stress regime)} \qquad (8a)$$

$$x_t = c^L + \Phi_1^L x_{t-1} + \Phi_2^L x_{t-2} + e_t^L \qquad \text{if} \qquad z_{t-d} \leq \tau \qquad \text{(low-stress regime),} \qquad (8b)$$

with

☒♦ = (👍✋💧💧♦🖮 ○📂🗎●□♑✋🏳♦)';

c⬩ and Φ⬩ regime-dependent coefficient vectors or matrices for states ⬩ =🖗 (high-stress regime)🖮 ☹ (low-stress regime);

⌘♦−♎ the threshold variable with ♎ ∈ 1,💻💻💻🖮 ♎0 and ♎0= 2 the max. threshold lag;

🕘 the threshold parameter;

✧♦⬩ vector the vector of regime-dependent regression errors.

4. Evaluation: Bivariate Threshold-VAR (cont'd)

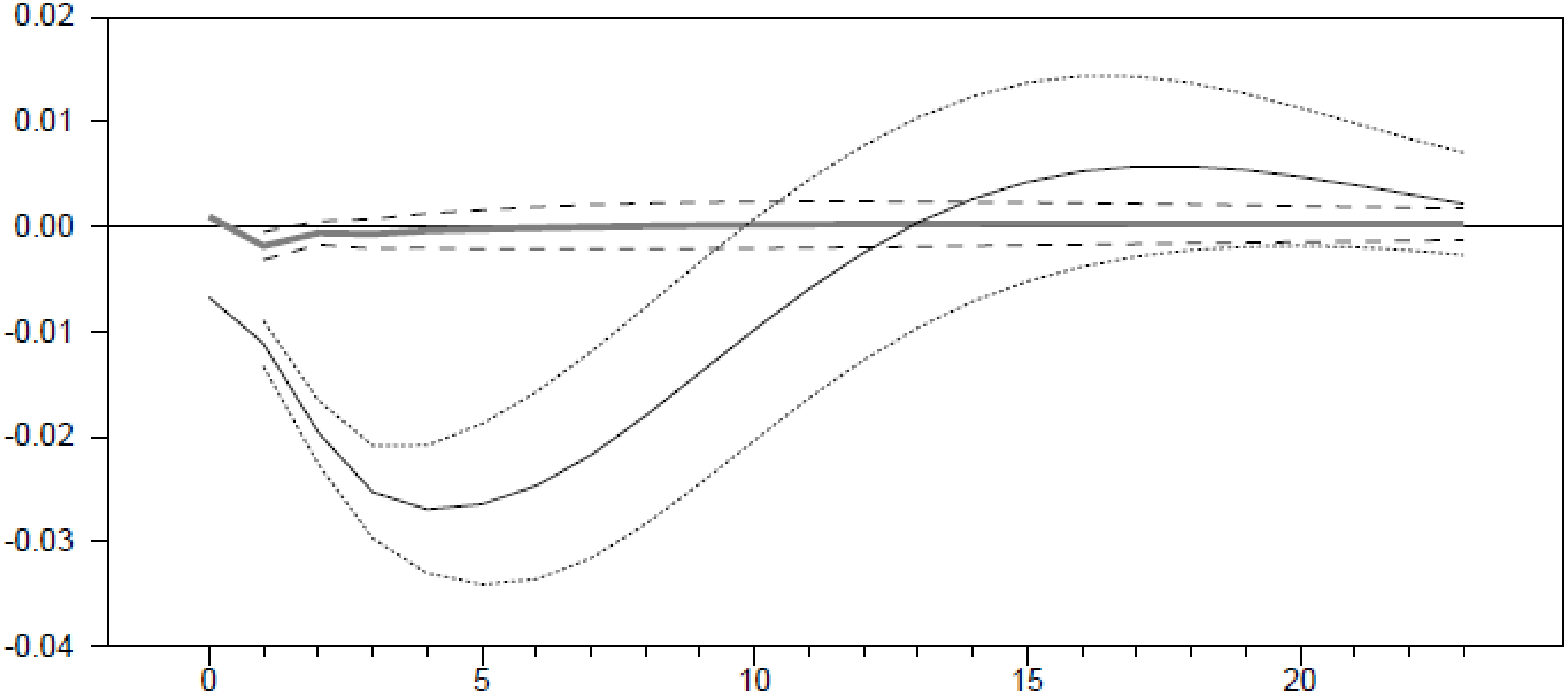
Table 4. Testing for threshold delay and threshold values

	Tsay (1998)-Test				Hansen (2000)-Test		
d	C(d)-Stat	p-value	tau	AIC	F-Stat	p-value	tau
1	20.03	0.0166	0.2960	-2741	13.46	0.0000	0.2957
2	19.24	0.0402	0.3233	-2766	12.59	0.0000	0.2747

Notes: *d* denotes the threshold delay and τ the threshold value. AIC is the Akaike information criterion. The C(*d*)-Statistic (p-value shown in the next column) tests for a statistically significant threshold effect in a bivariate VAR with two lags and the CISS and annual growth in industrial production for the euro area as endogenous variables. The F-Statistic tests for the presence of a single threshold in a regression of output growth on a constant, two of its own lags and the CISS with same lag length. Monthly data from Jan. 1987 to June 2011.

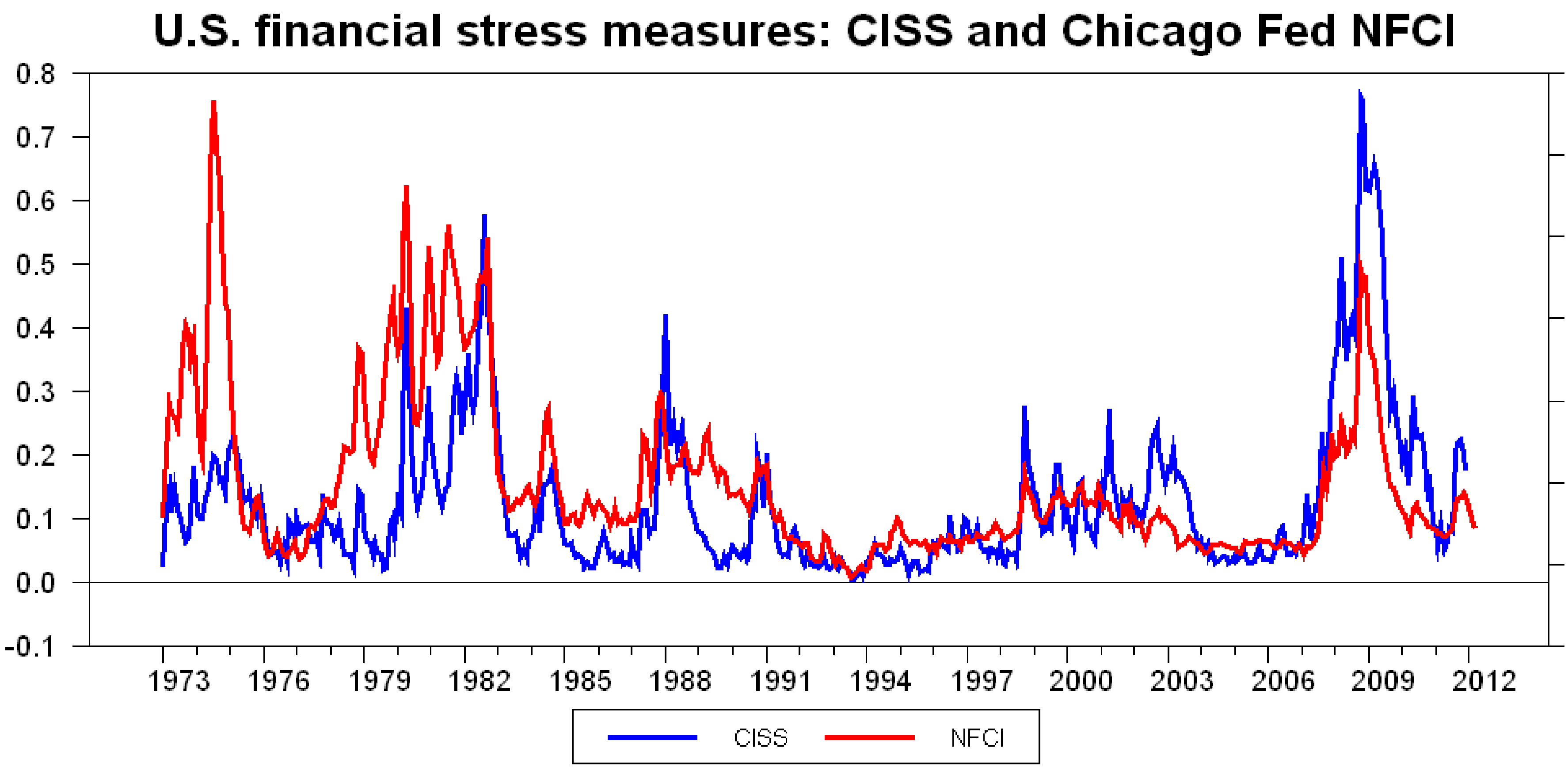
4. Evaluation: Bivariate Threshold-VAR (cont'd)

Fig. 14. Regime-dependent impulse response functions (IRF) of output growth to shocks in the CISS from the TVAR(2) model



black solid line: IRF of high-regime; grey solid line: IRF of low-regime. IRFs with one std. dev. analytical error bands

5. Preliminary US CISS



Notes: Monthly data.

5. To-Do List

- Expand geographical coverage (ongoing).
- CISS 2.0:
  - "2-stage" CISS to compute subindexes in a consistent fashion: merge computation of subindexes with computation of overall CISS by using the full 15 x 15 matrix of cross-correlations between all individual stress indicators.
- Performance evaluation:
  - Apply richer econometric model setups to assess linkages between financial stress and the real economy
    - MS-BVAR model for the euro area with endogenous CISS (Hartmann/Hubrich/Kremer/Tetlow)
  - Build longer time series to include more crises in econometric analysis and/or apply multi-country panel models
  - Design of meaningful "horse races" between different FSIs.

RESERVE SLIDES

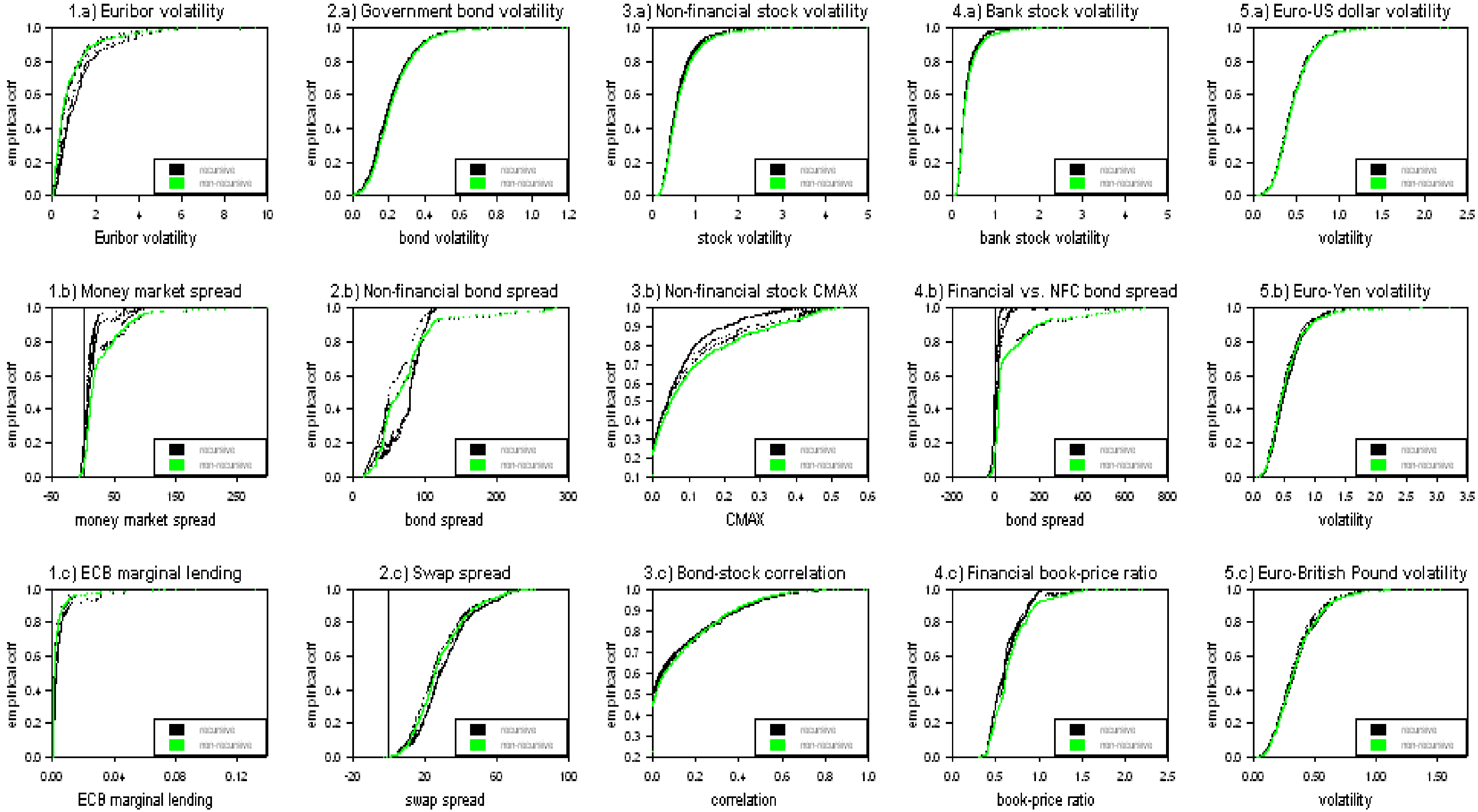
1. Motivation (cont'd)

- **The CISS could help policy makers to:**
  - **Monitor and assess the level of stress in the overall financial system in real time**
  - **Evaluate the impact of policy actions on the (in)stability of the financial system**
  - **Benchmark the current level of stress to that of past crises or market turbulence episodes**
  - **Better delineate historical financial crises (when did they start, when did they end?) …**
  - **… which could be used as more refined input into financial stability tools and models (e.g., early warning system models).**

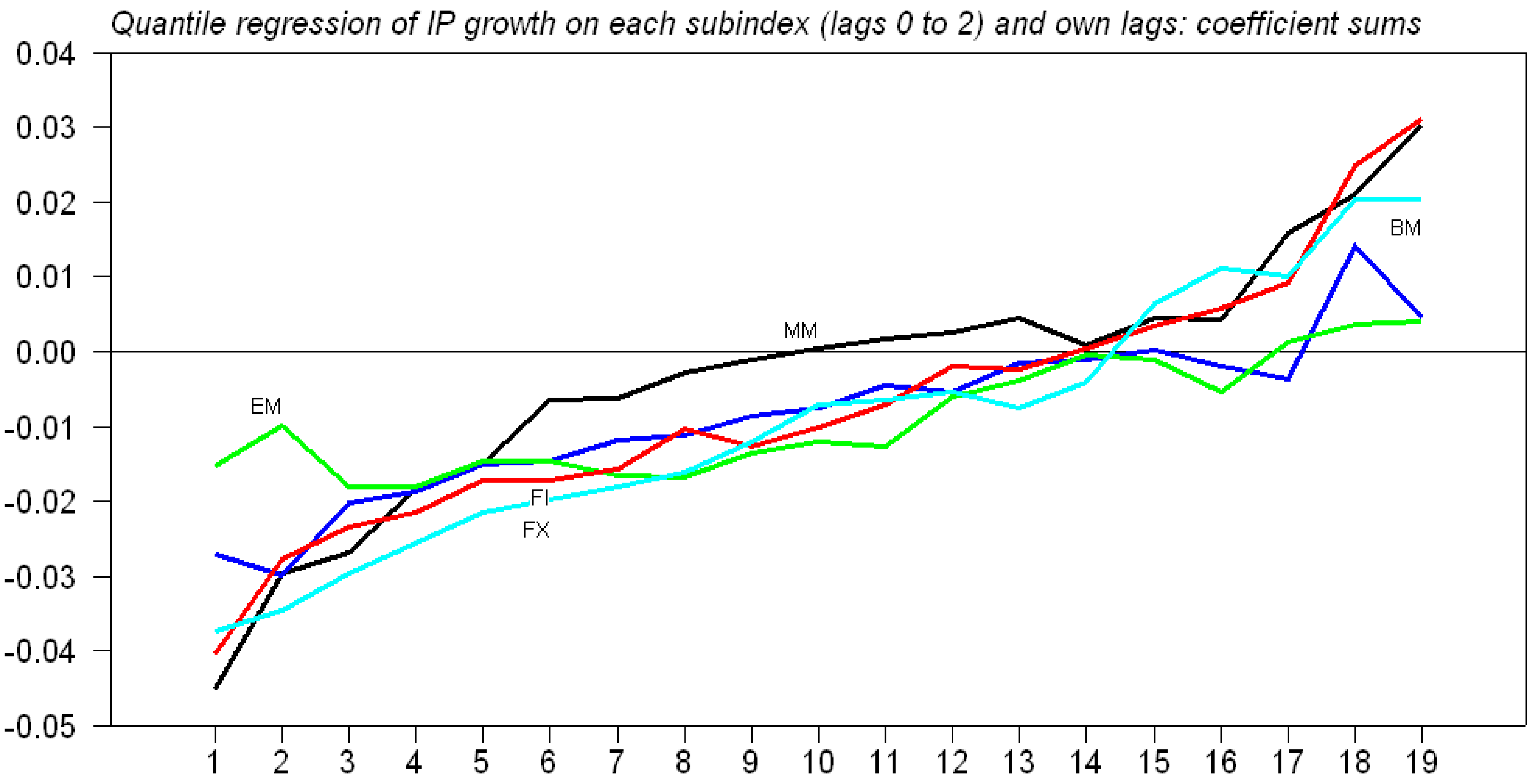
2. b) Raw stress indicators

- **Features of financial stress:**
  - Increases in agent's uncertainty (e.g., about asset valuations or the behaviour of other agents);
  - Increases in investor disagreement (differences of opinion);
  - Stronger information asymmetries (intensifying problems related to adverse selection and moral hazard);
  - Lower preferences for holding risky/illiquid assets (flight-to-quality / flight-to-liquidity).
- **Stress features bring about typical stress symptoms:**
  - Increased volatility; wider default and liquidity premia; market dry-ups for risky financial instruments; etc.
- **Measured by (mostly standard) raw stress indicators:**
  - Price-based indicators available at high frequencies without delay and with relatively long data histories;
  - Asset prices also informative about quantities (e.g., leverage).

2. c) Transformation of raw stress indicators

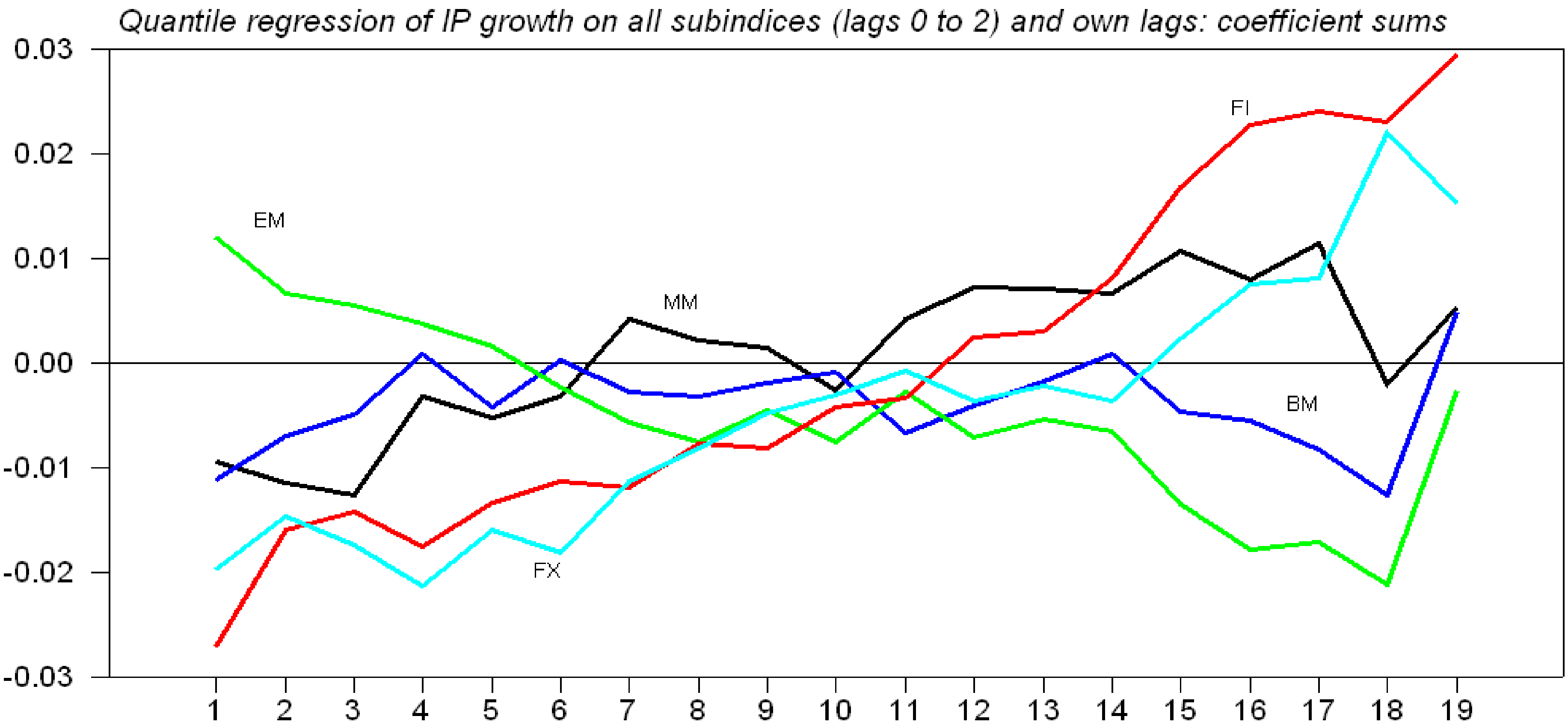


2. c) Weights from quantile regressions



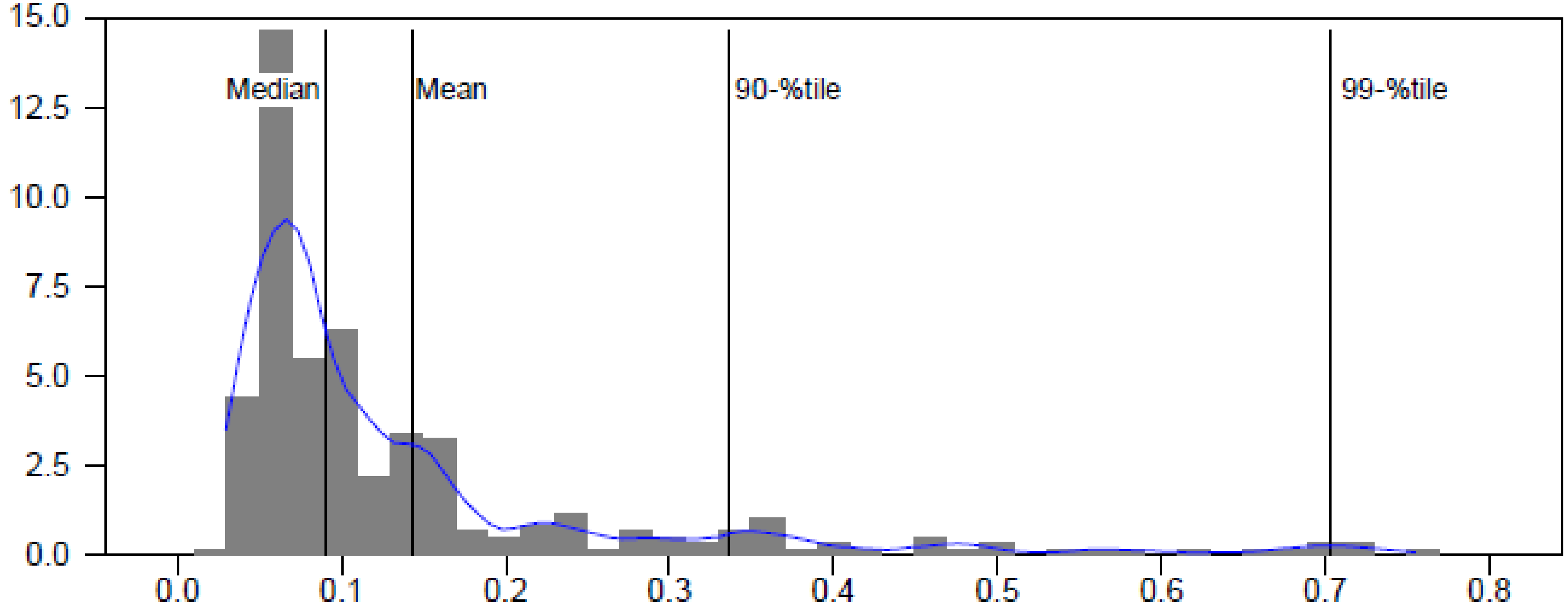
$$w = \left(\overline{w}_{MM}, \overline{w}_{BM}, \overline{w}_{EM}, \overline{w}_{FI}, \overline{w}_{FX}\right) = (0.19, 0.22, 0.14, 0.25, 0.20)$$

2. c) Weights from quantile regressions (cont'd)



4. Evaluation: CISS "regimes"

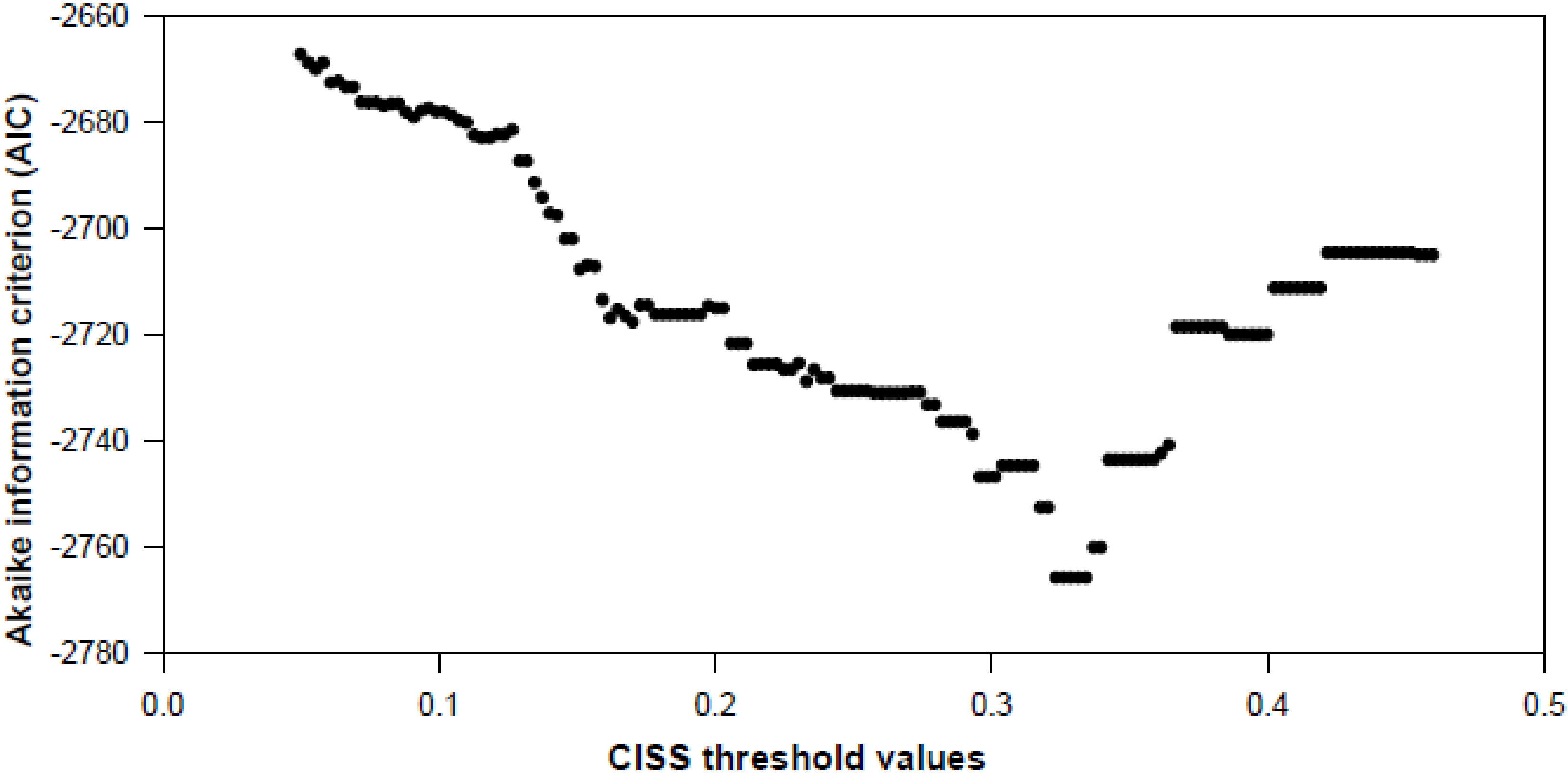
Fig. 10. Histogram and smoothed histogram for the CISS



Notes: Histograms calculated for the euro area CISS in "variance-equivalent" terms and based on monthly averages of weekly data from Jan. 1987 to June 2011. Smoothed histogram based on Epanechnikov kernel. The moments of the empirical distribution indicated in the chart have the following values: mean = 0.1425, median = 0.0909, 90-%tile = 0.3362, 99-%tile = 0.7037.

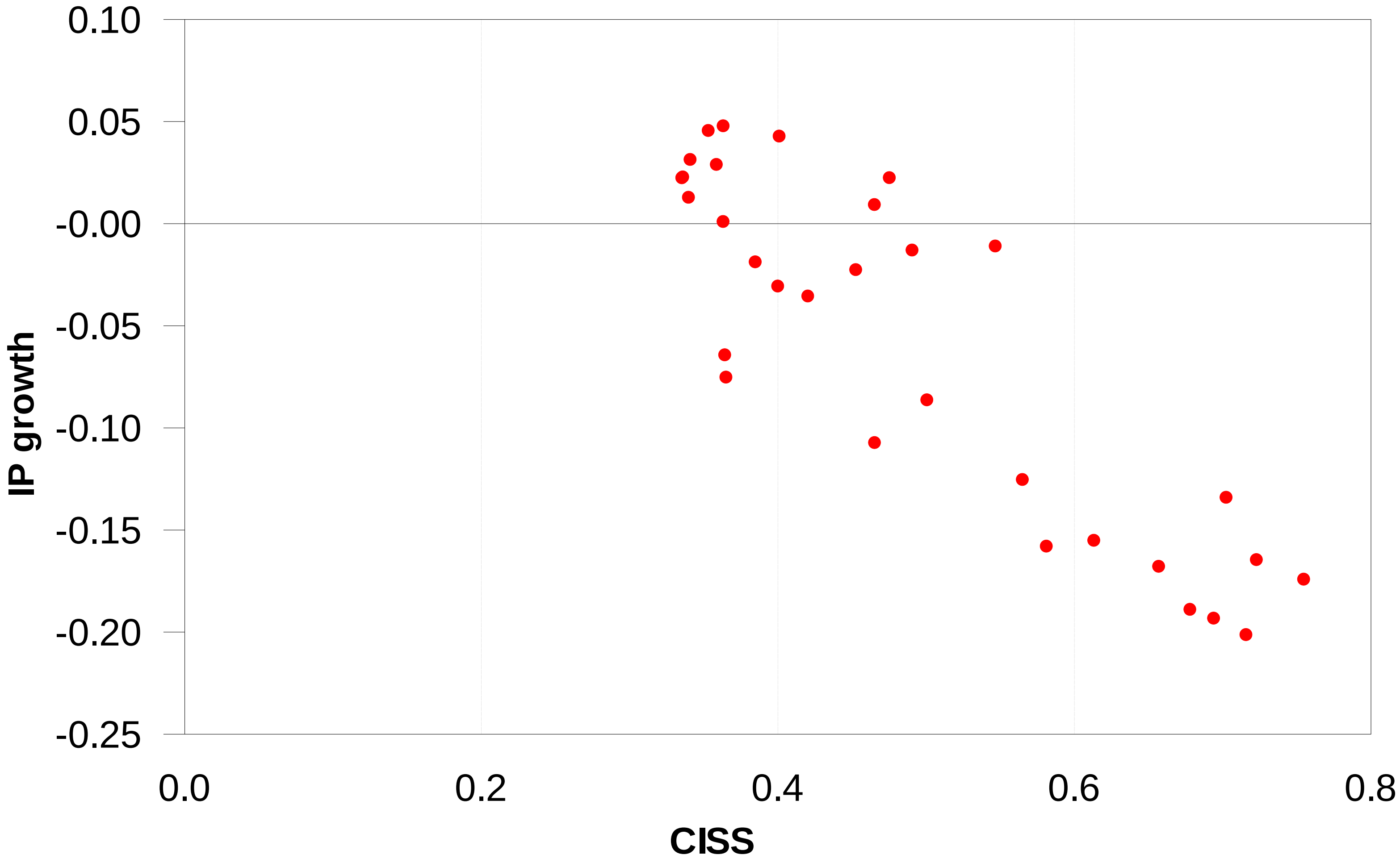
4. Evaluation: Bivariate Threshold-VAR (cont'd)

Fig. 13. Threshold estimation based on AIC values for the null hypothesis VAR(2) vs TVAR(2)



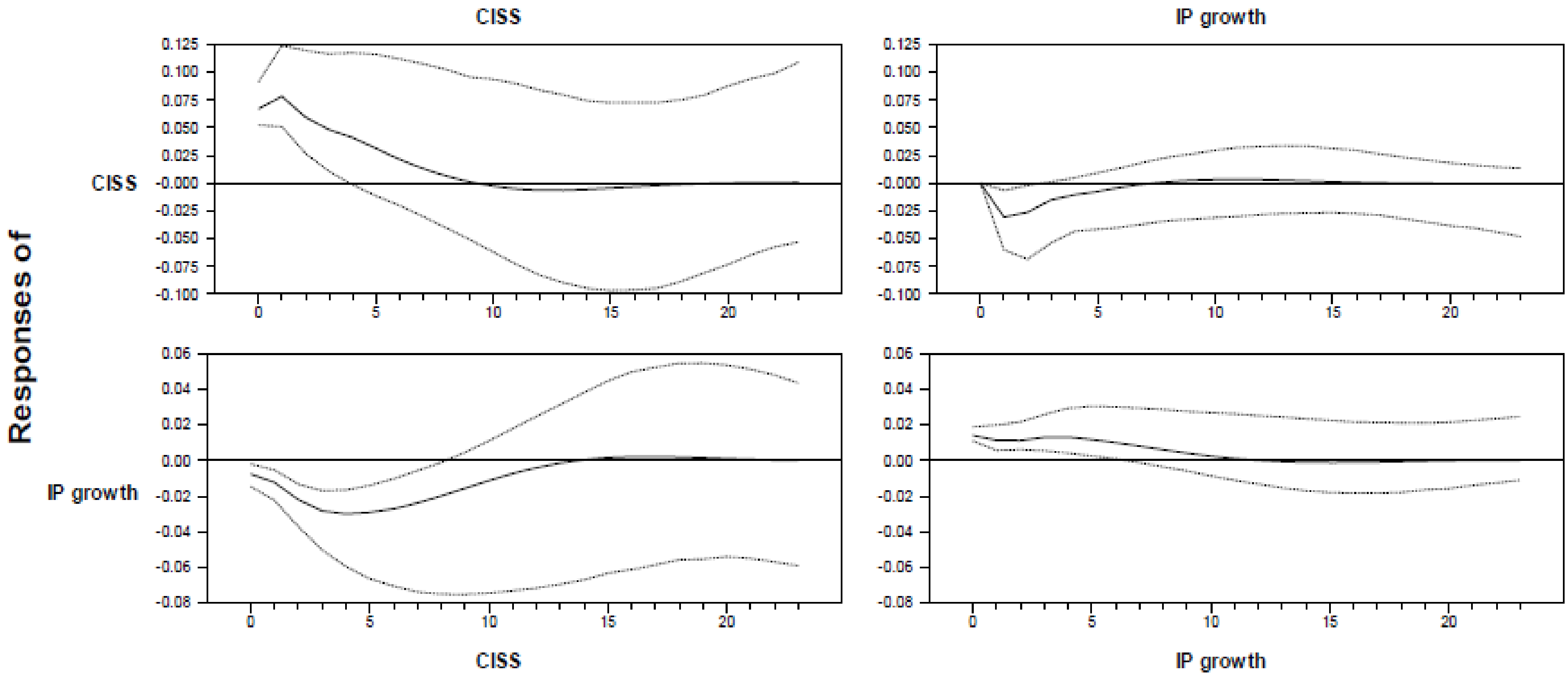
Notes: TVAR(2) denotes the bivariate threshold-VAR model with 2 lags, one threshold (two regimes) and the CISS and annual growth in industrial production for the euro area as endogenous variables. The chart plots the AIC against different potential threshold values for the CISS (with two lags). Monthly data from Jan. 1987 to June 2011.

4. Evaluation: Bivariate Threshold-VAR (cont'd)



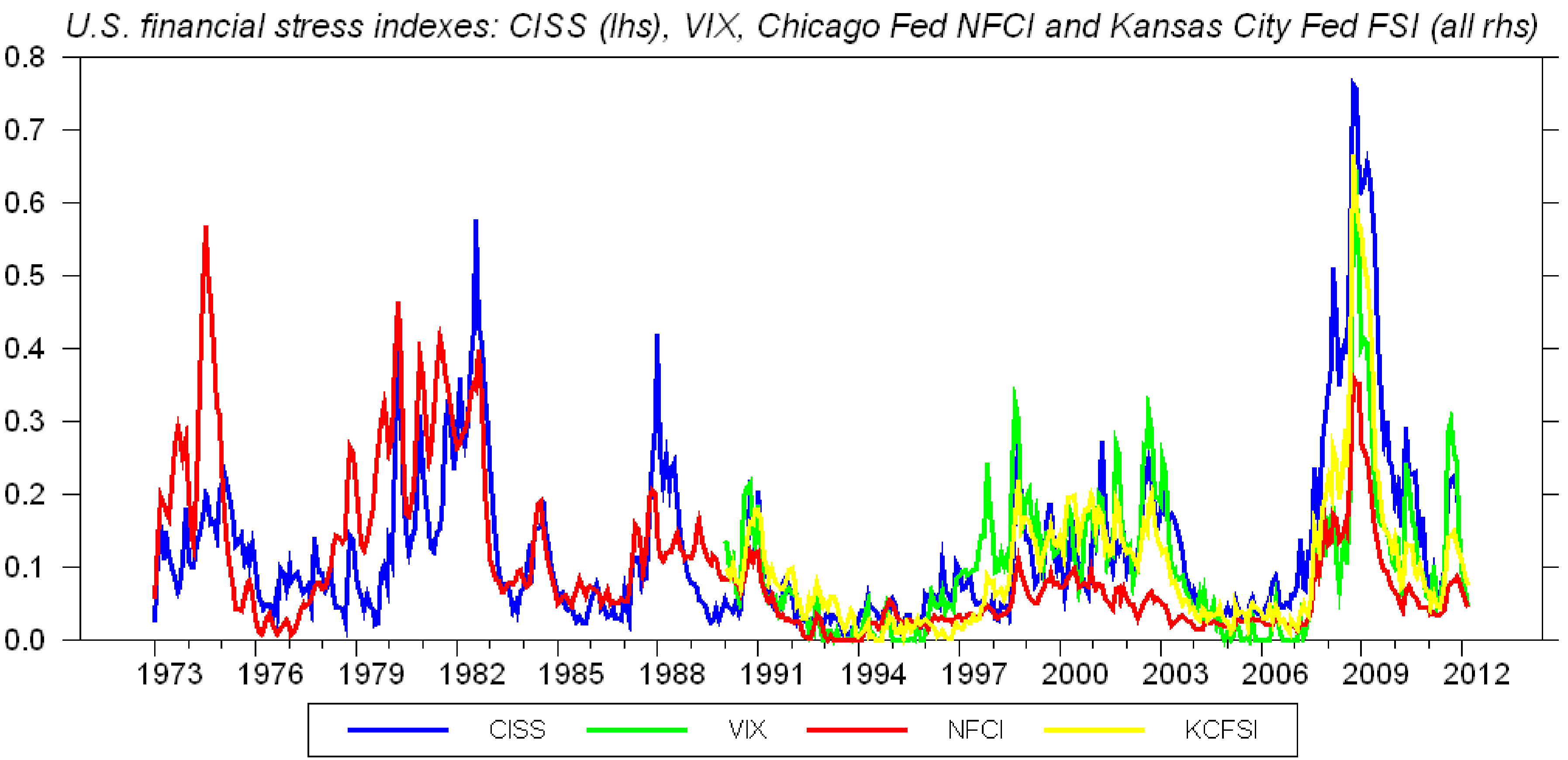
4. Evaluation: Bivariate Threshold-VAR (cont'd)

Fig. A.3. Impulse response functions from the TVAR(2) model for the high-stress regime



95% Monte Carlo error bands

5. Preliminary US CISS (cont'd)



Notes: Monthly data. VIX, NFCI and KCFSI standardised.