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NEW INSIGHTS ON THE US OIS SPREADS TERM STRUCTURE DURING THE RECENT FINANCIAL TURMOIL

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New Insights on the US OIS Spreads Term Structure During the Recent Financial Turmoil

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Abstract

The paper investigates the statistical features of the US OIS spreads term structure during the recent financial turmoil, originating from the subprime crisis and the ensuing euro area sovereign debt crisis. By means of a comprehensive econometric modeling strategy, new insights on US money market dynamics during the latter events are achieved. In particular, three common factors, bearing the interpretation of level, slope and curvature factors, are extracted from the term structure of US OIS spreads; the latter are found to convey additional information, relatively to commonly used credit risk measures like the TED or the BAA-AAA corporate spreads, which might be exploited, also within a composite indicator, for the construction of a macoreconomic risk barometer and macroeconomic forecasting.

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1 Introduction

The recent turbulence in money, credit and financial markets has raised some questions about the "controllability" by central banks of the term structure of interest rates. In fact, while central banks have generally kept close control of very-short term unsecured money market rates (i.e., for overnight interbank deposits) and were also able to keep a steady influence on some longer-term money market interest rates (i.e., overnight index swap rates and general collateral repo rates), they seemed at pain to steer the evolution of the term structure of unsecured money market rates (i.e., LIBOR rates), particularly in the early stages of the subprime crisis.

The role of *liquidity* and *counterparty (credit) risks,* in explaining money market spreads dynamics and their term structure, is a much debated issue in this respect. On the one side of the debate the subprime crisis has been seen as one of *banking solvency* (Taylor and Williams, 2009; Afonso et al., 2011); hence, liquidity interventions by the Fed during the crisis have been criticized for being either wrong or misguided and, at best, having had no effect. On the other side of the debate the crisis has been seen as evolving through various stages, being the initial stage marked mainly by *liquidity problems*, that subsequently "metastasized" into a solvency crisis; in this view, Fed liquidity injections have been seen as rather appropriate and successful (see McAndrews et al., 2008; Christensen, 2009; Christensen et al., 2009; Armantier et al., 2008; Wu, 2011; Frank and Hesse, 2009; Ait-Sahalia et al., 2012).

The paper contributes to the debate by assessing the empirical properties of the term structure of US LIBOR-OIS spreads (OIS spreads, thereafter), over the period May 6 2002 through August 3 2012. The time span investigated allows to gauge insights on risk dynamics not only during the early stages of the subprime crisis, but also over its post-crisis evolution, as well as during the recent euro area sovereign debt crisis.

As both LIBOR and OIS rates incorporate expectations of the average overnight rate until maturity, the latter cancel out when computing OIS spreads using rates of the same maturity. Then, if the resulting spreads are positive it is likely that this is due to counterparty risk, which is priced in the LIBOR rate but not in the OIS rate. Nevertheless, the spread is also likely to reflect liquidity funding/hoarding risk, as well as the state of investors *confidence*.[1] Overall, OIS spreads can be seen as indicators of

[1] If a bank has a rating downgrade its credit lines are tightened as a result, exposing it to higher financing risk; moreover, faced with larger uncertainty about the valuation of its own assets and the availability of longer-term funding, a bank would also be led to build up "excess reserves" (Allen et al., 2009; Caballero and Krishnamurthy, 2008). Moreover, a higher spread (higher LIBOR) might signal decreased willingness to lend by major banks,

banks'assessment of the creditworthiness of other financial institutions and liquidity conditions, and more generally as a measure of *stress conditions* in the interbank market.

The paper yields original contributions under different perspectives. Firstly, rather than focusing on a single maturity, i.e., the 3-month OIS spread (Taylor and Williams, 2009; Armantier et al., 2008; McAndrews et al., 2008; Wu, 2011; Olson et al., 2012; Ji and In, 2010), the entire OIS spreads term structure is investigated. Secondly, US money market dynamics are assessed not only over the subprime crisis period, but also over the recent euro area sovereign debt crisis. Thirdly, modeling is performed by means of a comprehensive approach, allowing for changing first and second unconditional moments, as well as long memory and breaks in persistence; as shown by the empirical analysis, accurate modeling of the persistence properties of US OIS spreads and the understanding of the effects of the recent financial crises do require the econometric strategy employed.[2]

In particular, three common components, bearing the interpretation of *level*, *slope* and *curvature* factors, can be extracted from the US OIS spreads term structure; the latter are characterized by a deterministic trend component (break process) and strongly persistent and heteroskedastic fluctuations about trend (long memory cyclical component); two common break processes, describing the long-term evolution of OIS spreads conditional variances, bearing the interpretation of *level* and *slope* factors for the volatility term structure, are also found.

Moreover, the two waves of money market stress, associated with the BNP Paribas episode in August 2007 and Lehman Brothers bankruptcy in September 2008, respectively, have lead to a wide increase in both the mean and variance OIS spreads trend levels and to a sizable increase in the persistence of money market shocks, as well as to stronger comovement along the term structure, due to increased relevance of level factor shocks; while at the short-end of the term structure mean trend components have progressively converged back to pre-crisis levels since December 2008, fluctuations about much higher values, than prevailing before the crisis, can be noted at its medium- to long-end, also over the post-subprime crisis period; differently, a contraction in volatility below pre-crisis levels, yet a further increase in persistence of money market shocks, can be found over the post-crisis period for all maturities. A sizable increase in OIS spreads mean trend levels at the medium- to long-end of the term structure can finally be associated with

while a lower spread might signal a more liquid interbank market.

[2] See also Frank and Hesse (2009) and Olson et al. (2012) for the modeling of changing unconditional moments in OIS spreads during the subprime crisis, by means of regime switching in mean and variance and discontinuous shifts in mean only, respectively.

the spillover of the euro area sovereign debt crisis to the Italian economy in September 2011.

By comparing the forward-looking properties of the OIS spreads term structure factors with alternative measures of credit/liquidity risk and financial fragility, the former are found to convey additional information, relatively to commonly used measures like the TED or the BAA-AAA corporate spreads, which might be exploited, also within a composite indicator, for macroeconomic risk forecasting.

To our knowledge no such an in depth study on the consequences of the subprime and euro area sovereign debt crises on the US money market has so far been contributed in the literature; the originality of the paper stems from its focus on the entire OIS spreads term structure and assessment of its information content for macroeconomic risk prediction; the time span investigated, covering also the euro area sovereign debt crisis, neglected in the US OIS spreads literature so far; the econometric strategy employed, allowing for an accurate understanding of the consequences of the recent financial crises on the US interbank market.

After this introduction, the paper is organized as follows. In Section 2 the econometric methodology is presented, while in Sections 3 and 4 the empirical investigation of US money market dynamics during the subprime and the euro area sovereign debt crises is performed; the information content of the OIS spreads term structure, for macroeconomic risk prediction, is also assessed in Section 4; finally, conclusions are drawn in Section 5.

2 The FI-HF-VAR model

Following Morana (2011), consider the fractionally integrated heteroskedastic factor vector autoregressive (FI-HF-VAR) model

$$\begin{aligned} x_t - \Lambda_\mu \mu_t - \Lambda_f f_t &= C(L)(x_{t-1} - \Lambda_\mu \mu_{t-1} - \Lambda_f f_{t-1}) + v_t && (1) \\ v_t &\sim iid(0, \Sigma_v) \\ P(L)D(L)f_t &= \eta_t = H_t^{1/2}\psi_t && (2) \\ \psi_t &\sim iid(0, I_R), \end{aligned}$$

where x_t in (1) is a $N \times 1$ vector of real valued integrated and heteroskedastic processes subject to structural breaks, $t = 1, ..., T$, in deviation from the unobserved common deterministic (μ_t) and stochastic (f_t) factors, $C(L) \equiv C_0 L^0 + C_1 L + C_2 L^2 + ... + C_s L^s$ is a finite order matrix of polynomials in the lag operator with all the roots outside the unit circle, C_j, $j = 0, .., s$, is a square matrix of coefficients of order N and v_t is a $N \times 1$ vector of zero mean idiosyncratic i.i.d. shocks, with contemporaneous covariance matrix Σ_v.[3]

The vector of common break processes μ_t is $M \times 1$, with $M \leq N$, and $N \times M$ matrix of loadings Λ_μ; the latter are assumed to be of unknown form, measuring recurrent or non recurrent changes in mean, with smooth or abrupt transition across regimes; the generic element in μ_t is $\mu_{i,t} \equiv z_{\mu,i}(t)$, where $z_{\mu,i}(t), i = 1, ..., M$, is a bounded function of the time index t, $t = 1, ..., T$.[4]

The vector of fractionally integrated and heteroskedastic common factors f_t is $R \times 1$, with $R \leq N$, and $N \times R$ matrix of loadings Λ_f; the integration order is d_i in mean and b_i in variance, with $0 \leq d_i \leq 1$, $0 \leq b_i \leq 1$, $i = 1, ..., R$; f_t is also assumed to be orthogonal to μ_t.

Moreover, $P(L) \equiv I_R - P_1 L - P_2 L^2 - ... - P_u L^u$ in (2) is a finite order matrix of polynomials in the lag operator with all the roots outside the unit circle, P_j, $j = 1, .., u$, is a square matrix of coefficients of order R; ψ_t is a $R \times 1$ vector of common zero mean i.i.d. shocks, with identity covariance matrix I_R, $E[\psi_{it} v_{js}] = 0$ all i, j, t, s, respectively; $D(L)$ is a $R \times R$ diagonal matrix in the lag operator, specified according to the integration order (in mean) of the common stochastic factors, i.e.,

$$D(L) \equiv diag\left\{(1-L)^{d_1}, (1-L)^{d_2}, ..., (1-L)^{d_R}\right\},$$

where $(1-L)^{d_i}$, $0 < d_i < 1$, is the fractional differencing operator[5].

Hence, the specification in (2) then also allows for short-term dynamics driving the common long memory factors, i.e., for a short memory vector autoregressive (VAR) structure, defined by $P(L)$, driving the fractionally differenced long memory factors $(D(L)f_t)$.

According to the specification in (1) and (2), OIS spreads (x_t) are then assumed to show two types of persistence, i.e., deterministic, as determined by the break processes (μ_t), as well as stochastic, as determined by the long memory components (f_t). As shown by the empirical analysis, both components are relavant for the modeling of OIS spreads level, slope and curvature features (see next section).

[3] v_t is assumed coherent with the condition of weak cross-sectional correlation stated in Bai (2003; Assumption E, p.143).

[4] $z_{\mu,i}(t)$ may be continuos, as yield by the Fourier expansion employed in Baillie and Morana (2012, 2013), i.e., $z_{\mu,i}(t) = \sum_{j=1}^{J} \delta_{i,j} \sin(2\pi jt/T) + \gamma_{i,j} \cos(2\pi jt/T)$, or discontinuous, i.e., $z_{\mu,i}(t) = z_1$, $0 \leq t \leq T_1$, $z_{\mu,i}(t) = z_2$, $T_1 + 1 \leq t \leq T_2$, ..., as in Bai and Perron (1998). Markow switching mechanisms, thresholds models and spline functions may also be employed. See Morana (2011) for details.

[5] See Baillie (1996) for an introduction to long memory processes.

Given the assumption of time-varying conditional covariance matrix $H_t \equiv Var(f_t|\Omega_{t-1})$, where Ω_{t-1} is the information set available at time period $t-1$, the common long memory factors also show non linear dependence. Following Bollerslev (1990) and Brunetti and Gilbert (2000), a constant conditional correlation (CCC) model is assumed for H_t, i.e., $H_t \equiv diag\left\{h_{1,t}, h_{2,t}, ..., h_{R,t}\right\}$; the ith generic element along the main diagonal of H_t has a $FIGARCH(1, b_i, 1)$ (Baillie et al., 1996) structure

$$(1 - \beta_i L)h_{i,t} = w_{i,t} + \left[1 - \beta_i L - (1 - \alpha_i L - \beta_i L)(1 - L)^{b_i}\right] \eta^2_{i,t}, \qquad (3)$$

where $\alpha_i + \beta_i < 1$, $0 < b_i < 1$, $w_{i,t} > 0$ for any t. The model in (3) is non standard, given the time-varying intercept $w_{i,t}$, allowing for the modeling of structural breaks in variance; similarly to the mean part of the model, the latter is assumed to be of unknown form, measuring recurrent or non recurrent changes in variance, with smooth or abrupt transition across regimes; then, $w_{i,t} \equiv z_{h,i}(t)$, where $z_{h,i}(t)$ is a bounded continuous or discontinuous function of the time index t, $t = 1, ..., T$.[6] As the unconditional variance is not defined for the $FIGARCH$ model, the component $w^*_{i,t} = \dfrac{w_{i,t}}{1-\beta_i}$, i.e., the break in variance process, then bears the interpretation of long-term conditional variance level. Sufficient conditions for non negativity of the conditional variance process at each point in time are available from various contributions; see Morana (2011) for details.

Estimation of the model is performed by means of an iterative procedure, bearing the interpretation of QML, implemented by means of the Expectation-Maximization algorithm (Dempster et al., 1977), yielding therefore consistent and asymptotically normal estimates. See Morana (2011) for details on the estimation procedure.

2.1 The VMA representation

The reduced form vector moving average representation (VMA) of the FI-HF-VAR model can be computed after estimation, yielding

$$(1 - L)\left(x_t - \Lambda_\mu \mu_t\right) = G(L)^+ \eta_t + F(L)^+ v_t, \qquad (4)$$

where $G(L)^+ \equiv \Lambda_f (1 - L) P(L)^{-1}$ and $F(L)^+ \equiv (1 - L)\left[I - C(L)L\right]^{-1}$.

The structural VMA representation can then be written as

[6] $z_{h,i}(t)$ may be specified according to various functional forms, similarly to $z_{\mu,i}(t)$. See Morana (2010) for details.

$$(1-L)(x_t - \Lambda_\mu \mu_t) = G^{\circ}(L)\xi_t + F^{\circ}(L)\varrho_t, \tag{5}$$

where $G^{\circ}(L) = G^{+}(L)H^{-1}$, $F^{\circ}(L) = F(L)^{+}\Theta^{-1}$ and $E\left[\varrho_{i,t}\xi'_{j,t}\right] = 0$ any i, j; $\xi_t = H\eta_t$ and $\varrho_t = \Theta v_t$.

The estimation of the H^{-1} and Θ^{-1} matrices, and therefore the identification of the common (ξ_t) and idiosyncratic (ϱ_t) structural shocks, can be performed by means of the Choleski decomposition of the contemporaneous variance covariance matrices $\hat{\Sigma}_{\hat{\eta}}$ and $\hat{\Sigma}_{\hat{v}}$. See Section 4 for details.

3 LIBOR-OIS spreads: empirical properties

The empirical properties of term structure of US LIBOR-OIS spreads (OIS spreads)[7] are assessed over the period May 6 2002 through August 3 2012. One- and two-week and one- through twelve-month maturities, for a total of 14 time series and 2675 working days, are considered. The data source is REUTERS.

The empirical analysis is structured as follows.

i) **Persistence analysis.** Firstly, structural break tests are carried out on the OIS spreads level series (x_t) and on (a proxy for) their volatility ($|\Delta x_t|$); based on the outcome, a structural break process is estimated for each series ($\hat{b}_{i,t}$, $\hat{c}_{i,t}$; $i = 1, ..., N$) and break-free OIS spreads computed ($\hat{l}_{i,t} = x_{i,t} - \hat{b}_{i,t}$; $\hat{v}_{i,t} = |\Delta x_{i,t}| - \hat{c}_{i,t}$); long-memory analysis is then performed using the break-free series, as well as the actual processes.

ii) **Copersistence analysis.** Commonalities across the OIS spreads term structure are then assessed by means of principal components analysis (PCA), carried out using the estimated break ($\hat{b}_{i,t}$, $\hat{c}_{i,t}$) and break-free ($\hat{l}_{i,t}$, $\hat{v}_{i,t}$) processes; at this stage, long memory analysis is performed on the common stochastic factors as well. Based on the findings, a decomposition in level, slope and curvature factors is also proposed. In addition to insights on common features characterizing the OIS spreads levels and volatilities, copersistence analysis yields an initial estimate of μ_t and f_t to be employed in the iterative procedure followed for the estimation of the FI-HF-VAR model.

[7] LIBOR is the acronym for London interbank offered rate; LIBOR rates are the floating rates of interest that banks apply to lend money to each other at various maturities. OIS is the acronym for Overnight Index Swap; OIS rates are the fixed rates of swaps contracts for various maturities, whereby one party to the contract pays the fixed rate and in exchange receives the average overnight interest rate over the maturity of the contract. US OIS spreads are then based on LIBOR Eurodollar rates and OIS rates derived from the Federal Reserve's Fed Funds rate.

iii) **Estimation of the FI-HF-VAR model.** Grounded on the evidence of common breaks and long memory factors in mean and variance, provided in *ii*) above, the FI-HF-VAR model is specified and estimated; policy analysis is then performed to gauge further insights on the behavior of the US money market during the recent financial turmoil, complementing the evidence provided in *i*); the information content of the proposed OIS spreads decomposition, concerning the prediction of macroeconomic risk, is then finally assessed.

3.1 Testing for structural breaks

The structural break analysis is performed using the Bai and Perron (1998) $UD_{\max}$ test, implemented on OIS spreads sampled at different frequencies;[8] firstly, structural break tests are carried out using (calendar) monthly data and the number and location of breaks determined also by means of information criteria (BIC, LWZ); this implies that no regimes lasting less then twenty/twenty-three working days are estimated. Then, in order to refine the estimated breaks location, the $UD_{\max}$ test is performed using daily observations, within a range centered about the break-point determined by the monthly data analysis. The results of the structural breaks analysis are reported in Table 1 (column 1-2, Panel A and B) for both OIS spread levels ($x_{i,t}$: x_t^{1w}, ..., x_t^{12m}) and volatilities ($|\Delta x_{i,t}|$); mean values for the daily OIS spread levels and volatilities, over the estimated regimes, are also reported (column 3-8, Panel A; column 3-5, Panel B).

3.1.1 OIS spread levels

As shown in Table 1 (Panel A), following the BNP Paribas episode on August 8 2007[9], daily OIS spreads increased sizably, from 7-13b.p. to 40-78b.p., on average, climbing even further following Lehman Brothers bankruptcy on September 15 2008, i.e., up to 272-354b.p. over October 8-13 2008 (144-230b.p. on average, over September through December 2008).

The disruption brought by the latter events is confirmed by the Bai-Perron tests, pointing to a first break point, located between August 9 and 14 2007, depending on maturity, as well as to a second break point, located between September 16 and 19 2008. The findings are then consistent with

[8] Validity of the Bai-Perron tests for the long memory case is discussed in Levielle and Moulines (2000). We also explicitly assess the validity of the candidate break process by relying on Granger and Hyung (2004). See below for details.

[9] On August 8 2007 BNP Paribas closed two of its investment funds exposed to subprime mortgage risk.

results of Cassola and Morana (2012) for the euro area, and Olson et al. (2012) for the US and other OECD countries.

Dating the resolution of the subprime crisis is less clear-cut. In the face of major difficulties in the banking sector in the US and Europe, various forms of liquidity injection and unconventional monetary policy measures were taken by central banks, aiming at defreezing the interbank and credit markets, and easing the banking sector from the burden of unperforming loans, as well as to facilitate its recapitalization, supported by governments interventions.[10]

Starting from mid-October 2008, OIS spreads have then progressively narrowed, albeit at a quicker pace for shorter than longer maturities: the Bai-Perron tests actually point to a third break point, located between December 9 and 12 2008 for the 1- and 2-week and 1-month rates, and on December 17 2008 for the remaining maturities. For shorter maturities, a reversal to pre-crisis values can then be found since mid-December 2008, persisting through the end of the sample (August 3 2012); differently, only a sizable contraction can be noted for longer maturities, which have kept fluctuating about much higher values than those prevailing before the crisis (12/2008-8/2009: 22-143b.p.; 9/2009-5/2011: 12-64b.p.; 6/2011-8/2012: 24-90b.p.). Overall, the latter evidence is consistent with Fed's non standard policy interventions being successful in defreezing the interbank market and recovering control over the interest rate transmission mechanism.

As pointed by the Bai-Perron tests, the post-subprime crisis period is marked by two additional break points, yet affecting maturities beyond 1-month only.

The fourth break point is then located between August 24 and September 11 2009, according to maturity. Following the end of the US recession (June 2009, according to the NBER's Business Cycle Dating Committee), a sizable contraction in OIS spread levels, to 12-64b.p. on average (from 22-143b.p.), can be noted, lasting until the spillover of the euro area sovereign debt crisis to Italy.[11]

[10] See Brunnermeier (2009) and Acharya and Richardson (2009) for an assessment of the US subprime crisis. See Veronesi and Zingales (2009) and Bianco (2012) for a summary of government measures in support of the US banking system. See also Krishnamurthy and Vissing-Jorgensen (2011), D'Amico et al. (2012) and Fratzscher et al. (2012) for an account of the effects of the quantitative easing policy implemented by the Fed in 2008-2009 and 2010-2011, as well as Reis (2009).

[11] Some relevant events along the EMU sovereign debt crisis time-line are as follows: April 11 2010, when EMU leaders agreed on a € 30 billion bailout plan for Greece; April 27 2010, when S&P dowgraded Greece debt below investment rating and Portugues debt two notches, also issuing a negative outlook; April 28 2010, when S&P downgraded Spain debt to AA-; May 8 2010, when EMU leaders agreed on a € 100 billion bailout plan

The fifth break point is actually located between September 6 and 12 2011, according to maturity, then anticipating of few days S&P's downgrading of Italian public debt on September 19 2011; the spillover of the euro area crisis to Italy then marks the beginning of a new regime of rising OIS spread levels, up to 24-90b.p. on average until the end of the sample (some reversion to lower values can however be noted starting in June 2012).

Overall, four regimes can then be detected at the short-end of the OIS spread levels term structure (1-week to 1-month), i.e., *pre-subprime crisis*, *subprime crisis I* (Pre-Lehman), *subprime crisis II* (Post-Lehman) and *post-subprime crisis*. Differently, six regimes can be selected for longer maturities, as the post-crisis regime can be further decomposed into three subperiods, i.e., *post-crisis I* (ongoing US recession), *post-crisis II* (post-US recession), *post-crisis III* (spillover of the euro area sovereign debt crisis to Italy).

3.1.2 OIS spreads volatilities

Differently, as shown in Table 1 (Panel B), two break points are detected by the Bai-Perron tests for the OIS spread volatility proxies[12], located in July 25/August 2 2007 and December 22 2008/February 11 2009, respectively; consistent with the results of the structural break analysis for the OIS spreads level series, the detected break points are then related to the beginning and the end of the subprime crisis. A sizable increase in daily OIS spreads volatility can in fact be measured over the subprime crisis period, rising from 1-4b.p. to 5-8b.p., on average; a contraction is then detected over the post-subprime crisis period, average volatility falling to 0.5-1.4 b.p, i.e., to even smaller values than what observed before the turmoil. The latter finding may be taken as a further evidence of the success of Fed's policies in leading to the exit from the subprime turmoil.

Hence, three regimes can be selected for the OIS spreads volatility series, corresponding to the *pre-subprime crisis*, *subprime crisis*, and *post-subprime crisis*, independently of the maturity.

for Greece; November 22 2010, when Ireland accepted the EMU-IMF bailout package; September 19 2011, when S&P downgraded Italy's public debt one notch from A to A-, October 13 2011, when S&P downgraded Spain's public debt one notch from AA to AA-, November 25 2011, when S&P downgraded Belgium's public debt one notch from AA+ to AA, January 13 2012, when S&P downgraded Italy's public debt two notches to BBB+, as well as public debt for France, Austria, Spain and other five euro area members, maintaining AAA rating only for Finland, Germany, Luxembourg and the Netherlands. See De Santis (2012) for an account of the euro area sovereign debt crisis.

[12] Monthly volatility figures have been obtained by means of the realized volatility estimator, computed using calendar month daily observations.

3.1.3 Estimation of the structural break process

Candidate break processes are estimated by means of an OLS regression of each OIS spread level series ($x_{i,t}$: $x_t^{1w}, ..., x_t^{12m}$) on dummies ($D_{m,j}$, $j = 1, .., k$) computed according to the findings of the structural break analysis; the regression functions are then specified as follows

$$\begin{aligned} x_{i,t} &= b_{i,t} + e_{i,t} \quad i = 1, ..., 14 \\ b_{i,t} &= \alpha_{i,0} + \sum_{j=1}^{k} \alpha_{i,j} D_{m,j,t} + \sum_{j=1}^{k} \gamma_{i,j} \left(D_{m,j,t} * T_t \right), \end{aligned} \tag{6}$$

where $k = 3, 5$, according to maturity. In particular, $D_{m,1}$ is a (first financial stress wave) step dummy variable with unity value over the period August 9/14 2007 through August 3 2012 inclusive, $D_{m,2}$ is a (second financial stress wave) step dummy variable with unity value over the period September 16/19 2008 through August 3 2012 inclusive, $D_{m,3}$ is a (first financial stress resolution) step dummy variable with unity value over the period December 9/18 2008 through August 3 2012 inclusive, $D_{m,4}$ is a (second financial/economic stress resolution) step dummy variable with unity value over the period August 24/September 11 2009 through August 3 2012 inclusive, $D_{m,5}$ is a (euro area crisis spillover) step dummy variable with unity value over the period September 6/12 2011 through August 3 2012 inclusive. The above dummies have also been interacted with a linear time trend ($T_t = 1, 2, ..., 2675$).

Similar regressions are performed using the volatility proxies

$$\begin{aligned} |\Delta x_{i,t}| &= c_{i,t} + u_{i,t} \quad i = 1, ..., 14 \\ c_{i,t} &= \beta_{i,0} + \sum_{j=1}^{q} \beta_{i,j} D_{v,j,t}, \end{aligned} \tag{7}$$

where $q = 2$ for all the OIS spreads maturities. For the latter case $D_{v,1}$ is a (financial stress wave) step dummy variable with unity value over the period July 25/August 2 2007 to August 3 2012 inclusive, $D_{v,2}$ is a (financial stress resolution) step dummy variable with unity value over the period December 22 2008/February 9 2009 to August 3 2012 inclusive.

An exponential smoother is applied to the estimated break processes $\hat{b}_{i,t}$ and $\hat{c}_{i,t}$, in order to yield smooth transition across regimes; this is consistent with data properties, suggesting smooth, yet rapid, transitions across regimes.

The smoothing parameter p in

$$k_{s,i,t} = pk_{s,i,t-1} + (1-p)k_{i,t} \quad i = 1, ..., 14 \quad t = 1, ..., T, \tag{8}$$

where $k_{i,t} = \hat{b}_{i,t}, \hat{c}_{i,t}$ is the generic break process to be smoothed and $k_{s,i,t} = \hat{b}_{s,i,t}, \hat{c}_{s,i,t}$ its smoothed estimate, is then selected in order to best fit (R^2) the transition across regimes to actual data. This yields $p = 0.69$ for the OIS spread level series and $p = 0.51$ for the OIS spread volatility series. Validation of the estimated candidate break processes is performed by assessing the long memory properties of the corresponding OIS spread break-free series (see below).

3.1.4 Testing and estimation of common break processes

As similarities concerning breaks location can be detected along the OIS spread level and volatility term structure, Principal Components Analysis (PCA) is then implemented on the estimated break processes, levels ($\hat{b}_{s,i,t}$) and volatilities ($\hat{c}_{s,i,t}$), in order to test for and estimating common deterministic factors.

As shown in Table 1 (Panel A), the first principal component (PC) extracted from the estimated break level processes ($\hat{b}_{s,i,t}$) accounts for about 95% of total variance, 80% of the variance for the 2-month and longer maturities, and 50% of the variance for shorter maturities (column 9); the second PC accounts for a residual 4% of total variance, yet for about 40% of the variance for the 1- and 2-week and 1-month maturities (column 10); moreover, the third PC accounts for residual commonalities (10%) involving the very short-end of the term structure (1- and 2-week rate; column 11).

According to the estimated loadings (column 12-14), the latter components bear the interpretation of *level*, *slope* and *curvature* (break) factors, respectively, for the OIS spread level term structure; in fact, the loadings of the first factor have all the same sign, while opposite sign at the short- and long-end of the term structure can be noted for the loadings of the second factor; moreover, the same sign at the short- and long-end of the term structure, yet opposite sign for intermediate maturities, can be noted for the loadings of the third factor.

Differently, 100% of total variance is accounted for by the first two PCs extracted from the volatility break processes ($\hat{c}_{s,i,t}$) (Panel B); the latter explain 96% and 4% of total variance, respectively; while the former component accounts for a proportion of variance in the range 70%-99% for each maturity (column 6), the second PC accounts for up to 30% of the variance for maturities at the short-end of the volatility term structure (1- and 2-week and

1-month; column 7). According to their estimated loadings (column 9-10), an interpretation in terms of (break) *level* and *slope* factors, respectively, for the OIS spread volatility term structure, can then be provided to the latter common components.

3.2 Long memory analysis

Due to structural change in variance, normalized break-free OIS spread level series are computed, i.e., $\hat{l}_{i,t} = \frac{x_{i,t}-\hat{b}_{s,i,t}}{\hat{\sigma}_{i,t}}$, where $\hat{\sigma}_{i,t}$ is the estimated unconditional standard deviation for the break-free series over the three selected volatility regimes, i.e., $\hat{\sigma}_{i,t} = \hat{\sigma}_1$ over the period May 6 2002 through July 25/August 2 2007, according to maturity; $\hat{\sigma}_{i,t} = \hat{\sigma}_2$ over the period July 26/August 3 2007 through December 22 2008/February 9 2009; $\hat{\sigma}_{i,t} = \hat{\sigma}_3$ over the period December 23 2008/February 10 2009 through August 3 2012.

Long memory analysis is then performed for both the actual ($x_{i,t}$) and break-free ($\hat{l}_{i,t}$) level series, using the broad band log-periodogram estimator (BBLP) of the fractional differencing parameter proposed by Moulines and Soulier (1999); additional testing is performed by means of the Dolado et al. (2005) augmented Dickey-Fuller test (DGM) and the Shimotsu (2006) KPSS test (SKPSS), both modified to account for the estimated non linear (smoothed) break processes, and the LM-test proposed by Demetrescu et al. (2006) (LM). As the DGM and SKPSS tests have a non standard distribution under the null hypothesis, critical values are obtained through Monte Carlo simulation. A similar analysis is carried out for the volatility proxies, both actual ($|\Delta x_{i,t}|$) and break-free ($\hat{v}_{i,t} = |\Delta x_{i,t}| - \hat{c}_{s,i,t}$).

As shown in Table 2, Panel A (column 1-2), strong persistence can be found for the OIS spread level series, both actual and break-free; the BBLP estimated fractional differencing parameter is in the range 0.85 to 1.10 and 0.46 to 0.69, for the actual and break-free series, respectively.

A hump-shaped profile can be noted in the cross-section of persistence, the latter increasing with maturity up to the two-month horizon and decreasing thereafter. The null hypothesis of constant persistence across maturities, i.e., $H_0 : d_1 = ... = d_N = \bar{d}$, $N = 14$, versus $H_1 : H_0$ is incorrect, where $\bar{d}$ is the mean value of the estimates of the fractional differencing parameter across maturities, is then tested by means of the Wald test statistic

$$\hat{W}_f = \left(T\hat{d}\right)^{-1} (T\Lambda T')^{-1} \left(T\hat{d}\right), \tag{9}$$

similarly to Ohanissian et al. (2008), where $\hat{d} = \begin{pmatrix} \hat{d}_1 & ... & \hat{d}_N \end{pmatrix}'$ is the multivariate BBLP estimator, $\Lambda = diag \begin{pmatrix} \sigma^2_{\hat{d}_1} & \cdots & \sigma^2_{\hat{d}_N} \end{pmatrix}$ its asymptotic variance-covariance matrix, and

$$\underset{(N-1,N)}{T} = \begin{pmatrix} 1-\frac{1}{N} & -\frac{1}{N} & -\frac{1}{N} & \cdots & -\frac{1}{N} & -\frac{1}{N} \\ -\frac{1}{N} & 1-\frac{1}{N} & -\frac{1}{N} & \cdots & -\frac{1}{N} & -\frac{1}{N} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ -\frac{1}{N} & -\frac{1}{N} & -\frac{1}{N} & \cdots & 1-\frac{1}{N} & -\frac{1}{N} \end{pmatrix},$$

yielding a clear-cut rejection for both the actual and break-free OIS spreads (the Wald tests are 37.2 and 50.4, respectively; column 1-2, last row).

Moreover, validation of the estimated break processes is provided by the DGM, DKH and SKPSS tests, as the null hypothesis of long memory is never rejected at the 1% level by the DKH and DGM tests, while the null of I(0) plus non linear break process is always rejected by the SKPSS test at the 1% level (column 3-5). The results of the tests are then coherent with the findings of long memory for the break-free series, as antipersistence ($-0.5 < \hat{d}_i < 0$) is induced by the removal of a spurious break process (Granger and Hyung, 2004).

As shown in Table 2, Panel B, long memory can also be detected for the volatility series, both actual and break-free (column 1-2); the estimated fractional differencing parameter is in the range 0.31-0.41 and 0.16-0.26, for the actual and break-free series, respectively, and not statistically different across maturities (column 1-2, last row). Coherently, genuine structural change and long memory is pointed out by the DGM, SKPSS and DKH tests, at the 1% level as well (column 3-5).

3.2.1 Testing and estimation of common long memory factors

Principal components analysis is then employed to assess the presence of common long memory factors driving break-free OIS spread levels and volatilities ($\hat{l}_{i,t}$: $\hat{l}_t^{1w}$, ..., $\hat{l}_t^{12m}$; $\hat{v}_{i,t}$: $\hat{v}_t^{1w}$, ..., $\hat{v}_t^{12m}$).

As shown in Table 2, Panel A (column 6-8), the first three PCs extracted from the break-free OIS spread level series ($\hat{l}_{i,t}$) jointly account for over 95% of total variance, i.e., 79%, 12% and 5%, respectively; the first PC also accounts for a sizable fraction of variance for all the maturities (column 6), i.e., over 80% for the 2-month and longer maturities, and 30%-50% for shorter maturities (1- and 2-week and 1-month); differently, the second PC accounts for common fluctuations at the very short-end of the term structure, i.e., 30%-50% of variance for the 1- and 2-week and the 1-month OIS spreads (column 7); moreover, the third PC accounts for residual commonalities, 10%-20% involving intermediate maturities (2- and 3-month OIS spreads; column 8).

According to the estimated factor loadings (column 9-11), similar to what found for the mean break processes, an interpretation in terms of *level*, *slope* and *curvature* (break-free) factors, respectively, for the OIS spread level term structure, can be provided to the estimated PCs. In fact, the loadings for the first PC all have the same sign, while loadings with opposite sign at the short- and long-end of the term structure can be detected for the second PC, and loadings with the same sign at the short- and long-end of the term structure, yet of opposite sign for intermediate maturities, can be noted for the third PC.

Consistent with the results for the individual break-free series, the three PCs also show long-memory, of similar degree, with average fractional differencing parameter equal to 0.53 (0.46-0.60), and not statistically different at the 1% level (the Wald test W_{ff} is equal to 6.15, which is computed as in (9), with $N = 3$; last row).

As shown in Table 2, Panel B, commonalities across the (break-free) volatility term structure can also be noted, as the first three PCs extracted from the volatility break-free series ($\hat{v}_{i,t}$) account for about 93% of their total variance, i.e., 62%, 24% and 7%, respectively (column 6-8); the latter evidence is consistent with the finding of three common long memory factors for the break-free OIS spread level series, which, according to ARCH tests, are strongly heteroskedastic (the p-value of the test is virtually zero for each of the factors; not reported). Moreover, also consistent with the findings for the OIS spread level series, the first PC accounts for about 70%-85% of variance for the 2-month and longer maturities, and 30%-50% for shorter maturities (column 6); the second PC for about 50% of variance for the 1- and 2-week maturities, and 10%-20% for the 8-month and longer maturities (column 7); the third PC for about 20% of variance for intermediate maturities, i.e., within the 1- through 4-month interval (column 8). As can be gauged from the estimated loadings (column 9-11), the estimated PCs bear the interpretation of *level*, *slope* and *curvature* (break-free) components for the OIS spreads volatility term structure.

Finally, consistent with the individual break-free series analysis, evidence of stationary long memory in volatility can be detected also for the estimated PCs, of similar degree, with fractional differencing parameter equal to 0.16 on average (0.12-0.19), and not statistically different across factors (the Wald test W_{ff} is equal to 1.92; last row).

3.2.2 Fractional differencing parameter constancy tests

Persistence stability over time has been investigated by splitting the sample in three regimes, i.e., pre-crisis, crisis and post crisis, consistent with the results of the structural breaks analysis carried out on the actual OIS spread level series. Hence, two permanent breaks in persistence are assumed, i.e., August 9 2007 and December 9 2008.

The null hypothesis of constant persistence across regimes $H_0 : d_{i,1} = ... = d_{i,N} = \bar{d}_i$, $i = 1, ..., 14$, $N = 3$, versus $H_1 : H_0$ is incorrect, is tested by means of the Wald test in (9), where $\bar{d}_i$ is the mean value of the estimates of the fractional differencing parameter across regimes for the ith break-free OIS spread series, yielding the statistic $\hat{W}_{i,3}$, $i = 1, ..., 14$.

A Wald test is also employed to test the null hypothesis of equal fractional differencing parameter across the OIS spreads term structure for each of the three subsamples determined according to the above scenario. The null hypothesis of constant persistence across series, for each regime, is again as in (9), with $i = 1, ..., 3$, $N = 14$, where $\bar{d}_i$ is the mean value of the estimates of the fractional differencing parameter across series in regime i; this yields the Wald test statistics $\hat{W}_{pre}$, $\hat{W}_c$ and $\hat{W}_{post}$ for the pre-crisis, crisis and post-crisis subsamples, respectively.

The analysis is similarly carried out for the estimated common factors, yielding the statistics $\hat{W}_{f,3}$ and $\hat{W}_{f,pre}$, $\hat{W}_{f,c}$ and $\hat{W}_{f,post}$.

As shown in Table 3, Panel A (column 1-3), there is strong evidence of temporal instability in the fractional differencing parameter for each of the break-free OIS spread level series. The null of constant persistence across regimes is rejected for each maturity, as the p-value of the $\hat{W}_{i,3}$ tests is virtually zero in all cases (column 4). Differently, while the null of equal fractional differencing parameter across the term structure is rejected for the pre-crisis period ($\hat{W}_{pre}$, column 1, last row), the latter is largely not rejected for the crisis and post-crisis regimes ($\hat{W}_c$ and $\hat{W}_{post}$; column 2-3, last row). Average estimates of the fractional differencing parameter across the term structure are 0.47, 0.55 and 0.93 for the pre-crisis, crisis and post-crisis periods, respectively.

Coherently, as shown in Panel B, long memory of similar and not statistically different degree is found across factors for each regime (column 1-3, last row). The estimated fractionally differencing parameter, on average across factors, is 0.40 (0.32-0.48), 0.65 (0.55-0.76) and 0.80 (0.73-0.87), for the pre-crisis, crisis, and post-crisis regime, respectively. Instability across regimes can also be detected for each common factor ($\hat{W}_{i,3}$, column 4), pointing to a statistically significant increase in persistence, from stationary long memory during the pre-crisis period to non-stationary long memory for the crisis/post-crisis periods.

To assess the robustness of the findings, the LM fractional differencing parameter constancy test of Hassler and Meller (2008, HM) is also implemented. The results reported in Table 3, Panel A and B, are for the test statistic computed with reference to the candidate break dates in the above scenario, i.e., August 9 2007 (column 5) and December 9 2008 (column 8), in addition to the two candidate break points endogenously selected by the HM test (column 6-7 and column 9-10). As shown in the Table, a first change in persistence can be detected for the various break-free OIS spread level series, taking place already in June 2007 for the 5- to 12-month maturities and in the aftermath of the subprime crisis (September 12 2007) for shorter maturities; the evidence is clear-cut (1% significance level) for all the maturities, apart from the very short-end of the term structure. A second change in persistence can then be detected, taking place after the selected end point for the crisis period (December 8 2008), i.e., in December 17 2008 for the 1- to 12-month maturities, and in February 7 2009 for the 1- and 2-week maturities. Similar dating can be noted for the common long memory factors, i.e., May-August 2007 and September 2008, for the first and second break-point respectively.

Differently, as shown in Table 4, Panel A-B, the null hypothesis of common degree of persistence, across the volatility term structure ($\hat{W}_{pre}$, $\hat{W}_{c}$ and $\hat{W}_{post}$) and common factors ($\hat{W}_{f,pre}$, $\hat{W}_{f,c}$ and $\hat{W}_{f,post}$) is never rejected at the 5% level for each regime (column 1-3, last row); similarly, no rejection of the null hypothesis of constant persistence across regimes is found for each maturity ($\hat{W}_{i,3}$) and factor ($\hat{W}_{f,3}$) (column 4). The evidence of persistence constancy across regimes is also confirmed by the HM test, which does not allow to reject the null of stability of the fractional differencing parameter, at any relevant significance level, for any maturity and factor (column 5-6, 8-9).

As a consequence of the subprime crisis, a sizable increase in persistence can then be detected along the whole OIS spread levels term structure, from stationary long memory for the pre-crisis regime, in general, to non stationary long memory for the crisis and post crisis regimes; money market disturbances are then taking longer to fade away than before the crisis.

4 Estimation of the FI-HF-VAR model

On the basis of the BIC information criterion, a sixth order diagonal VAR specification is selected for the $P(L)$ matrix in (2), with $D(L)$ matrix set according to the results of the long memory analysis; differently, a ninth order diagonal VAR specification is selected for the $C(L)$ matrix in (1) (Table 5, column 14, last row).[13] Moreover, the ith generic element along the main diagonal of the conditional variance-covariance matrix H_t in (2) is of the FIGARCH$(1, b_i, 1)$ type, augmented with a time-varying intercept; consistent with the findings of the structural break analysis, the latter shows a factor structure, with two common break processes in variance, i.e., the time-varying intercept component $w_{i,t}$ for the ith generic conditional variance process is specified as

$$w_{i,t} = \begin{bmatrix} \Lambda_{i,1} & \Lambda_{i,2} \end{bmatrix} \begin{bmatrix} g_{1,t} \\ g_{2,t} \end{bmatrix}, \qquad (10)$$

where the common break processes $g_{j,t}$ and factor loadings $\Lambda_{i,j}$, $j = 1, 2$, are also estimated by PCA, implemented within the iterative procedure followed for the maximization of the log-likelihood function. Also consistent with the structural break and common factor analysis, three common break processes and long memory factors in mean are allowed for.

As shown in Table 5, the final estimates of the common deterministic (column 4-6) and stochastic (column 1-3) factors obtained for the conditional mean model are comparable with their starting estimates (reported in Table 1-2, Panel A), both in terms of proportion of explained variance, total and for each series, as well as in terms of their interpretation as level, slope and curvature break and break-free components, respectively.

In fact, the first PCs account for the bulk of total variance for the (non-normalized) break-free OIS spread level series (75%; column 1) and estimated break processes (95%; column 4), and for over 70% of the variance for the 2-month and longer maturities and 40%-60% for shorter maturities (1- and 2-week and 1-month) in both cases; the latter components are loaded with the same sign across the term structure, consistent with their *level* factor interpretation (trend: break process; persistent deviation about trend: long memory component; column 7 and 10).

Moreover, the second PCs account for residual 14% and 4% of total variance for the break-free series and estimated break processes, respectively, yet explaining a sizable proportion of variance for each of the shortest maturities, i.e., about 40% for the 1- and 2-week and 1-month OIS spreads (columns 2 and 5) in both cases; the latter components are loaded with opposite signs at the short- and medium- to long-end of the term structure, consistent with their *slope* factor interpretation (column 8 and 11).

In addition, the third PCs account for residual commonalities involving some of the maturities at the short-end of the term structure only (about

[13] Results for the parameters in $C(L)$ and $P(L)$ are not reported for reasons of space, and are available upon request from the author.

10%) for both sets of series; the latter components are loaded with opposite signs at the short-/long- and medium-end of the term structure, consistent with their *curvature* factor interpretation (column 9 and 12).

By adding to the estimated common long memory factors conditional mean, obtained from (2), the corresponding estimated common break process, the overall estimate of the level, slope and curvature factors is then obtained; for instance, the level factor is computed by adding to the estimated conditional mean for the first common long memory factor the first estimated common break process; the slope and curvature factors are obtained analogously.

Also, the first two PCs extracted from the common long memory factors conditional variance break processes ($w_{i,t}$), consistent with the findings for the OIS spreads volatility proxies (reported in Table 1, Panel B), account for 100% of their total variance (column 14-15, first row); while the first PC explains 84%-99% of the variance for the level, slope and curvature factor *long-term* (*trend*) conditional variances, the second PC accounts for up to 16% of the variance for the level factor *long-term* conditional variance only (g_i, $i = 1, 2$, in column 14-16). According to their estimated loadings ($\Lambda_{i,j}$, $j = 1, 2$, in column 14-16), an interpretation in terms of *level* and *slope* factors for the OIS spreads *variance term structure* can then be provided to the estimated common break processes in variance.

The estimated level, slope and curvature factors, and their conditional standard deviations, are plotted in Figure 1; as is shown in the plots, the estimated conditional mean and standard deviation factors well describe the effects of the subprime crisis, pointing to a persistent increase in the level factor and in its volatility during the financial turmoil triggered by the BNP Paribas event (August 8 2007) and Lehman Brothers bankruptcy (September 15 2008), as well as in the volatility of the slope and curvature factors. Some permanent effects of the crisis (up to the end of the investigated sample, i.e., August 3 2012) can also be noted in the plots, as the trend component for all the term structure factors has not reverted to pre-crisis levels, while deviations about trend have become both less volatile and more persistent.

Finally, from the estimation of the FIGARCH part of the model, consistent with the results of the long memory analysis carried out on the volatility proxies, strong evidence of persistence in variance can be found for the three common long memory factors; a fractional differencing parameter (b) in the range 0.33-0.42 is, in fact, estimated for their conditional variance processes (b in Table 5, column 14-16). The higher persistence in variance detected by means of the FIGARCH model than by using the BBLP estimator is not surprising, due to the likely noisiness of the volatility proxies employed ($|\Delta x_t|$), which may impart a downward bias to the BBLP estimator.

4.1 Impulse responses and forecast error variance decomposition

Due to instability in variance, impulse response analysis and forecast error variance decomposition have been made dependent on the estimated volatility regimes, i.e., structural common factor shocks have been computed using the estimated variance-covariance matrix $\hat{\Sigma}_{\eta,s}$, where $s = \textit{pre-crisis}$, $\textit{crisis}$, $\textit{post-crisis}$. As the orthogonality of the common factors is imposed over the full sample, and therefore does not necessarily hold over each subsample, the identification of the structural common factor shocks, and therefore the estimation of the H matrix (H_s, being regime dependent) in the structural VMA representation of the FI-HF-VAR model in (5) requires 3 additional restrictions ($R(R-1)/2$; $R = 3$), which are imposed through a recursive specification for the structural form of the system of equations in (2), assuming the level factor ordered first and the curvature factor last; then, the H_s matrix is estimated by means of the Choleski decomposition of the contemporaneous variance-covariance matrix of the reduced form common factor innovations, yielding $\hat{H}_s^{-1} = chol(\hat{\Sigma}_{\hat{\eta},s})$.

Due to the possible dependence of the results on the selected ordering, impulse responses are also carried out by assuming a diagonal structure for the $\hat{\Sigma}_{\eta,s}$ matrix and, therefore, for the matrix H_s, as it would be implied by the orthogonality of the common factors over each subsample; the results of the impulse response analysis obtained from the latter model are fully coherent, in terms of sign, profile and magnitude, with those obtained by means of the recursive structure, which is evidence of robustness of the findings to identifying restrictions.[14]

Moreover, the identification of the idiosyncratic shocks requires additional 91 restrictions ($N(N-1)/2$; $N = 14$), which are similarly imposed by selecting a recursive structure for the system of equations in (1). The latter assumes the 1-week rate spread ordered first and the 12-month spread ordered last, and therefore contemporaneous forward transmission of shocks along the OIS spreads term structure, yet only delayed (one-day at least) feedback from longer to shorter maturities. Hence, the Θ matrix in the structural VMA representation of the FI-HF-VAR model in (5) is estimated by means of the Choleski decomposition of the contemporaneous variance-covariance

[14] In terms of magnitude of the median contemporaneous impact, absolute deviations no larger than 0.4b.p., 0.09 b.p. on average, are found for the OIS spreads responses to the slope factor shock; figures for the curvature factor shock are 1b.p. for the median impact and 0.2b.p. on average. By construction, no differences for the responses to the level factor shock are found for the two identification strategies. Detailed results are not reported for reasons of space; they are however available upon request from the author.

matrix of the idiosyncratic innovations, i.e., $\hat{\Theta}^{-1} = chol(\hat{\Sigma}_{\hat{v}})$.

4.1.1 Impulse response analysis

The results of the impulse response analysis are reported in Figure 2-4, where median impulse responses, with 90% significance bands, are plotted for the three regimes investigated, over a twenty-five-day horizon; for reasons of space, only selected maturities, i.e., 1-week, 1-, 3-, 6-, 9-, and 12-month, are considered.[15]

As shown in Figure 2-4, independently of the regime considered, the interpretation of the structural common persistent disturbances in terms of level, slope and curvature factor shocks is supported by the results of the impulse response analysis; in fact, a 1-standard deviation level shock drives upward the whole OIS spreads term structure (Figure 2), while responses of opposite sign can be noted at the short- and medium-/long-end of the OIS spreads term structure, following a 1-standard deviation slope shock (Figure 3); moreover, responses of opposite sign can be noted at the short-/long-end and at the medium-end of the OIS spreads term structure, following a 1-standard deviation curvature shock (Figure 4).

Consistent with the finding of long memory in the common stochastic factors, the effects of the level, slope and curvature factor shocks tend to fade away slowly, showing a hyperbolic rate of decay, being still statistically significant also after twenty days.

By comparing impulse responses to each shock across regimes, it can be noted that the subprime crisis has lead to an increase in the persistence of all the common shocks, lasting also after its end. Moreover, the crisis has also magnified the contemporaneous impact of all the common shocks. For instance, for the level shock, a three to five fold larger effect can be noted for the crisis regime, i.e., 7b.p. to 11b.p., relatively to the pre-crisis regime, i.e., 1.7b.p. to 2.6b.p, while a two to three fold larger effect can be noted for the post-crisis period, i.e., 5b.p. to 7.5b.p.; results for the other common persistent shocks are similar, i.e., -0.4b.p. to 0.75b.p., -1b.p. to 3b.p., and -1b.p. to 2b.p., for the pre-crisis, crisis, and post-crisis periods, respectively, for the slope factor shock; figures for the curvature factor shock are -0.2b.p. to 1.5b.p., -0.8b.p. to 5b.p. and -0.5b.p. to 3b.p., for the three regimes, respectively.

[15] Additional results are available from the author upon request.

4.1.2 Forecast error variance decomposition

The results of the median forecast error variance decomposition (FEVD) are reported in Table 6. For reasons of space only a selection of the results is reported, i.e., FEVD at the 1- and 20-day horizons, for the three regimes considered.[16]

As shown in Table 6, robust conclusions can be drawn concerning the relevance of money market shocks, independently of the regime considered.

Firstly, the level factor shock (column 3, 10 and 17) is the key driver of OIS spreads fluctuations from the 2-month maturity onwards (63%-86% pre-crisis; 78%-96% crisis; 84%-98% post-crisis), exercising, in general, stronger effects at longer (20-day) than shorter (1-day) horizons.

Secondly, the slope factor shock (column 4, 11 and 18) is most important at the short-end of the term structure (24%-45% pre-crisis; 30%-55% crisis; 28%-60% post-crisis), independently of the horizon considered (1- or 20-day); the latter also accounts for some fluctuations at the long-end of the term structure.

Thirdly, the curvature factor shock (column 5, 12 and 19) accounts for fluctuations common to intermediate maturities, i.e., 2- to 4-month (7%-12% pre-crisis; 3%-9% crisis; 2%-6% post-crisis), as well as to the short- (1-week) and long- (1-year) end of the term structure (8%-12% pre-crisis; 4%-10% crisis; 3%-9% post-crisis).

Fourthly, idiosyncratic fluctuations (columns 7-9, 14-16, and 21-23) are more important at the short- than at the long-end of the term structure (1-week through 1-month spreads: 11%-32% pre-crisis; 6%-22% crisis; 12%-15% post-crisis; 2- through 12-month spreads: 5%-12% pre-crisis; 0%-7% crisis; 0%-5% post-crisis).

Additional interesting findings, related to the consequences of the sub-prime financial crisis, can also be noted.

Firstly, while the impact (1-day) contribution of the slope factor shock (column 4, 11, 18) to short-end term structure fluctuations (1-week through 1-month maturities) is fairly unchanged, i.e., 30%-45%, a sizable increase can be noted at longer horizons (20-day), i.e., from 24%-45% (pre-crisis) to 31%-55% (crisis) and then 34%-60% (post-crisis). Fairly unchanged is also the contribution of the slope factor shock to fluctuations for longer maturities (0%-12% pre-crisis; 0%-8% crisis and post-crisis).

Secondly, independent of maturity and horizon, the contribution of the level factor shock (column 3, 10, 17) to OIS spreads fluctuations has increased across regimes, more sizably during the crisis than post-crisis period, and for short/long maturities than for intermediate maturities (in terms of relative

[16] Additional results are available from the author upon request.

changes); for instance, the contribution of the level factor shock to 1-week OIS spread fluctuations (20-day horizon) has increased from 20% (pre-crisis) to 30% (crisis) and then 32% (post-crisis); figures for the 12-month maturity are 63%, 86% and 88%, respectively; 82%, 95% and 97%, respectively, for the 4-month maturity.

Thirdly, the increasing contribution of the level factor shock to OIS spreads fluctuations across regimes (59%-92% pre-crisis; 83%-99% crisis; 85%-99% post-crisis) has been matched by a sizable decline for the idiosyncratic shocks (7%-41% pre-crisis; 1%-22% crisis; 0%-15% post-crisis) and a more subdued contraction for the curvature factor shock (0%-12% pre-crisis; 0%-10% crisis; 0%-9% post-crisis); overall, the crisis appears to have magnified the role of common (level factor) over idiosyncratic shocks, triggering increased comovement across the OIS spreads term structure.

4.2 Information content of the OIS spreads term structure for macroeconomic risk forecasting

In Figure 5, the OIS spreads *level* factor (LEV) is plotted, as well as other widely employed business cycle predictors, i.e., the TED spread (TED), the $BAA - AAA$ spread (COR) and the *mortgage* spread (MOR)[17]; the shaded areas in the plots correspond to the most recent US recession, as dated by NBER's Business Cycle Dating Committee, i.e., December 2007 through June 2009, and the euro area crisis, decomposed into three subperiods, marked by the negative assessment by the EU-IMF of Greece's public finances in February 2010, the spreading of the crisis to Portugal, Spain and Ireland by November 2010, and its spillover to Italy by September 2011. The data source is FRED2.

As shown in the plots all the spreads appear to be informative concerning the dating of the recession ensuing from the subprime crisis; in particular, from eyeball inspection, TED and LEV show some leading indicator property, sharply increasing before its beginning; albeit strongly correlated with TED (the correlation coefficient for the two series is 0.65), LEV does appear to contain also different information, pointing to stress in the interbank market, over the period March through May 2009, not signalled by

[17] The TED spread, i.e., the spread between the 3-month LIBOR rate (Euro dollar deposit rate) and the yield on 3-month Treasury bills, being the difference between an unsecured deposit rate and a risk-free rate, yields a measure of credit and liquidity risk; differently, the spread between BAA-rated and AAA-rated corporate bonds ($BAA - AAA$) yields a measure of corporate default risk, as well as a measure of investors' risk-taking attitude; moreover, the *mortgage* spread is the spread between the conventional 30-year mortgage rate and 30-year Treasury bonds yield, measuring stress in the mortgage market.

the TED; overall, LEV, MOR and TED date quite closely the end of the US recession, while COR lags somewhat behind. Differently from the other measures, LEV also shows some coincident indictor properties for the EA sovereign debt crisis, particularly concerning its beginning in February 2010 and its transmission to Italy in September 2011.

In Figure 5 (top plot), a composite fragility measure ($FRAG$), computed as the common component in LEV, TED, COR and MOR, i.e., their first principal component, is also plotted.[18] The latter accounts for 80% of total variance, and for 44% (LEV) to 71% (COR) of the variance for each individual series. By reflecting several dimensions of economic and financial fragility, i.e., interbank market stress-credit/liquidity risk and mortgage market and corporate sector conditions, the latter might also be useful as risk barometer.

The forward-looking properties of the proposed OIS spreads term structure decomposition in level, slope and curvature factors, as well as of the composite indicator ($FRAG$), are assessed by means of an out of sample forecasting exercise, concerning the prediction of US industrial production, inflation and unemployment rate dynamics. A forecasting accuracy comparison is also carried out, with reference to the TED, COR and MOR spreads. Different horizons are considered, i.e., 1-, 3-, 6- and 12-month; the forecasting sample is from August 2007 through July 2012.

Monthly spreads (TED, COR and MOR) data have been computed by averaging daily figures over calendar month; similarly for the OIS spreads level, slope and curvature factors, albeit, for the latter, daily figures are not observed, and therefore obtained by means of recursive estimation of the the FI-HF-VAR model.

Forecasts for the macroeconomic variables of interest are computed by means of VAR models, using different specifications, i.e., the F model, including the estimated level (LEV), slope and curvature factor conditional means; the $F1$ model, including LEV only; the $F2$ model, including the estimated slope factor conditional mean only; the $F3$ model including the estimated curvature factor conditional mean only; the C model including the composite indicator ($FRAG$) only; the CF model, including $FRAG$ and the estimated slope and curvature factors conditional means. The above models are contrasted with other VAR specifications, considering alternative risk measures to OIS spreads term structure factors; in particular, the $A1$ model, including the corporate spread (COR); the $A2$ model including the TED spread; the $A3$ model including the mortgage spread (MOR); the B

[18]The estimated weights are 1.194, 1.214, 0.622 and 1.078 for the LEV, COR, TED and MOR series, respectively.

model, including the Federal funds rate and the term spread (computed using 10-year and 3-month Treasury constant maturity rate bonds and bills); the $B1$ model, including the Federal funds rate only; the $B2$ model, including the term spread only; finally, the "no change" forecasting model ($NAIVE$) and an autoregressive model (AR) for the macroeconomic variables of interest are considered as well.

The assessment of the forecasting properties of the various models is performed by means of the root mean square forecast error ($RMSFE$) and the Theil's inequality (IC) statistics. In order to make conclusions robust to lag selection, forecasts are generated from specifications containing up to 5 lags; then, the best outcome for each forecasting model, across dynamic specifications, is reported in Table 7 for any horizon. By comparing the performance of the various VAR models against the AR model, the excess information contained in the proposed indicators, relatively to the past history of the own macroeconomic variables, is assessed.

As shown in Table 7 (Panel A), concerning the prediction of unemployment rate dynamics, the C model performs best at the 1- and 3-month horizons, while the CF model yields the best outcome at longer horizons; yet, while the IC statistic selects CF as best model also at the 1-year horizon, the $A2$ model is selected according to the $RMSFE$ statistic. The C and CF models also yield the most synchronous forecasts, in terms of correlation coefficient, with actual unemployment rate dynamics. Finally, the excess information content of the proposed risk indicators can be easily gauged by comparing C, CF and AR model figures: a 5% to 50% reduction in the IC and $RMSFE$ statistics can be noted across forecasting horizons, therefore pointing to the usefulness of the proposed indicators.

Moreover, also concerning industrial production dynamics (Panel B), VAR models containing OIS spreads term structure information perform best: according to the $RMSFE$ statistic, $F2$ at the 1-, 6- and 12-month horizons; F at the 3-month horizon; according to the IC statistic, F at the 3- and 6-month horizon; $F2$ at the 12-month horizon; CF at the 1-month horizon. Also sizable is the excess information provided by the proposed credit risk indicators: 5% to 30% reductions in the IC and $RMSFE$ statistics can be noted across horizons; moreover, also very sizable is the correlation between actual and forecasted values using the F, $F2$ and CF models.

Finally, interesting results are obtained for inflation rate forecasting (Panel C) at short horizons, as $F3$ and CF perform best at the 1-month horizon according to the $RMSFE$ and IC statistics, respectively; a 20% reduction in the $RMSFE$ and IC statistics, relatively to AR model figures, and fairly correlated forecasted and actual values, can be noted as well.

Overall, the above findings look then promising concerning the use of the proposed indicators for macroeconomic risk forecasting.

5 Conclusions

The paper investigates the dynamic properties of US OIS spreads over the subprime and euro area sovereign debt crises, by means of a comprehensive econometric modeling strategy, allowing for common features across the OIS spreads term structure, described by deterministic and stochastic factors, both in mean and variance, as well as strong persistence and heteroskedasticity.

Three common components, bearing the interpretation of *level*, *slope* and *curvature* factors, can then be extracted from the OIS spreads term structure; the latter are characterized by a deterministic trend component and strongly persistent and heteroskedastic fluctuations about trend; two common break processes, describing the long-term evolution of OIS spreads conditional variances, bearing the interpretation of *level* and *slope* factors for the volatility term structure, are also found.

We find that the subprime crisis has lead to a wide increase in both the mean and variance of OIS spreads trend levels and to a sizable increase in the persistence of money market shocks, as well as to stronger comovement along the term structure, due to increased relevance of level factor shocks; while at the short-end of the term structure mean trend components have progressively converged back to pre-crisis levels since December 2008, fluctuations about much higher values, than prevailing before the crisis, can be noted at its medium- to long-end, also over the post-subprime crisis period; differently, a contraction in volatility below pre-crisis levels, yet a further increase in persistence of money market shocks, can be found over the post-crisis period for all maturities. A sizable widening in OIS spreads mean trend levels at the medium- to long-end of the term structure can finally be associated with the spillover of the euro area sovereign debt crisis to the Italian economy in September 2011. Should wide OIS spreads become a long-lasting feature of the US money market, surely important challenges for theoretical models of the yield curve and for the pricing of interest rate and credit derivatives would then raise.

By comparing the forward-looking properties of the OIS spreads term structure factors with alternative measures of credit/liquidity risk and financial fragility, we find the former conveying additional information, relatively to commonly used measures like the TED or the $BAA - AAA$ corporate spreads, which might be exploited, also within a composite indicator, for the prediction of macroeconomic risk.

To our knowledge no such an in-depth study on the consequences of the subprime and euro area sovereign debt crisis on the US money market has previously been contributed to the literature; the comprehensive econometric framework employed in the paper does appear to be needed for the modeling of OIS spreads term structure features and understanding of the effects of the recent financial turmoil.

References

[1] Ait-Sahalia, Y., Andritzky, J., Jobst, A., Nowak, S., Tamirisa, N., 2012, Market response to policy initiatives during the global financial crisis, Journal of International Economics 87, 162-177.

[2] Acharya, V.V., Richardson, M.P., 2009. Causes of the financial crisis. Critical Review 21, 195-210.

[3] Afonso, G., Kovner, A., Scholar, A., 2011. Stressed, not frozen: The Federal funds market during the financial crisis. Federal Reserve of New York Staff Report, no. 437.

[4] Ait-Sahalia, Y., Andritzky, J., Jobst, A., Nowak, S., Tamirisa, N., 2012. Journal of International Economics 87, 162-177.

[5] Alexander, C.O., 2002. Principal component models for generating large covariance matrices. Economic Notes 31, 337-359.

[6] Allen, F., Carletti, E., Gale, D., 2009. Interbank market liquidity and central bank intervention. Journal of Monetary Economics 56, 639-652.

[7] Armantier, O., McAndrews, J.J., Krieger, S., 2008. The Federal Reserve's term auction facility. Federal Reserve Bank of New York Current Issues in Economics and Finance 14, no. 5.

[8] Baillie, R.T., 1996. Long memory processes and fractional integration in econometrics. Journal of Econometrics 73, 5-59.

[9] Baillie, R.T., Bollerslev, T., Mikkelsen, H.O., 1996. Fractionally integrated generalized autoregressive conditional heteroskedasticity. Journal of Econometrics 74, 3-30.

[10] Baillie, R.T., Morana, C., 2009, Modeling long memory and structural breaks in conditional variances: An adaptive FIGARCH approach. Journal of Economic Dynamics and Control 33, 1577-1592.

[11] Baillie R.T., Morana, C., 2012. Adaptive ARFIMA models with applications to inflation. Economic Modelling 29, 2451-2459.

[12] Bai, J.., Perron, P., 1998. Testing for and estimation of multiple structural changes. Econometrica 66, 47-79.

[13] Bai, J., 2003. Inferential theory for factor models of large dimensions. Econometrica 71, 135-171.

[14] Bai, J., 2004. Estimating cross-section common stochastic trends in nonstationary panel data. Journal of Econometrics 122, 137-38.

[15] Bai, J., Ng, S., 2006. Confidence intervals for diffusion index forecasts and inference with factor-augmented regressions. Econometrica 74, 1133-1150.

[16] Bai, J., Ng, S., 2008. Forecasting economic time series using targeted predictors. Journal of Econometrics 146, 304-317.

[17] Bai, J., Ng, S., 2013. Principal components estimation and identification of static factors. Journal of Econometrics 176, 18-29.

[18] Bianco, K., 2012. A retrospective of the troubled asset relief program. Wolters Kluwer Law & Business, mimeo.

[19] Bierens, H.J., 2000. Non parametric nonlinear cotrending analysis, with an application to interest and inflation in the United States. Journal of Business and Economic Statistics 18, 323-37.

[20] Brunnermaier, M., 2009. Deciphering the liquidity crisis. Journal of Economic Perspectives 23, 77-100.

[21] Brunetti, C., Gilbert, C.L., 2000. Bivariate FIGARCH and fractional cointegration. Journal of Empirical Finance 7, 509-530.

[22] Bollerslev, T., 1990. Modelling the coherence in short-run nominal exchange rates: A multivariate generalized ARCH approach. Review of Economics Studies 72, 489-505.

[23] Caballero, R.J., Krishnamurthy, A., 2008. Collective risk management in aflight to quality episode. Journal of Finance 63, 2195-2230.

[24] Cassola, N., Morana, C., 2012. Euro money market spreads during the 2007-? financial crisis. Journal of Empirical Finance 19, 548-557.

[25] Christensen, J.H.E., 2009. Have the Fed liquidity facilities had an effect on Libor? FRBSF Economic Letter, issue Aug 10 2009.

[26] Christensen, J.H.E., Lopez, J.E., Rudebusch, G.D., 2009. Do central bank liquidity facilities. Federal Reserve Bank of San Francisco Working Paper.

[27] D'Amico, S., English, W., Lopez-Salido, J.D., Nelson, E., 2012. The Federal Reserve's large-scale asset purchase programs: Rational and effects, CEPR Discussion Papers, no. 9145.

[28] Demetrescu, M., Kuzin, V., Hassler, U., 2006. Long memory testing in time domain. Goethe University Frankfurt, mimeo.

[29] Dempster, A.P., Laird, N.H., Rubin, D.B., 1977. Maximum likelihood from incomplete data via the EM algorithm. Journal of the Royal Statistical Society Series B 39, 1-38.

[30] De Santis, R.A., 2012. The euro area sovereign debt crisis. Safe haven, credit rating agencies and the spread of the fever from Greece, Ireland and Portugal, ECB Working Paper Series, no. 1419.

[31] Dolado, J.J., Gonzalo, J., Mayoral, L., 2005. A simple test of long memory vs. structural breaks in the time domain. Universidad Carlos III de Madrid, mimeo.

[32] Filipovic, D., Trolle, A., 2013. The term structure of interbank risk. Journal of Financial Economics 109, 707-733.

[33] Frank, N., Hesse, H., 2009. The effectiveness of central bank interventions during the first phase of the subprime crisis, IMF Working Paper, no. 206.

[34] Fratzscher, M., Lo Duca, M., Straub, R., 2013. On the international spillovers of US quantitative easing. ECB Working Paper Series, no. 1557.

[35] Granger, C.W., Jeon, Y., 2004. Thick modelling. Economic Modelling 21, 323-43.

[36] Granger, C.W.J, Hyung, N., 2004. Occasional structural breaks and long memory with an application to the S&P500 absolute returns. Journal of Empirical Finance 11, 399-421.

[37] Hassler, U., Meller, B., 2009. Detecting a change in inflation persistence in the presence of long memory: A new test. Goethe University Frankfurt, mimeo.

[38] Hatanka, M., Yamada, H., 1994. Co-trending: An extended version. University of Hiroshima. Mimeo.

[39] Ji, P., In, F., 2010. The impact of the global financial crisis on the cross-currency linkage of LIBOR-OIS spreads. Journal of International Finanacial Markets Institutions and Money 20, 575-589.

[40] Krishnamurthy, A., Vissing-Jorgessen, A., 2011. The effects of quantitative easing on interest rates: Channels and implications for policy. NBER Working Paper Series, no.17555.

[41] Lavielle, M., Moulines, E., 2000. Least-squares estimation of an unknown number of shifts in a time series. Journal of Time Series Analysis 21, 33-59.

[42] McAndrews, J., Asani, S., Wang, Z., 2008. The effect of the term auction facility on the London inter-bank offered rate. Federal Reserve Bank of New York Staff Reports, no.335.

[43] Morana, C., 2007. Multivariate modelling of long memory processes with common components. Computational Statistics and Data Analysis 52, 919-934.

[44] Morana, C., 2011, Factor vector autoregressive estimation of heteroskedastic persistent and non persistent processes subject to structural breaks, Università di Milano-Bicocca, available at SSRN: http://ssrn.com/abstract=1756376 or http://dx.doi.org/10.2139/ssrn.1756376.

[45] Moulines, E., Soulier, P., 1999. Broadband log-periodogram regression of time series with long range dependence. The Annals of Statistics 27, 1415-39.

[46] Ohanissian, A., Russell, J. R., Tsay, R.S., 2008. True of spurious long memory? A new test. Journal of Business and Economic Statistics 26, 161-175.

[47] Olson, E., Miller, S., Wohar, M., 2012. Black Swans before the Black Swan: Evidence from international LIBOR-OIS spreads. Journal of International Money and Finance 31, 1339-1357.

[48] Reis, R., 2009. Interpreting unconventional US monetary policy. Brooking Papers on Economic Activity Fall, 119-182.

[49] Schwert, G.,W., 1989. Test for unit roots: A Monte Carlo investigation. Journal of Business and Economic Statistics 7, 147-160.

[50] Shimotsu, K., 2006. Simple (but effective) tests of long memory versus structural breaks. Queen's University, Department of Economics Working Paper, no. 1101.

[51] Taylor, J.B., Williams, J.C., 2009. A black swan in the money market. American Economic Journal: Macroeconomics 1, 58-83.

[52] Veronesi, P., Zingales, L., 2009. Paulson's gift. NBER Working Paper No. 15458.

[53] Wu, T., 2011. The U.S. money market and the term auction facility in the financial crisis of 2007–2009- The Review of Economics and Statistics 93, 617-631.

Table 1: OIS spreads, Bai-Perron structural break tests and common break process (PCA) analysis

Panel A: OIS spread levels														
	Structural break analysis								*Principal components analysis*					
	Bai-Perron test		*Mean value over regime*						*Explained variance*			*Factor loadings*		
	UDmax	*Break Points*	*PrC*	*C1*	*C2*	*PoC1*	*PoC2*	*PoC3*	μ_{m1}	μ_{m2}	μ_{m3}	μ_{m1}	μ_{m2}	μ_{m3}
x^{1w}	39.9	8/9/07; 9/16/08; 12/9/08	0.074	0.403	1.437	0.129	0.082	0.078	0.46	0.42	0.111	0.030	-0.010	0.001
x^{2w}	47.8	8/9/07; 9/16/08; 12/10/08	0.079	0.446	1.565	0.172	0.088	0.102	0.51	0.40	0.086	0.020	-0.010	0.001
x^{1m}	47.9	8/9/07; 9/19/08; 12/12/08	0.087	0.493	1.839	0.217	0.095	0.134	0.58	0.37	0.026	0.020	-0.007	0.001
x^{2m}	69.6	8/9/07; 9/19/08; 12/17/08; 8/24/09; 9/12/11	0.099	0.611	2.097	0.558	0.121	0.237	0.81	0.16	0.023	0.020	-0.004	-0.002
x^{3m}	84.1	8/9/07; 9/19/08; 12/18/08; 8/24/09; 9/12/11	0.108	0.692	2.210	0.770	0.151	0.354	0.89	0.08	0.028	0.020	-0.004	-0.002
x^{4m}	105.3	8/10/07; 9/19/08; 12/17/08; 9/7/09; 9/9/11	0.109	0.727	2.240	0.963	0.201	0.439	0.95	0.03	0.02	0.021	-0.003	0.001
x^{5m}	107.1	8/10/07; 9/19/08; 12/17/08; 9/10/09; 9/7/11	0.112	0.759	2.270	1.108	0.261	0.511	0.98	0.01	0.01	0.022	-0.001	-0.002
x^{6m}	128.6	8/14/07; 9/19/08; 12/17/08; 9/9/09; 9/12/11	0.117	0.784	2.299	1.222	0.321	0.588	0.99	0.00	0.01	0.025	0.000	-0.002
x^{7m}	141.9	8/14/07; 9/19/08; 12/17/08; 9/10/09; 9/6/11	0.118	0.772	2.284	1.271	0.379	0.642	0.99	0.00	0.00	0.027	0.001	-0.001
x^{8m}	165.6	8/10/07; 9/19/08; 12/17/08; 9/10/09; 9/9/11	0.121	0.756	2.263	1.314	0.435	0.691	0.99	0.01	0.00	0.030	0.002	-0.001
x^{9m}	193.7	8/10/07; 9/19/08; 12/17/08; 9/11/09; 9/6/11	0.122	0.740	2.241	1.351	0.489	0.740	0.98	0.02	0.00	0.032	0.004	-0.001
x^{10m}	217.7	8/9/07; 9/19/08; 12/17/08; 9/11/09; 9/6/11	0.124	0.729	2.218	1.380	0.538	0.790	0.97	0.03	0.00	0.035	0.005	0.001
x^{11m}	232.8	8/9/07; 9/19/08; 12/17/08; 9/11/09; 9/8/11	0.125	0.714	2.192	1.407	0.586	0.842	0.95	0.04	0.01	0.037	0.006	0.001
x^{12m}	261.6	8/9/07; 9/19/08; 12/17/08; 9/11/09; 9/6/11	0.125	0.701	2.164	1.432	0.635	0.898	0.93	0.06	0.01	0.039	0.007	0.001
			Explained total variance						**0.95**	**0.04**	**0.01**			

Panel B: OIS spread volatilities											
	Structural break analysis					*Principal components analysis*					
	Bai-Perron test		*Mean value over regime*			*Explained variance*			*Factor loadings*		
	UDmax	*Break Points*	*PrC*	*C*	*PoC*	μ_{v1}	μ_{v2}	μ_{v3}	μ_{v1}	μ_{v2}	μ_{v3}
$\mid \Delta x^{1w} \mid$	55.7	8/2/07; 1/2/09	0.010	0.074	0.007	0.76	0.23	0.00	0.026	-0.010	0.001
$\mid \Delta x^{2w} \mid$	59.8	8/2/07; 12/23/08	0.007	0.068	0.005	0.69	0.30	0.01	0.023	-0.010	0.001
$\mid \Delta x^{1m} \mid$	82.9	8/2/07; 12/22/08	0.007	0.052	0.005	0.74	0.25	0.01	0.018	-0.007	0.001
$\mid \Delta x^{2m} \mid$	71.9	8/2/07; 2/2/09	0.007	0.047	0.005	0.83	0.12	0.03	0.017	-0.004	-0.002
$\mid \Delta x^{3m} \mid$	64.8	8/2/07; 2/2/09	0.009	0.047	0.006	0.88	0.09	0.02	0.018	-0.004	-0.002
$\mid \Delta x^{4m} \mid$	74.2	8/2/07; 1/3/09	0.012	0.050	0.007	0.93	0.05	0.00	0.021	-0.003	0.001
$\mid \Delta x^{5m} \mid$	82.1	7/27/07; 2/11/09	0.015	0.052	0.007	0.97	0.01	0.02	0.022	-0.001	-0.002
$\mid \Delta x^{6m} \mid$	97.0	7/25/07; 2/11/09	0.018	0.058	0.008	0.98	0.00	0.02	0.025	0.000	-0.002
$\mid \Delta x^{7m} \mid$	106.7	7/25/07; 2/3/09	0.021	0.060	0.009	0.99	0.00	0.00	0.027	0.001	-0.001
$\mid \Delta x^{8m} \mid$	118.0	7/25/07; 2/11/09	0.024	0.064	0.010	0.98	0.01	0.01	0.030	0.002	-0.001
$\mid \Delta x^{9m} \mid$	124.2	7/25/07; 2/9/09	0.028	0.067	0.011	0.97	0.03	0.00	0.032	0.004	-0.001
$\mid \Delta x^{10m} \mid$	128.5	7/25/07; 1/28/09	0.031	0.070	0.012	0.96	0.04	0.00	0.035	0.005	0.001
$\mid \Delta x^{11m} \mid$	127.3	7/25/07; 2/2/09	0.034	0.073	0.013	0.95	0.05	0.00	0.037	0.006	0.001
$\mid \Delta x^{12m} \mid$	128.8	7/25/07; 2/2/09	0.037	0.077	0.014	0.93	0.07	0.00	0.039	0.007	0.001
			Explained total variance			**0.96**	**0.04**	**0.00**			

The Table reports the results of the structural break and principal components analyses for the various OIS spread levels (x; Panel A) and volatilities ($\mid \Delta x \mid$; Panel B). The results of the Bai-Perron (1989) *UDmax* test, implemented using monthly data, over the period May 2002 through July 2012, and the estimated break points using daily data, are reported in column 2 and 3, respectively. Mean daily values for the series, over the various regimes, are also reported in column 3-8 in Panel A and 3-5 in Panel B. The estimated regimes for the OIS spread level series are: *Pre-crisis*: 5/6/02 - 8/8/07 (*PrC*); *Crisis, pre-Lehman*: 8/9/07 - 9/15/08 (*C1*); *Crisis, post-Lehman*: 9/16/08 -12/8/08 (*C2*); *Post-crisis I*: 12/9/08 - 8/21/09 (*PoC1*); *Post-crisis II*: 8/24/09- 9/5/11 (*PoC2*); *Post-crisis III*: EA crisis 9/6/11-8/3/12 (*PoC3*). The estimated regimes for the OIS spread volatility series are: *Pre-crisis*: 5/6/02 - 8/8/07 (*PrC*); *Crisis*: 8/9/07 - 12/8/08 (*C*); *Post-crisis*: 12/9/08 - 8/3/12 (*PoC*). In the Table the results of the principal components analysis implemented using the estimated break processes are also reported. In particular, the fraction of variance of each individual series attributable to the first three extracted principal components is reported in column 9-11 in Panel A ($\mu_{m1}, \mu_{m2}, \mu_{m3}$) and column 6-8 in Panel B ($\mu_{v1}, \mu_{v2}, \mu_{v3}$); the estimated factor loadings are reported in column 12-14 in Panel A ($\mu_{m1}, \mu_{m2}, \mu_{m3}$) and column 9-11 in Panel B ($\mu_{v1}, \mu_{v2}, \mu_{v3}$); the last row (*Explained total variance*) then shows the fraction of total variance explained by the first three principal components. Results are for the various OIS spread maturities available, i.e., from 1-week ($x^{1w}, \mid \Delta x^{1w} \mid$) to one-year ($x^{12m}, \mid \Delta x^{12m} \mid$).

Table 2: OIS spreads: Full sample long memory and common long memory factor (PCA) analyses

Panel A: OIS spread levels											
	Long memory analysis					*Principal components analysis*					
	BBLP – full sample estimates		*Long memory tests*			*Explained variance*			*Factor loadings*		
	level (x)	*break-free (l)*	*SKPSS*	*DGM*	*DKH*	f_{m1}	f_{m2}	f_{m3}	f_{m1}	f_{m2}	f_{m3}
x^{1w}	0.885 (0.039)	0.519 (0.039)	0.021	-2.773	-2.233	0.32	0.49	0.06	0.608	-0.649	0.310
x^{2w}	0.973 (0.039)	0.603 (0.039)	0.025	-2.011	-0.787	0.38	0.53	0.03	0.663	-0.681	0.172
x^{1m}	1.019 (0.039)	0.691 (0.039)	0.055	-2.286	-1.182	0.52	0.30	0.00	0.752	-0.510	-0.058
x^{2m}	1.082 (0.039)	0.688 (0.039)	0.051	-3.826	-2.103	0.76	0.02	0.17	0.875	-0.178	-0.393
x^{3m}	1.098 (0.039)	0.689 (0.039)	0.051	-3.238	-1.751	0.84	0.00	0.12	0.922	-0.100	-0.322
x^{4m}	1.074 (0.039)	0.668 (0.039)	0.067	-2.808	-2.019	0.92	0.00	0.05	0.954	-0.015	-0.208
x^{5m}	1.055 (0.039)	0.643 (0.039)	0.078	-2.473	-1.903	0.95	0.01	0.02	0.975	0.067	-0.129
x^{6m}	1.017 (0.039)	0.592 (0.039)	0.107	-2.218	-1.858	0.96	0.02	0.00	0.979	0.117	-0.041
x^{7m}	1.002 (0.039)	0.575 (0.039)	0.116	-2.147	-1.898	0.94	0.03	0.00	0.970	0.176	0.009
x^{8m}	0.983 (0.039)	0.550 (0.039)	0.127	-2.147	-1.966	0.94	0.04	0.01	0.967	0.212	0.062
x^{9m}	0.958 (0.039)	0.505 (0.039)	0.174	-1.904	-1.697	0.93	0.04	0.02	0.961	0.220	0.133
x^{10m}	0.944 (0.039)	0.503 (0.039)	0.166	-2.008	-1.865	0.90	0.05	0.04	0.950	0.242	0.168
x^{11m}	0.928 (0.039)	0.484 (0.039)	0.202	-1.955	-1.834	0.89	0.05	0.05	0.940	0.257	0.192
x^{12m}	0.908 (0.039)	0.461 (0.039)	0.241	-1.927	-1.778	0.85	0.06	0.07	0.921	0.276	0.228
			Explained total variance			**0.79**	**0.12**	**0.05**			
Mean	**0.995 (0.039)**	**0.584 (0.039)**			***BBLP$_f$***	**0.595 (0.039)**	**0.460 (0.039)**	**0.499 (0.039)**			
W$_f$	**37.16 [0.000]**	**56.38 [0.000]**				***Mean$_f$*: 0.528 (0.039) *W$_{ff}$*: 6.15 [0.046]**					

Panel B: OIS spread volatilities											
	Long memory analysis					*Principal components analysis*					
	BBLP – full sample estimates		*Long memory tests*			*Explained variance*			*Factor loadings*		
	level (|Δx|)	*break-free (v)*	*SKPSS*	*DGM*	*DKH*	f_{v1}	f_{v2}	f_{v3}	f_{v1}	f_{v2}	f_{v3}
$\|\Delta x^{1w}\|$	0.308 (0.039)	0.175 (0.039)	0.571	0.174	0.181	0.33	0.56	0.06	0.030	-0.038	0.012
$\|\Delta x^{2w}\|$	0.325 (0.039)	0.211 (0.039)	0.471	1.142	0.568	0.40	0.47	0.01	0.029	-0.032	0.004
$\|\Delta x^{1m}\|$	0.366 (0.039)	0.243 (0.039)	0.476	0.755	0.550	0.50	0.08	0.22	0.022	-0.009	-0.014
$\|\Delta x^{2m}\|$	0.394 (0.039)	0.236 (0.039)	0.502	-0.738	-0.010	0.67	0.03	0.24	0.022	-0.004	-0.013
$\|\Delta x^{3m}\|$	0.409 (0.039)	0.257 (0.039)	0.491	-1.318	-0.222	0.71	0.01	0.21	0.023	-0.002	-0.013
$\|\Delta x^{4m}\|$	0.390 (0.039)	0.232 (0.039)	0.686	-1.569	-0.461	0.78	0.00	0.15	0.023	0.000	-0.010
$\|\Delta x^{5m}\|$	0.377 (0.039)	0.201 (0.039)	1.080	-1.602	-0.533	0.84	0.02	0.07	0.024	0.003	-0.007
$\|\Delta x^{6m}\|$	0.364 (0.039)	0.181 (0.039)	1.418	-1.658	-0.648	0.85	0.05	0.02	0.025	0.006	-0.004
$\|\Delta x^{7m}\|$	0.341 (0.039)	0.164 (0.039)	1.728	-1.057	-0.392	0.83	0.09	0.00	0.026	0.009	-0.001
$\|\Delta x^{8m}\|$	0.331 (0.039)	0.146 (0.039)	2.065	-1.225	-0.540	0.82	0.12	0.01	0.027	0.010	0.002
$\|\Delta x^{9m}\|$	0.333 (0.039)	0.162 (0.039)	2.203	-0.384	-0.106	0.78	0.16	0.02	0.028	0.012	0.005
$\|\Delta x^{10m}\|$	0.331 (0.039)	0.158 (0.039)	2.511	-0.644	-0.308	0.75	0.18	0.04	0.029	0.014	0.007
$\|\Delta x^{11m}\|$	0.319 (0.039)	0.150 (0.039)	2.566	-0.105	0.015	0.72	0.18	0.06	0.029	0.015	0.009
$\|\Delta x^{12m}\|$	0.325 (0.039)	0.159 (0.039)	3.034	0.486	0.434	0.69	0.19	0.07	0.030	0.016	0.010
			Explained total variance			**0.62**	**0.24**	**0.07**			
Mean	**0.351 (0.039)**	**0.191 (0.039)**			***BBLP$_f$***	**0.193 (0.039)**	**0.175 (0.039)**	**0.119 (0.039)**			
W$_f$	**8.50 [0.810]**	**12.22 [0.509]**				***Mean$_f$* : 0.162 (0.039) *W$_{ff}$*: 1.92 [0.383]**					

The results reported in the Table refer to OIS spread levels (Panel A) and volatilities (Panel B). The fractional differencing parameter, estimated using the Moulines and Soulier (1999) broad band log periodogram estimator (*BBLP*), as well as its mean value across maturities (*Mean*), is reported for the actual (column 1) and break-free (column 2) series, with standard error in round brackets; W_f is the Wald test for the null of homogeneous persistence across the term structure, with p-value in square brackets. The results of the Shimotsu (2006) (SKPSS, column 3), Dolado et. al. (1995) (DGM, column 4), and Demetrescu et al. (2006) (DKH, column 5) long memory tests are also reported: the tabulated critical values at the 1%, 5% and 10% significance level are -4.866, -4.332, -3.924, respectively, for the DGM test; 0.032, 0.021, 0.016, for the SKPSS test; -2.33, -1.96, -1.65, for the DKH test. In the Table the results of the principal components analysis implemented using the estimated break-free processes are also reported. In particular, the fraction of variance of each individual series attributable to the first three extracted principal components is reported in column 7-9 (f_{m1}, f_{m2}, f_{m3}; f_{v1}, f_{v2}, f_{v3}); the estimated factor loadings are reported in column 10-12; the fraction of total variance explained by each principal components is denoted as *Explained total variance* at the bottom of the Table. Finally, $BBLP_f$ is the estimated fractional differencing parameter for each of the principal components, $Mean_f$ its mean value across factors, W_{ff} the Wald test for the null hypothesis of homogeneous persistence across factors; standard errors and p-value are reported in round and square brackets, respectively. Results are for the various OIS spread maturities available, i.e., from 1-week (x^{1w} , $|\Delta x^{1w}|$) to one-year (x^{12m} , $|\Delta x^{12m}|$).

Table 3: Fractional differencing parameter subsample estimates and constancy tests: break-free OIS spread level series and their common factors

Panel A: Break-free OIS spread levels										
	BBLP – subsamples estimates			***Equality tests***	***HM persistence break test***					
	Pre-crisis	***Crisis***	***Post-crisis***	$W_{i,3}$	HM_b	$HM_{max,b}$	***Date***	HM_e	$HM_{max,e}$	***Date***
x^{1w}	0.396 (0.055)	0.413 (0.109)	0.739 (0.066)	18.05 [0.000]	5.744	5.818	9/12/2007	8.811	8.869	2/7/2009
x^{2w}	0.529 (0.055)	0.543 (0.109)	0.904 (0.066)	21.34 [0.000]	5.158	5.187	9/12/2007	8.937	9.286	2/7/2009
x^{1m}	0.658 (0.055)	0.650 (0.109)	0.936 (0.066)	14.58 [0.000]	8.661	8.690	9/12/2007	7.549	9.343	12/17/2008
x^{2m}	0.661 (0.055)	0.801 (0.109)	1.009 (0.066)	13.98 [0.000]	14.642	14.862	9/12/2007	13.137	16.398	12/17/2008
x^{3m}	0.627 (0.055)	0.816 (0.109)	1.069 (0.066)	24.85 [0.000]	24.099	24.505	9/12/2007	20.248	26.707	12/17/2008
x^{4m}	0.588 (0.055)	0.717 (0.109)	1.016 (0.066)	22.04 [0.000]	48.212	48.311	9/12/2007	32.430	52.644	12/17/2008
x^{5m}	0.535 (0.055)	0.671 (0.109)	1.035 (0.066)	30.40 [0.000]	68.586	69.536	6/12/2007	48.445	71.116	12/17/2008
x^{6m}	0.482 (0.055)	0.600 (0.109)	0.973 (0.066)	31.53 [0.000]	85.460	88.589	6/12/2007	59.277	84.822	12/17/2008
x^{7m}	0.437 (0.055)	0.579 (0.109)	0.961 (0.066)	36.91 [0.000]	95.827	99.125	6/12/2007	67.510	97.558	12/17/2008
x^{8m}	0.398 (0.055)	0.552 (0.109)	0.953 (0.066)	39.63 [0.000]	110.558	114.791	6/12/2007	75.426	110.940	12/17/2008
x^{9m}	0.364 (0.055)	0.542 (0.109)	0.913 (0.066)	40.29 [0.000]	126.253	131.522	6/12/2007	88.581	122.541	12/17/2008
x^{10m}	0.351 (0.055)	0.510 (0.109)	0.893 (0.066)	40.28 [0.000]	116.760	120.323	6/12/2007	84.513	117.137	12/17/2008
x^{11m}	0.327 (0.055)	0.477 (0.109)	0.881 (0.066)	41.94 [0.000]	122.487	127.610	6/12/2007	87.733	121.338	12/17/2008
x^{12m}	0.307 (0.055)	0.451 (0.109)	0.866 (0.066)	44.09 [0.000]	129.910	134.434	6/12/2007	102.408	129.304	12/17/2008
Mean	**0.476 (0.055)**	**0.545 (0.109)**	**0.929 (0.066)**							
	W_{pre}**: 66.95 [0.000]**	W_c**: 16.16 [0.304]**	W_{post}**: 16.49 [0.285]**							
Panel B: Common long memory factors										
	BBLP – subsamples estimates			***Equality tests***	***HM persistence break test***					
	Pre-crisis	***Crisis***	***Post-crisis***	$W_{f,3}$	HM_b	$HM_{max,b}$	***Date***	HM_e	$HM_{max,e}$	***Date***
f_{m1}	0.482 (0.055)	0.755 (0.144)	0.872 (0.061)	22.79 [0.000]	72.791	75.119	8/17/2007	48.229	75.922	9/8/2008
f_{m2}	0.318 (0.055)	0.639 (0.144)	0.798 (0.061)	34.32 [0.000]	14.061	14.385	10/5/2007	24.635	24.388	9/4/2008
f_{m3}	0.396 (0.055)	0.547 (0.144)	0.727 (0.061)	16.00 [0.000]	28.025	28.043	8/20/2007	41.012	44.194	9/4/2008
Mean	**0.399 (0.055)**	**0.647 (0.109)**	**0.799 (0.066)**							
	$Wf_{,pre}$**: 4.44 [0.217]**	$Wf_{,c}$**: 1.05 [0.789]**	$Wf_{,post}$**: 2.80 [0.424]**							

In the Table the fractional differencing parameter, estimated using the Moulines and Soulier (1999) broad band log periodogram estimator (BBLP), with standard error in round brackets, is reported for the break-free OIS spread level series (Panel A) and for their first three principal components (Panel B) for various subsamples, assuming a first permanent break in the persistence parameter occurring in August 9 2007 and a second permanent break occurring in December 9 2008. The *pre-crisis* sample therefore corresponds to the period May 6 2002 through August 8 2007, the *crisis* sample to the period August 9 2007 through December 8 2008, and the *post-crisis* sample to the period December 9 2008 through August 3 2012. The Wald test for the null hypothesis of equal fractional differencing parameter across the term structure (W_s; *s*: *pre, c, post*) and across factors ($W_{f,s}$; *s*: *pre, c, post*), estimated mean values (*Mean*) for each subsample, as well as Wald tests for the null hypothesis of equal fractional differencing parameter across regimes for each maturity ($W_{i,3}$) and factor ($W_{f,3}$), are also reported, with p-values in square brackets. The results of the Hassler and Meller (2009) test (HM) are then reported with reference to the beginning of the *crisis* (HM_c) and *post-crisis* (HM_{pc}) periods, and for the two break points selected by the HM statistic ($HM_{max,c}$ and $HM_{max,pc}$); tabulated critical values are 5.398, 6.904 and 10.287 for the 10%, 5% and 1% significance level, respectively. The results are for the various OIS spread maturities available, i.e., from 1-week (x^{1w}) to one-year (x^{12m}) and the three estimated common long memory factors (f_{m1}, f_{m2}, f_{m3}).

Table 4: Fractional differencing parameter subsample estimates and constancy tests: break-free OIS spread volatility series and their common factors

Panel A: Break-free OIS spread levels										
	BBLP – subsamples estimates			***Equality tests***	***HM persistence break test***					
	Pre-crisis	***Crisis***	***Post-crisis***	$W_{i,3}$	HM_b	$HM_{max,b}$	***Date***	HM_e	$HM_{max,e}$	***Date***
$\lvert \Delta x^{1w} \rvert$	0.231 (0.055)	0.318 (0.109)	0.250 (0.066)	0.50 [0.918]	0.377	0.604	5/18/2007	2.382	2.256	1/22/2009
$\lvert \Delta x^{2w} \rvert$	0.197 (0.055)	0.304 (0.109)	0.236 (0.066)	0.81 [0.847]	0.119	0.081	5/18/2007	4.525	6.422	1/22/2009
$\lvert \Delta x^{1m} \rvert$	0.221 (0.055)	0.272 (0.109)	0.326 (0.066)	1.50 [0.682]	0.091	0.046	5/18/2007	2.598	3.198	1/22/2009
$\lvert \Delta x^{2m} \rvert$	0.239 (0.055)	0.414 (0.109)	0.198 (0.066)	2.91 [0.405]	0.339	0.002	5/18/2007	0.372	6.057	8/6/2009
$\lvert \Delta x^{3m} \rvert$	0.248 (0.055)	0.446 (0.109)	0.224 (0.066)	3.22 [0.359]	0.239	0.082	5/18/2007	0.288	4.683	8/6/2009
$\lvert \Delta x^{4m} \rvert$	0.232 (0.055)	0.415 (0.109)	0.151 (0.066)	4.29 [0.232]	0.319	0.022	5/18/2007	1.397	4.609	8/6/2009
$\lvert \Delta x^{5m} \rvert$	0.257 (0.055)	0.372 (0.109)	0.245 (0.066)	1.09 [0.782]	0.207	0.256	5/18/2007	0.330	2.303	8/6/2009
$\lvert \Delta x^{6m} \rvert$	0.265 (0.055)	0.337 (0.109)	0.250 (0.066)	0.47 [0.925]	0.329	0.651	5/18/2007	0.382	0.978	8/6/2009
$\lvert \Delta x^{7m} \rvert$	0.250 (0.055)	0.287 (0.109)	0.238 (0.066)	0.15 [0.985]	0.189	0.319	5/18/2007	0.365	0.040	8/6/2009
$\lvert \Delta x^{8m} \rvert$	0.237 (0.055)	0.266 (0.109)	0.275 (0.066)	0.20 [0.978])	0.230	0.387	5/18/2007	0.291	0.551	8/6/2009
$\lvert \Delta x^{9m} \rvert$	0.236 (0.055)	0.221 (0.109)	0.281 (0.066)	0.35 [0.951]	0.711	1.049	5/18/2007	0.498	0.940	8/6/2009
$\lvert \Delta x^{10m} \rvert$	0.219 (0.055)	0.199 (0.109)	0.284 (0.066)	0.73 [0.866]	0.426	0.707	5/18/2007	0.439	1.911	8/6/2009
$\lvert \Delta x^{11m} \rvert$	0.212 (0.055)	0.214 (0.109)	0.249 (0.066)	0.19 [0.979]	0.650	1.042	5/18/2007	0.431	1.608	8/6/2009
$\lvert \Delta x^{12m} \rvert$	0.209 (0.055)	0.220 (0.109)	0.274 (0.066)	0.58 [0.900]	0.411	0.617	5/18/2007	0.590	2.040	8/6/2009
Mean	0.232 (0.055)	0.306 (0.109)	0.249 (0.066)							
	W_{pre}: 1.58 [0.999]	**W_c: 5.20 [0.983]**	**W_{post}: 16.49 [0.285]**							
Panel B: Common long memory factors										
	BBLP – subsamples estimates			***Equality tests***	***HM persistence break test***					
	Pre-crisis	***Crisis***	***Post-crisis***	$W_{f,3}$	HM_b	$HM_{max,b}$	***Date***	HM_e	$HM_{max,e}$	***Date***
f_{v1}	0.240 (0.055)	0.379 (0.109)	0.268 (0.066)	1.28 [0.733]	0.220	0.604	9/7/2007	0.287	1.168	1/11/2008
f_{v2}	0.266 (0.055)	0.250 (0.109)	0.283 (0.066)	0.08 [0.994]	1.942	1.990	8/16/2007	0.528	1.677	12/4/2007
f_{v3}	0.190 (0.055)	0.158 (0.109)	0.253 (0.066)	0.79 [0.853]	0.317	0.488	12/8/2006	0.891	2.359	5/6/2009
Mean	0.232 (0.055)	0.262 (0.109)	0.268 (0.066)							
	$Wf_{,pre}$: 0.98 [0.612]	**$Wf_{,c}$: 16.16 [0.304]**	**$Wf_{,post}$: 16.49 [0.285]**							

In the Table the fractional differencing parameter, estimated using the Moulines and Soulier (1999) broad band log periodogram estimator (BBLP), with standard error in round brackets, is reported for the break-free OIS spread volatility series (Panel A) and for their first three principal components (Panel B) for various subsamples, assuming a first permanent break in the persistence parameter occurring in August 9 2007 and a second permanent break occurring in December 9 2008. The *pre-crisis* sample therefore corresponds to the period May 6 2002 through August 8 2007, the *crisis* sample to the period August 9 2007 through December 8 2008, and the *post-crisis* sample to the period December 9 2008 through August 3 2012. The Wald test for the null hypothesis of equal fractional differencing parameter across the term structure (W_s; *s*: *pre, c, post*) and across factors ($W_{f,s}$; *s*: *pre, c, post*), estimated mean values (*Mean*) for each subsample, as well as Wald tests for the null hypothesis of equal fractional differencing parameter across regimes for each maturity ($W_{i,3}$) and factor ($W_{f,3}$), are also reported, with p-values in square brackets. The results of the Hassler and Meller (2009) test (HM) are then reported with reference to the beginning of the *crisis* (HM_c) and *post-crisis* (HM_{pc}) periods, and for the two break points selected by the HM statistic ($HM_{max,c}$ and $HM_{max,pc}$); tabulated critical values are 5.398, 6.904 and 10.287 for the 10%, 5% and 1% significance level, respectively. The results are for the various OIS spread maturities available, i.e., from 1-week ($\lvert \Delta x^{1w} \rvert$) to one-year ($\lvert \Delta x^{12m} \rvert$) and the three estimated common long memory factors (***f_{v1}, f_{v2}, f_{v3}***).

Table 5: OIS spreads, FI-HF-VAR estimates

	Proportion of explained variance						**Factor loadings**						**Proportion of explained variance**			
	break-free OIS spreads (x-b)			***break processes (b)***			***Common long memory factors***			***Common break processes***			***Conditional variance processes***			
	f_{m1}	f_{m2}	f_{m3}	μ_{m1}	μ_{m2}	μ_{m3}	f_{m1}	f_{m2}	f_{m3}	μ_{m1}	μ_{m2}	μ_{m3}		g_1	g_2	
Tot	**0.746**	**0.136**	**0.047**	**0.956**	**0.036**	**0.001**							***Tot***	**0.993**	**0.007**	
x^{1w}	0.37	0.49	0.09	0.44	0.40	0.12	0.020 (.006)	-0.063 (.009)	0.000 (.015)	0.051 (.002)	-0.117 (.010)	0.081 (.012)				
x^{2w}	0.51	0.42	0.03	0.49	0.39	0.09	0.023 (.006)	-0.056 (.009)	0.013 (.010)	0.058 (.002)	-0.116 (.007)	0.049 (.006)		h_1	h_2	h_3
x^{1m}	0.63	0.09	0.04	0.56	0.36	0.02	0.027 (.005)	-0.028 (.009)	0.051 (.013)	0.069 (.001)	-0.113 (.003)	-0.029 (.022)	g_1	0.836	0.997	0.976
x^{2m}	0.80	0.02	0.13	0.72	0.14	0.02	0.027 (.003)	-0.017 (.005)	0.017 (.006)	0.093 (.001)	-0.069 (.004)	-0.112 (.014)	g_2	0.1636	0.001	0.002
x^{3m}	0.86	0.01	0.09	0.81	0.08	0.03	0.029 (.003)	-0.014 (.004)	-0.003 (.006)	0.106 (.001)	-0.039 (.004)	-0.127 (.008)	**Factor loadings**			
x^{4m}	0.91	0.00	0.04	0.89	0.03	0.02	0.029 (.002)	-0.006 (.003)	-0.021 (.007)	0.114 (.001)	-0.004 (.003)	-0.108 (.008)	$\Lambda_{i,1}$	2.511	3.262	4.017
x^{5m}	0.90	0.02	0.01	0.92	0.01	0.01	0.028 (.002)	0.001 (0.003)	-0.027 (.007)	0.120 (.001)	0.023 (.003)	-0.081 (.009)	$\Lambda_{i,2}$	-0.406	0.034	0.226
x^{6m}	0.87	0.04	0.00	0.93	0.00	0.01	0.027 (.002)	0.007 (.003)	-0.028 (.007)	0.126 (.001)	0.048 (.002)	-0.058 (.010)	**FIGARCH parameters**			
x^{7m}	0.90	0.06	0.00	0.92	0.00	0.00	0.026 (.002)	0.011 (.003)	-0.020 (.004)	0.126 (.001)	0.064 (.001)	-0.019 (.008)	α	0.092 (.103)	0.000 (.)	0.000 (.)
x^{8m}	0.89	0.08	0.01	0.90	0.01	0.00	0.026 (.002)	0.013 (.002)	-0.011 (.002)	0.126 (.001)	0.079 (.001)	0.020 (.006)	β	0.292 (.144)	0.008 (.030)	0.076 (.043)
x^{9m}	0.87	0.10	0.02	0.87	0.02	0.00	0.025 (.002)	0.016 (.003)	-0.001 (.003)	0.126 (.001)	0.094 (.003)	0.055 (.005)	b	0.415 (.044)	0.395 (.014)	0.326 (.024)
x^{10m}	0.83	0.12	0.04	0.84	0.03	0.00	0.025 (.002)	0.019 (.003)	0.007 (.004)	0.126 (.001)	0.107 (.004)	0.087 (.004)				
x^{11m}	0.77	0.12	0.06	0.81	0.04	0.01	0.025 (.002)	0.021 (.004)	0.016 (.007)	0.125 (.001)	0.120 (.005)	0.117 (.005)	BIC_{cv}	0.556	-0.403	-1.452
x^{12m}	0.69	0.13	0.07	0.78	0.05	0.01	0.025 (.002)	0.023 (.004)	0.026 (.009)	0.124 (.001)	0.134 (.006)	0.150 (.006)	BIC_{sys}	-124.921		

The Table reports the results of the estimation of the FI-HF-VAR model, implemented using the OIS spread maturities available, i.e., from 1-week (x^{1w}) to one-year (x^{12m}). Columns 1-12 contain results for the conditional mean processes, while columns 14-16 for the conditional variance processes. In columns 1-6 the first row (*Tot*) shows the fraction of total variance explained by the first three principal components extracted from the break-free OIS spread level series (f_{m1}, f_{m2}, f_{m3}; column 1-3) and estimated break processes (μ_{m1}, μ_{m2}, μ_{m3}; column 4-6); the subsequent fifteen rows display the fraction of the variance of each individual series attributable to the extracted principal components for each set of series. In columns 14-16 the first row (*Tot*) shows the fraction of total variance explained by the first two principal components extracted from the conditional variance break processes for the common long memory factors (g_1, g_2); then, in in the subsequent two rows the proportion of variance of each individual conditional variance break process attributable to the extracted principal components is reported. Factor loadings for the common stochastic and deterministic factors in mean and variance are reported in column 7-12 and 14-16 ($\Lambda_{i,j}$), respectively. Parameters for the FIGARCH component in the conditional variance model are reported in column 14-16; finally, the BIC information criterion is reported for each conditional variance equation (BIC_{cv}) and for the whole system (BIC_{sys}). Robust standard errors are reported in round brackets.

Table 6: FI-HF-VAR model: Forecast error variance decomposition

		Pre-crisis sample							Crisis sample							Post-crisis sample						
		Common factors shocks				Idiosyncratic shocks			Common factors shocks				Idiosyncratic shocks			Common factors shocks				Idiosyncratic shocks		
	Horizon	f_1	f_2	f_3	*all*	*own*	*other*	*all*	f_1	f_2	f_3	*all*	*own*	*other*	*all*	f_1	f_2	f_3	*all*	*own*	*other*	*All*
x^{1w}	**1**	16.9	44.5	11.6	**73.0**	27.0	0.0	**27.0**	22.6	45.4	10.4	**78.5**	21.5	0.0	**21.5**	29.3	48.0	8.8	**86.0**	14.0	0.0	**14.0**
	20	18.6	42.1	10.9	**71.5**	28.5	0.0	**28.5**	29.2	55.2	6.2	**90.6**	9.4	0.0	**9.4**	32.0	59.7	5.3	**97.1**	2.9	0.0	**2.9**
x^{2w}	**1**	24.8	45.0	4.9	**74.7**	13.4	11.8	**25.3**	31.6	44.4	4.1	**80.2**	19.6	0.2	**19.8**	40.0	45.3	3.5	**88.8**	8.9	2.3	**11.2**
	20	28.7	44.9	4.9	**78.5**	11.4	10.1	**21.5**	39.3	51.9	2.4	**93.7**	6.3	0.1	**6.3**	41.9	54.4	2.1	**98.3**	1.3	0.3	**1.7**
x^{1m}	**1**	38.8	32.8	2.7	**74.3**	20.1	5.5	**25.7**	45.8	29.6	2.3	**77.7**	21.9	0.4	**22.3**	54.8	28.2	1.8	**84.8**	15.2	0.0	**15.2**
	20	33.1	23.9	2.0	**59.1**	32.2	8.7	**40.9**	51.5	30.7	1.2	**83.4**	16.3	0.3	**16.6**	59.0	34.0	1.1	**94.0**	6.0	0.0	**6.0**
x^{2m}	**1**	67.4	5.9	11.1	**84.3**	10.2	5.4	**15.7**	77.8	5.3	9.3	**92.3**	7.1	0.6	**7.7**	84.1	4.5	6.1	**94.7**	5.0	0.3	**5.3**
	20	67.3	5.1	9.9	**82.2**	12.1	5.7	**17.8**	86.1	5.6	4.9	**96.5**	3.2	0.3	**3.5**	89.2	5.5	3.9	**98.7**	1.3	0.1	**1.3**
x^{3m}	**1**	73.3	1.3	12.1	**86.7**	5.4	7.9	**13.3**	82.3	1.1	9.1	**92.6**	3.3	4.1	**7.4**	88.0	0.9	6.0	**94.9**	2.4	2.7	**5.1**
	20	74.8	1.1	11.0	**86.9**	5.3	7.8	**13.1**	91.1	1.2	5.0	**97.3**	1.2	1.5	**2.7**	93.8	1.1	4.0	**99.0**	0.5	0.6	**1.0**
x^{4m}	**1**	80.8	0.0	7.6	**88.3**	6.2	5.5	**11.7**	89.8	0.0	5.4	**95.2**	1.6	3.2	**4.8**	93.2	0.0	3.7	**96.9**	1.0	2.1	**3.1**
	20	81.8	0.0	6.7	**88.5**	6.1	5.4	**11.5**	95.4	0.0	2.8	**98.2**	0.6	1.2	**1.8**	97.0	0.0	2.3	**99.4**	0.2	0.4	**0.6**
x^{5m}	**1**	84.1	0.7	3.1	**87.9**	6.1	6.0	**12.1**	93.5	0.7	2.4	**96.6**	1.0	2.4	**3.4**	95.7	0.5	1.6	**97.8**	0.6	1.6	**2.2**
	20	80.6	0.6	2.6	**83.8**	8.3	7.9	**16.2**	96.5	0.6	1.2	**98.3**	0.5	1.2	**1.7**	97.8	0.6	1.0	**99.4**	0.2	0.4	**0.6**
x^{6m}	**1**	84.4	3.3	0.7	**88.4**	7.2	4.3	**11.6**	93.3	2.8	0.6	**96.7**	1.4	1.9	**3.3**	95.3	2.3	0.4	**97.9**	0.7	1.3	**2.1**
	20	79.2	2.7	0.5	**82.4**	11.2	6.4	**17.6**	95.1	2.7	0.3	**98.1**	0.8	1.1	**1.9**	96.4	2.7	0.2	**99.3**	0.2	0.4	**0.7**
x^{7m}	**1**	83.5	4.5	0.0	**87.9**	9.3	2.8	**12.1**	94.7	3.8	0.0	**98.5**	0.6	0.9	**1.5**	95.7	3.1	0.0	**98.8**	0.4	0.8	**1.2**
	20	80.0	3.7	0.0	**83.7**	12.7	3.6	**16.3**	95.7	3.6	0.0	**99.3**	0.3	0.4	**0.7**	96.1	3.5	0.0	**99.7**	0.1	0.2	**0.3**
x^{8m}	**1**	85.4	5.6	0.6	**91.6**	6.2	2.2	**8.4**	93.5	4.6	0.4	**98.6**	0.9	0.6	**1.4**	95.1	3.7	0.3	**99.1**	0.5	0.4	**0.9**
	20	86.2	4.9	0.5	**91.5**	6.2	2.2	**8.5**	94.8	4.5	0.2	**99.5**	0.3	0.2	**0.5**	95.3	4.3	0.2	**99.8**	0.1	0.1	**0.2**
x^{9m}	**1**	82.4	6.7	2.4	**91.5**	7.6	0.9	**8.5**	91.0	5.6	1.7	**98.4**	0.9	0.7	**1.6**	93.3	4.6	1.1	**98.9**	0.6	0.4	**1.1**
	20	84.9	6.0	2.2	**93.1**	6.2	0.7	**6.9**	93.2	5.5	0.9	**99.5**	0.3	0.2	**0.5**	93.8	5.4	0.7	**99.8**	0.1	0.1	**0.2**
x^{10m}	**1**	77.9	7.3	4.6	**89.7**	8.2	2.1	**10.3**	88.1	6.4	3.2	**97.6**	0.6	1.8	**2.4**	91.2	5.1	2.2	**98.5**	0.5	1.0	**1.5**
	20	80.9	6.6	4.1	**91.6**	6.6	1.7	**8.4**	91.4	6.3	1.7	**99.3**	0.2	0.5	**0.7**	92.3	6.1	1.4	**99.8**	0.1	0.2	**0.2**
x^{11m}	**1**	73.4	7.8	6.9	**88.1**	5.5	6.3	**11.9**	84.7	7.0	5.1	**96.8**	0.9	2.3	**3.2**	88.4	5.7	3.6	**97.7**	0.7	1.7	**2.3**
	20	74.2	6.9	6.1	**87.1**	6.1	6.8	**12.9**	89.1	7.0	2.7	**98.7**	0.4	0.9	**1.3**	90.5	6.8	2.2	**99.5**	0.2	0.4	**0.5**
x^{12m}	**1**	64.9	8.0	9.0	**81.9**	7.9	10.1	**18.1**	80.0	7.7	7.4	**95.0**	0.6	4.4	**5.0**	84.8	6.3	5.2	**96.3**	0.7	2.9	**3.7**
	20	62.6	6.7	7.5	**76.8**	10.4	12.8	**23.2**	85.9	7.8	3.8	**97.5**	0.3	2.2	**2.5**	88.1	7.7	3.2	**99.0**	0.2	0.8	**1.0**

The Table reports for each OIS spread level series, i.e., from 1-week (x^{1w}) to one-year (x^{12m}), the median forecast error variance decomposition at the 1- and 20-day horizons, obtained from the structural VMA representation of the FI-HF-VAR model. Three subsamples are considered, i.e., the *pre-crisis* sample (May 6 2002 through August 8 2007), the *crisis* sample (August 9 2007 through December 8 2008) and the *post-crisis* sample (December 9 2008 through August 3 2012). For each OIS spread series and subsample, the percentage of forecast error variance attributable to each common factor shock (f_1, f_2 and f_3) and their sum (*all*), as well as to the own idiosyncratic shock (*own*), the sum of the other idiosyncratic shocks (other), and all the idiosyncratic shocks jointly (all), are reported.

Table 7: Out of sample forecasting analysis

Panel A: Unemployment rate changes														
Step	NAIVE	AR	B	B1	B2	F	F1	F2	F3	A1	A2	A3	C	CF
CC														
1	0.449	0.411	0.426	0.422	0.412	0.586	0.515	0.549	0.475	0.614	0.602	0.580	0.670	**0.632**
3	0.550	0.508	0.536	0.552	0.513	0.748	0.623	0.777	0.480	0.692	0.792	0.758	0.808	**0.809**
6	0.540	0.401	0.531	0.499	0.411	0.729	0.519	0.793	0.344	0.619	0.732	0.732	0.755	**0.859**
12	0.493	0.142	0.514	0.392	0.159	0.557	0.295	0.638	0.090	0.376	0.584	0.613	0.559	**0.696**
RMSFE														
1	0.239	0.213	0.207	0.207	0.211	0.185	0.193	0.196	0.206	0.178	0.180	0.200	**0.167**	0.177
3	0.600	0.502	0.471	0.460	0.506	0.368	0.431	0.410	0.508	0.400	0.359	0.449	**0.322**	**0.322**
6	1.189	1.032	0.925	0.900	1.036	0.818	0.911	0.763	1.011	0.880	0.684	0.892	0.726	**0.570**
12	2.448	2.047	1.683	1.737	2.068	1.878	2.012	1.547	2.011	2.661	**1.530**	1.773	1.780	1.991
U														
1	0.492	0.509	0.504	0.508	0.507	0.445	0.463	0.476	0.489	0.411	0.446	0.478	**0.407**	0.414
3	0.449	0.436	0.433	0.427	0.437	0.339	0.378	0.398	0.475	0.343	0.350	0.394	**0.271**	0.279
6	0.461	0.479	0.450	0.446	0.479	0.370	0.421	0.377	0.505	0.386	0.354	0.418	0.307	**0.246**
12	0.499	0.589	0.493	0.507	0.590	0.490	0.519	0.445	0.603	0.539	0.412	0.498	0.459	**0.402**

Panel B: Industrial production growth rate														
Step	NAIVE	AR	B	B1	B2	F	F1	F2	F3	A1	A2	A3	C	CF
CC														
1	0.441	0.458	0.486	0.483	0.402	0.589	0.463	**0.625**	0.490	0.467	0.588	0.592	0.555	0.582
3	0.557	0.483	0.614	0.563	0.495	0.732	0.517	0.770	0.509	0.608	0.686	**0.771**	0.664	0.678
6	0.569	0.311	0.534	0.434	0.336	0.671	0.405	**0.706**	0.325	0.483	0.569	0.675	0.547	0.667
12	0.407	0.010	0.402	0.246	0.048	0.459	0.115	**0.462**	-0.004	0.162	0.275	0.415	0.258	0.435
RMSFE														
1	1.163	0.985	0.994	0.965	1.021	0.917	0.994	**0.895**	1.009	1.009	0.930	0.968	0.916	0.928
3	2.839	2.281	2.087	2.137	2.312	**1.858**	2.257	1.909	2.290	2.266	1.899	2.063	1.977	2.090
6	5.546	4.768	4.324	4.354	4.730	4.022	4.771	**3.857**	4.758	5.261	3.944	4.228	4.272	4.827
12	12.53	8.785	8.202	8.300	8.992	11.07	8.819	**7.591**	8.820	15.81	8.124	8.285	8.844	14.37
U														
1	0.521	0.558	0.523	0.551	0.559	0.463	0.533	0.463	0.508	0.527	0.509	0.513	0.491	**0.461**
3	0.476	0.502	0.459	0.498	0.497	**0.382**	0.482	0.427	0.508	0.435	0.448	0.419	0.405	0.395
6	0.480	0.577	0.508	0.540	0.567	**0.414**	0.536	0.447	0.595	0.504	0.497	0.473	0.472	0.429
12	0.581	0.699	0.569	0.625	0.687	0.572	0.672	**0.560**	0.717	0.683	0.607	0.581	0.644	0.615

Panel C: Inflation rate														
Step	NAIVE	AR	B	B1	B2	F	F1	F2	F3	A1	A2	A3	C	CF
CC														
1	0.588	0.338	0.381	0.402	0.394	0.591	0.378	0.533	0.598	0.371	0.511	0.418	0.350	**0.604**
3	**0.336**	0.162	0.111	0.103	0.180	0.120	-0.032	0.175	0.146	0.091	0.071	0.203	0.009	0.097
6	**0.085**	0.080	-0.079	-0.077	0.043	-0.079	-0.213	-0.039	0.083	-0.027	-0.031	0.054	-0.160	-0.115
12	-0.130	-0.135	-0.409	-0.368	-0.312	-0.247	-0.111	-0.426	**0.071**	-0.116	-0.218	-0.188	-0.248	-0.202
RMSFE														
1	0.460	0.435	0.438	0.428	0.421	0.382	0.438	0.397	**0.364**	0.468	0.400	0.421	0.455	0.376
3	1.548	1.077	1.104	1.093	**1.072**	1.137	1.197	1.157	1.119	1.254	1.143	1.142	1.256	1.230
6	3.238	1.672	1.714	1.690	**1.645**	1.818	1.808	1.839	1.715	2.070	1.841	1.845	2.044	2.140
12	6.243	2.067	2.087	2.079	**2.035**	2.463	2.198	2.346	2.101	3.323	2.431	2.418	2.616	3.571
U														
1	0.498	0.554	0.535	0.526	0.539	0.429	0.535	0.455	0.438	0.529	0.469	0.514	0.533	**0.426**
3	0.616	0.559	0.577	0.585	0.568	0.592	0.641	0.545	0.565	0.590	0.566	**0.537**	0.633	0.607
6	0.721	**0.519**	0.559	0.579	0.539	0.569	0.590	0.538	0.524	0.608	0.543	0.520	0.622	0.609
12	0.817	**0.415**	0.469	0.467	0.440	0.504	0.461	0.451	0.424	0.600	0.461	0.445	0.526	0.616

The Table reports the results of the out of sample forecasting analysis for the unemployment rate (in changes; Panel A), the industrial production growth rate (Panel B) and the CPI inflation rate (Panel C), at different horizons, i.e., 1-, 3-, 6- and 12-month; the forecasting sample is from August 2007 through July 2012. The reported statistics are the simple correlation coefficient between actual and forecasted values (CC), the root mean square forecast error (RMSFE) and the Theil's *IC* coefficient. Forecasts are generated from AR/VAR models with up to 5-lags; the best outcome for each forecasting indicator is then reported in the table for any horizon. In addition to the "no change" forecasting model (NAIVE) and the autoregressive model, including information about the own target variable only (AR), VAR models for the target variable and various indicators are employed, i.e., the B model, including the Federal funds rate and the term spread; the B1 model, including the Federal funds rate only; the B2 model, including the term spread only; the F model, including the estimated level, slope and curvature factor conditional means; the F1 model, including the estimated level factor conditional mean only; the F2 model, including the estimated slope factor conditional mean only; the F3 model, including the estimated curvature factor conditional mean only; the A1 model, including the corporate spread; the A2 model, including the TED spread; the A3 model, including the mortgage spread; the C model, including the composite indicator constructed from the common component in the estimated level factor and the TED, corporate and mortgage spreads (FRAG); the CF model, including FRAG and the estimated slope and curvature factor conditional means. The best outcome for the various statistics is highlighted in bold.

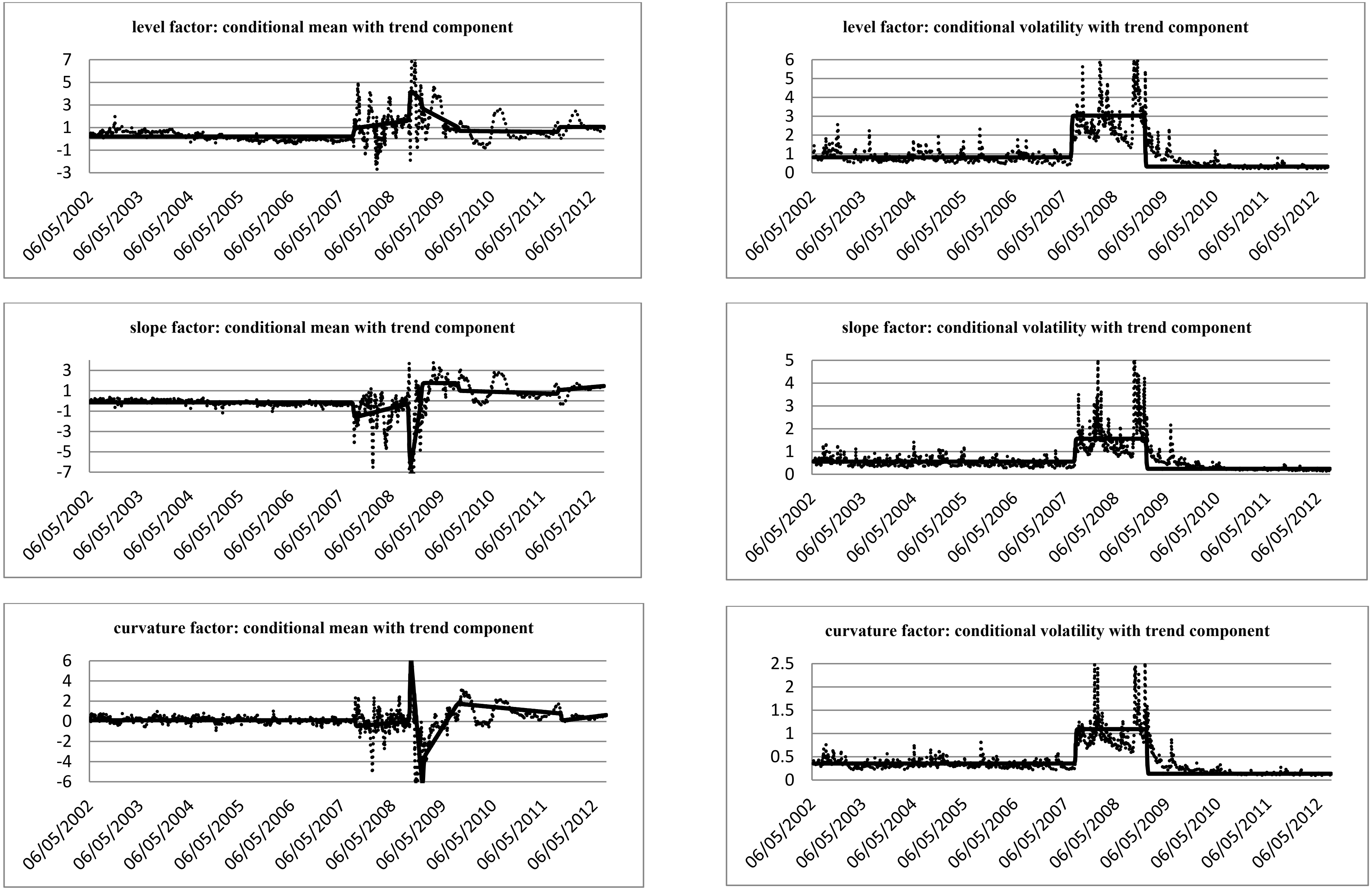

Figure 1: FI-HF-VAR model estimates of common factors in mean and variance.

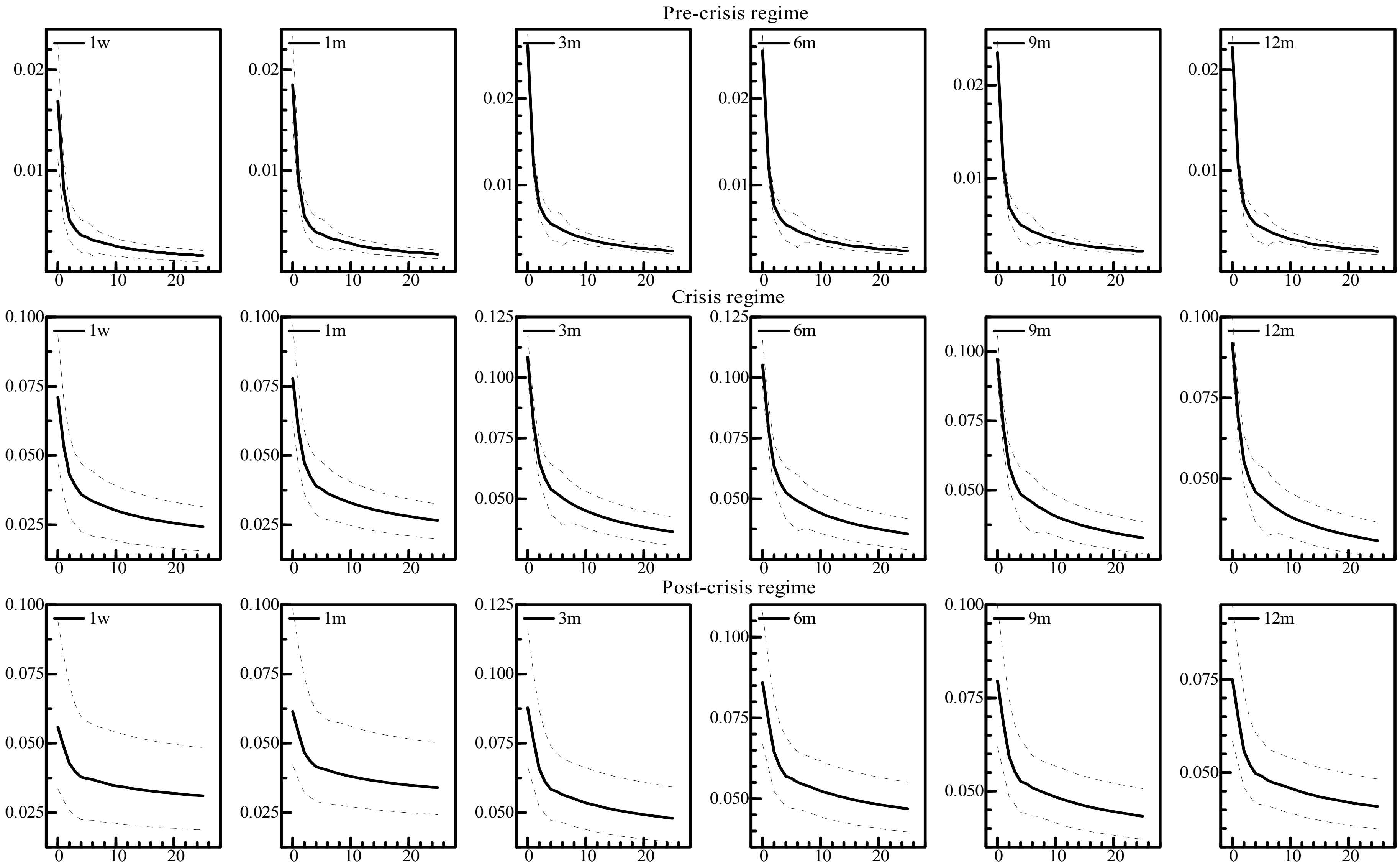

Figure 2: Impulse responses to 1 standard deviation level factor shock for various of OIS spread level series, from 1-week (1w) to 12-month (12m); top plots refer to the pre-crisis period, center plots to the crisis period and bottom plots to the post-crisis period.

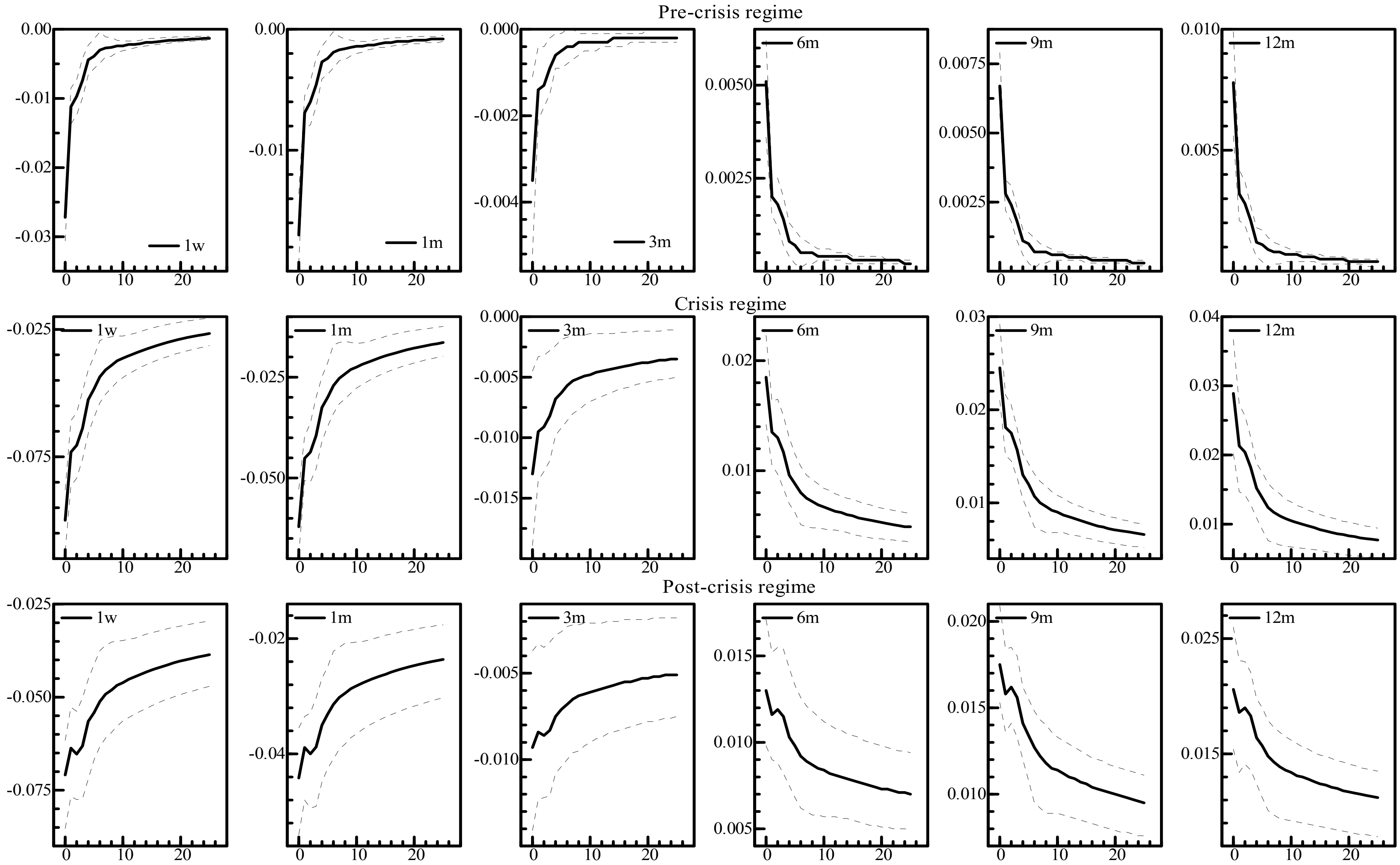

Figure 3: Impulse responses to 1 standard deviation slope factor shock for various of OIS spread level series, from 1-week (1w) to 12-month (12m); top plots refer to the pre-crisis period, center plots to the crisis period and bottom plots to the post-crisis period.

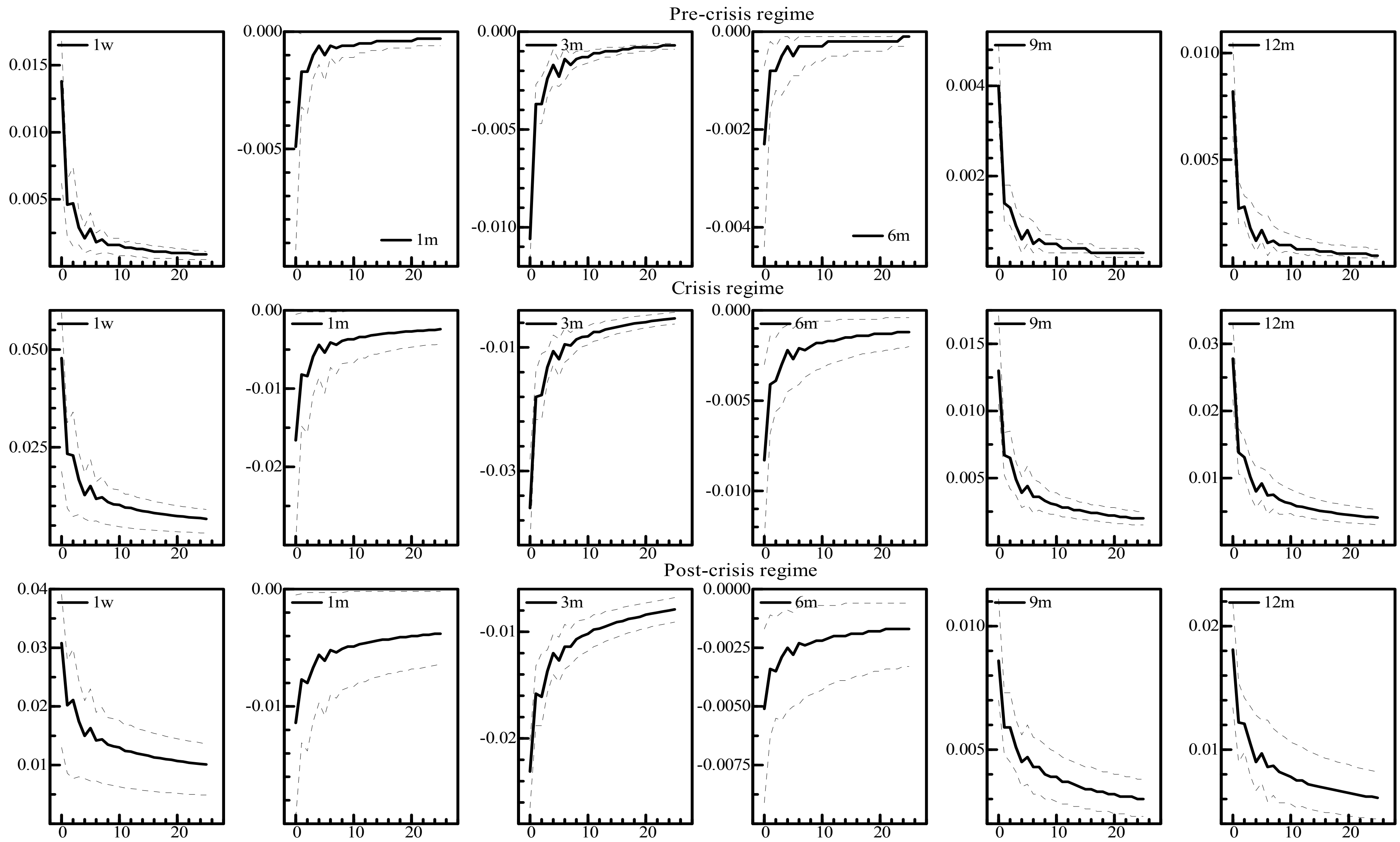

Figure 4: Impulse responses to 1 standard deviation curvature factor shock for various of OIS spread level series, from 1-week (1w) to 12-month (12m); top plots refer to the pre-crisis period, center plots to the crisis period and bottom plots to the post-crisis period.

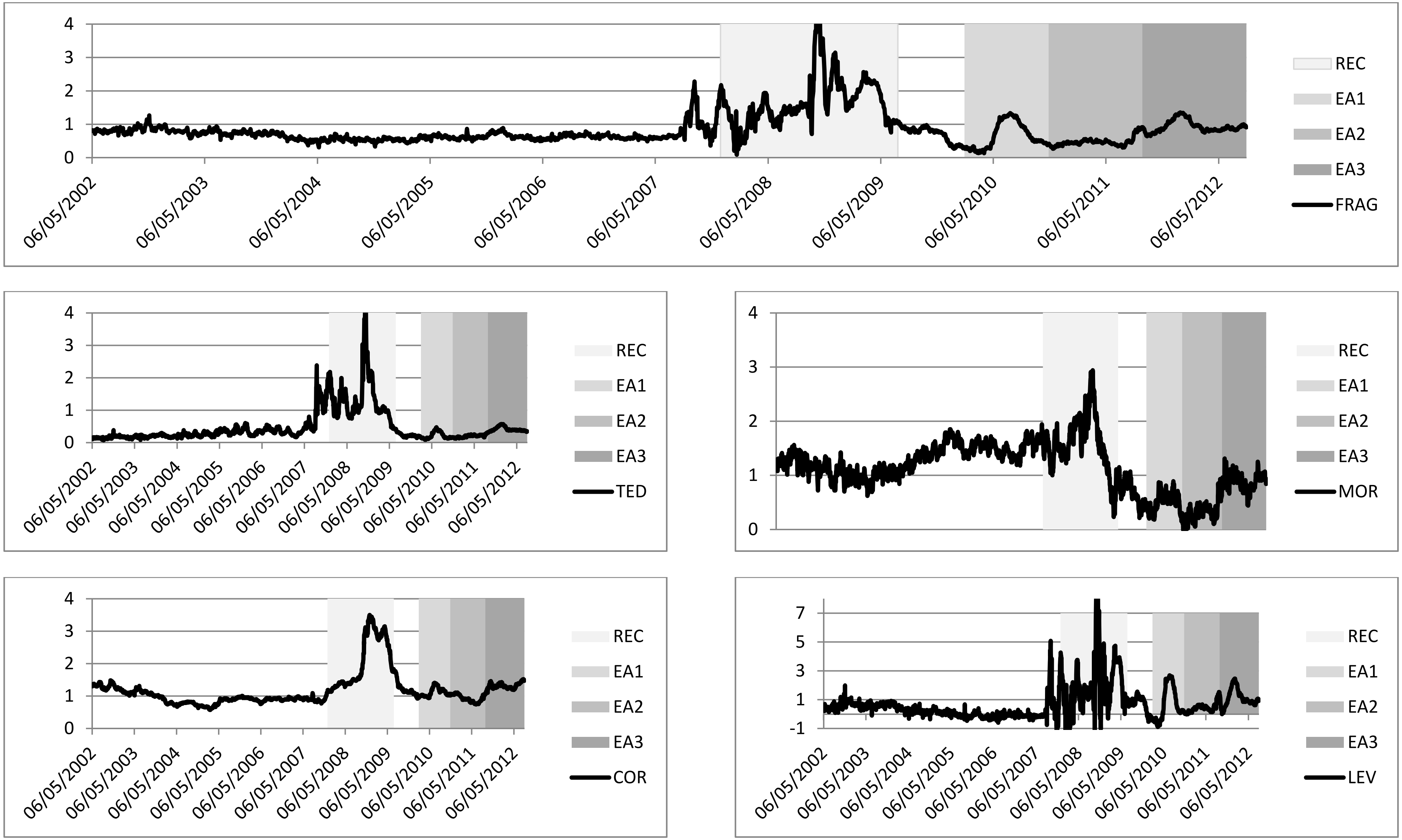

Figure 5: Risk measures: composite fragility indicator (FRAG), TED spread (TED), corporate spread (COR), OIS spreads level factor (LEV), mortgage spread (MOR); shaded areas refer to the December 2007 through June 2009 US recession (REC) and the three phases of the euro area sovereign debt crisis, i.e. Febraury 2010 through October 2010 (EA1), November 2010 through August 2011 (EA2) and September 2011 through July 2012 (EA3).

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N° 5/01	Vincenzo Andrietti	Occupational Pensions and Interfirm Job Mobility in the European Union. Evidence from the ECHP Survey
N° 4/01	Peter Diamond	Towards an Optimal Social Security Design
N° 3/00	Emanuele Baldacci Luca Inglese	Le caratteristiche socio economiche dei pensionati in Italia. Analisi della distribuzione dei redditi da pensione (only available in the Italian version)
N° 2/00	Pier Marco Ferraresi Elsa Fornero	Social Security Transition in Italy: Costs, Distorsions and (some) Possible Correction
N° 1/00	Guido Menzio	Opting Out of Social Security over the Life Cycle