Economics Letters 159 (2017) 153–156

Contents lists available at ScienceDirect

Economics Letters

journal homepage: www.elsevier.com/locate/ecolet

Beyond spreads: Measuring sovereign market stress in the euro area[☆]

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ARTICLE INFO

Article history:
Received 8 July 2016
Accepted 28 June 2017
Available online 3 August 2017

JEL classification:
C43
E44
F45
G01
H63

Keywords:
Financial stress index
Systemic risk
Sovereign debt crisis
Spillover index

ABSTRACT

We develop a novel composite indicator to measure sovereign bond market stress in the euro area. The indicator integrates yield and liquidity spreads along with volatility into an overall measure of sovereign market stress. An application to the spillover literature suggests that stress mainly originates from a few countries, but that spillover patterns also vary over time.

1. Introduction

This paper proposes a composite indicator of sovereign bond market stress in the euro area: the Composite Indicator of Systemic Sovereign Stress (SovCISS). Sovereign stress is important to quantify as tensions in sovereign bond markets – due to their benchmark status and sheer size – can easily spill over to other market segments and thereby create systemic risks for the financial system as a whole. Sovereign market stress is most often measured by the yield spread between a country's bond and a safe reference security (see, e.g., Cronin et al., 2016). However, bond market stress can also reveal itself in higher volatility and lower liquidity; incorporating these two stress symptoms along with yield spreads into an overall measure of sovereign market stress thus makes sense to begin with.

We construct a SovCISS for the euro area as a whole that aggregates information from eleven member states. This makes it possible to monitor euro area wide sovereign tensions with one single indicator. To our best knowledge, this is not yet done in the literature. In addition, we decompose the euro area indicator into eleven country-specific ones. The SovCISS builds on the methodological concept of the Composite Indicator of Systemic Stress (CISS) from Holló et al. (2012) who apply basic portfolio theory to the aggregation of market-specific stress indicators into a composite index.

In an empirical application, we adopt the framework proposed by Diebold and Yilmaz (2009, 2012) to assess sovereign stress spillovers across euro area countries. While the literature identifies different spillover patterns for returns (or risk spreads) versus volatilities (Diebold and Yilmaz, 2009), the SovCISS enables an integrated analysis of the cross-country transmission of both stress symptoms.

2. Statistical methodology and data

The construction of the SovCISS involves three major steps, namely the selection of the input series, their transformation, and their aggregation into the composite index (see Holló et al., 2012),

2.1. Data

The SovCISS consists of a range of indicators capturing certain symptoms of a market in distress. We measure stress symptoms along three dimensions: (i) *risk spreads* capture the pricing of credit and liquidity risk of the underlying bonds; (ii) *yield volatilities* measure the degree of fragility and uncertainty prevailing in the market; and (iii) *bid–ask spreads* reflect transaction costs and market liquidity conditions more generally. These three stress dimensions are not completely independent from each other. However, for our

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[☆] The views expressed in this paper are those of the authors and do not necessarily reflect those of the European Central Bank.

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http://dx.doi.org/10.1016/j.econlet.2017.06.042
0165-1765/

purpose it suffices that they tend to correlate more strongly in crisis times than under normal circumstances. In fact, such time-varying correlation patterns provide the rationale for the portfolio-theoretic aggregation approach we aim at in this paper.

Risk spreads are measured as the absolute difference between a government bond yield and the euro interest rate swap rate for 2-year and 10-year contracts. Whenever 2-year bonds are not available (Finland, Greece and Ireland), we use 3-year yields instead.[1] *Volatility* is computed as absolute daily yield changes for both maturities. *Bid–ask spreads* for 2-year and 10-year bonds show as mid-price percentages. All indicators are computed as weekly averages. Raw interest rates are collected from Datastream, bid and ask prices from Reuters.

This selection yields six stress components for each of eleven euro area members states, namely Austria (AT), Belgium (BE), Germany (DE), Spain (ES), Finland (FI), France (FR), Greece (GR), Ireland (IE), Italy (IT), Netherlands (NL) and Portugal (PT). Our data spans from September 2000 to March 2016.

2.2. Transformation

We transform each input series by applying the probability integral transform (PIT). The theorem of the PIT states that for any continuous random variable X with cumulative distribution function (CDF) $F(x)$, the random variable defined by $Y = F(X)$ has a standard uniform distribution regardless of the form of the original distribution (Cassela and Berger, 2002): $Y = F(X) \sim U(0, 1)$.

In practice we work with the discontinuous sample analogue of the CDF, the empirical CDF. Assume we have a sample of T observations of a raw indicator $x = (x_1, x_2, \ldots, x_T)$. The observations are first ranked in ascending order, i.e. $x_{[1]} \leq x_{[2]} \leq \cdots \leq x_{[T]}$, where $x_{[1]}$ represents the sample minimum and $x_{[T]}$ the maximum. The transformed indicators y_t result from replacing each original observation x_t with its respective empirical CDF value $F(x_t)$. That value can be computed as the ranking number r of observations not exceeding a particular value x_t, divided by the total number of observations T:

$$y_t = F(x_t) := \begin{cases} \dfrac{r}{T} \text{ for } x_{[r]} \leq x_t < x_{[r+1]},\, r = 1, 2, \ldots, T-1 \\ 1 \text{ for } x_t \geq x_T. \end{cases} \tag{1}$$

In the case of tied observations, that is when m identical observations share the same rank r, the functional value assigned to each of them is computed as $((r + 1) + (r - m))/2T$. All transformed indicators are unit-free and approximately uniform distributed over the range (0, 1].

The PIT possesses the distinct advantage that whatever is the original distribution of the raw indicators, the transformed indicators are homogeneous in terms of scale and distribution. Since it involves the use of order statistics, the PIT also robustifies the composite indicator against the addition of outliers in sub-sample computations. This property is important as we compute the SovCISS "in real time" over an expanding data window as from 25 December 2006. Moreover, the distributional homogeneity helps avoid that the dynamics of the composite indicator is dominated by those components whose original distribution function is likely to produce more observations far away from the sample mean. On the downside, the PIT implies losing the extra information contained only in the cardinal scale of the original data.

2.3. Aggregation 1: SovCISS for individual countries

The SovCISS for country $c = AT, \ldots, PT$ is computed as:

$$SovCISS_{c,t} = \sqrt{(w \circ s_{c,t})\Omega_{c,t}(w \circ s_{c,t})'}, \tag{2}$$

with $w = (1/6, \ldots, 1/6)$ a 1×6 vector of equal indicator weights, $s_{c,t}$ a 1×6 vector containing the transformed stress indicators $s_{c,j,t}$ with $j = 1, \ldots, 6$ and country index c; $w \circ s_{c,t}$ denotes the element-wise product of both vectors; and $\Omega_{c,t}$ the symmetric 6×6 matrix collecting time-varying (Spearman's) rank-correlations between the $s_{c,j,t}$ for country c. The time-varying cross-correlations are computed from an exponentially-weighted moving average (EWMA) estimate of the variance–covariance matrix $H_{c,t}$ of the demeaned stress indicators $\widetilde{s}_{c,t} = (s_{c,t} - 0.5)$, where the smoothing parameter or decay factor λ is set at 0.93 which is rather conventional for daily and weekly data (see Engle, 2002):

$$H_{c,t} = \lambda H_{c,t-1} + (1 - \lambda)\widetilde{s}_{c,t}\widetilde{s}_{j,t}. \tag{3}$$

The elements $\omega_{c,ij,t}$ of correlation matrix $\Omega_{c,t}$ are simply computed from the elements $h_{c,ij,t}$ of $H_{c,t}$ as $\omega_{c,ij,t} = h_{c,ij,t}/\sqrt{h_{c,ii,t}}\sqrt{h_{c,jj,t}}$.

2.4. Aggregation 2: SovCISS for the euro area as a whole

The SovCISS for the euro area as a whole is computed in the same way by stacking all the country-specific individual stress indicators into a 1×66 vector $s_{EA,t}$ and estimating a 66×66 matrix $\Omega_{EA,t}$ of cross-correlations between all of them:

$$SovCISS_{EA,t} = \sqrt{(w \circ s_{EA,t})\Omega_{EA,t}(w \circ s_{EA,t})'}. \tag{4}$$

The weights w attached to each $s_{EA,j,t}$ is set to 1/66 in case of equal weights, or to $(1/6) \cdot (\overline{GDP}^r_c / \sum_{k=AT,\ldots,PT} \overline{GDP}^r_k)$ for a SovCISS with real GDP weights; these weights are held constant and proportional to the average relative real GDP of each country from 1999:Q1 to 2012:Q4. Alternatively, taking a weighted or unweighted average of the eleven country-specific indices also delivers a euro area aggregate SovCISS.

3. Empirical implementation

Fig. 1 plots the SovCISS for eleven euro area countries – panel (a) – and for the euro area as a whole—panel (b).[2] The upper panel illustrates the rather homogeneous path of sovereign stress across euro area countries from the beginning of the sample until around mid-2009. Since then, developments in sovereign stress become much more dispersed, partly following opposing trends. The lower panel displays the euro area aggregate SovCISS which we compute in four different ways. The first two apply the full 66×66 matrix of cross-correlations $\Omega_{EA,t}$ according to Eq. (4), one using real GDP-weights for the cross-country aggregation (black line) and one with equal country weights (blue line). The two series begin to diverge only from the start of the sovereign debt crisis which hit some of the smaller countries particularly hard. More recently, this gap closes again at around pre-crisis levels of the SovCISS, which suggests a general convergence and dissipation of sovereign stress across euro area member states. However, simple averages of the eleven country SovCISSes (either with equal-weights or GDP-weights—in red and green respectively) recognises

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[1] As from March 2012, the Greek SovCISS includes only three input series derived from 10-year bonds since 3-year bonds stopped being traded.

[2] Monthly updates of the SovCISS series can be obtained from the ECB's Statistical Data Warehouse: http://sdw.ecb.europa.eu/browse.do?node=9551138. The published series, however, are computed from Eqs. (4) and (2) without taking the square root; they can therefore be thought of variance-equivalent rather than volatility-equivalent CISS indicators (see Holló et al., 2012).