

European Economic and Monetary Union Sovereign Debt Markets

Abmet Sensoy
Erk Hacıhasanoglu
Ahmed Rostom



WORLD BANK GROUP

Finance and Markets Global Practice Group

January 2015

Abstract

This paper focuses on developments in the European Economic and Monetary Union sovereign debt markets in the past decade. The first part analyzes the integration and segmentation structure of the bond markets of the Economic and Monetary Union before and after the sovereign debt crisis, by introducing the novel concept of correlation-based stable networks. Accordingly, a fair integration is observed between the bond markets during the pre-crisis period. However, a strict segmentation emerges, separating the members struggling with debt problems and the ones with relatively strong fiscal performances during

the sovereign debt turmoil. The segmentation structure is clearly visualized, revealing the potential paths for crisis and recovery transmission in the future. In the second part, the paper comments on the recent decreasing trend in Economic and Monetary Union member bond yields and their increasing degree of co-movement. Accordingly, the paper argues that these changes do not depend on the fiscal performances of the member countries, but depend on the illusion of quality that appeared with the Fed (U.S. Federal Reserve) tapering signals in early 2013.

This paper is a product of the Finance and Markets Global Practice Group. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at <http://econ.worldbank.org>. The authors may be contacted at arostom@worldbank.org.

The Policy Research Working Paper Series disseminates the findings of work in progress to encourage the exchange of ideas about development issues. An objective of the series is to get the findings out quickly, even if the presentations are less than fully polished. The papers carry the names of the authors and should be cited accordingly. The findings, interpretations, and conclusions expressed in this paper are entirely those of the authors. They do not necessarily represent the views of the International Bank for Reconstruction and Development/World Bank and its affiliated organizations, or those of the Executive Directors of the World Bank or the governments they represent.

European Economic and Monetary Union Sovereign Debt Markets

Ahmet Sensoy (a), Erk Hacıhasanoğlu (b), Ahmed Rostom (c)

(a) Specialist, Research & Business Development Department, Borsa Istanbul

(b) Group Manager, Research & Business Development Department, Index & Data Department, Borsa Istanbul

(c) Financial Sector Specialist, Finance and Market Global Practice, The World Bank

JEL Classification: D08, E44, G02, G12,

Keywords: Sovereign Debt, European Economic and Monetary Union, Network Analysis, Monetary Policy, Tapering.

1. Introduction

The creation of the European Economic and Monetary Union (EMU) in January 1999 and the launch of the single currency “euro” led to a convergence of government bond yields of eurozone countries, with remaining yield spreads being mainly attributed to differences in the levels of idiosyncratic credit and liquidity risks. A byproduct was that not only the yields converged, but an overall increase in co-movements in euro area bond markets was also observed, suggesting a high degree of integration (Ehrmann et al., 2011). Moreover, unemployment and inflation have fallen below pre-EMU levels in most participating countries (Gruner, 2010). In brief, EMU was a big success story and it performed much better than many economists and academics predicted.¹

However, after 10 years of stability, the collapse of Lehman Brothers triggered severe tensions in financial markets worldwide, including the eurozone bond market. The financial turmoil turned into a global financial crisis which directed attention to the macroeconomic and fiscal imbalances within EMU countries. During the period of stability, markets seemed to turn a blind eye to the possibility that governments might default (Beirne and Fratscher, 2013). As a consequence, the low yield spreads of government bonds issued by the member states of the EMU were no longer observed anymore (Sibbertsen et al., 2014), moreover their co-movement degree was rapidly decreasing. In fact, creditors have started to distinguish clearly between the different member states of the euro area (see Fig. 1). Eventually, the global financial crisis turned into a major sovereign debt crisis. Since then, European policymakers have been consistently taking measurements; although, whether these measurements are

¹For example, see Gruner and Hefeker (1999); Cukierman and Lippi (1999) for the papers with negative foresights on the performance of EMU prior to its introduction.

failure or success is a controversial subject.

In this study, we first try to display how investors have distinguished between the different EMU members during the sovereign debt crisis. In particular, by introducing the concept of “*correlation based stable networks*”, we demonstrate the integration and segmentation structure of EMU bond markets before and after the debt crisis. Then, we reveal the potential paths for crisis/recovery transmission in the future. In the second part, we comment on a recent development in the behavior of EMU sovereign bond yields: Interestingly, since early 2013, bond yields of the struggling EMU members started to experience similar large decreasing trends and all EMU bond yields again tended to co-move in a great harmony. We focus on the co-movement part and ask the following questions: (i) why do we observe such a change? and (ii) what happens next?

In the rest, Section 2 presents the data and the methodologies used in this paper. Section 3 displays the results and finally, Section 4 concludes.

2. Data and Methodology

In order to carry out our analysis, we use daily 10-year benchmark government bond yields (obtained from Thomson Reuters datastream) for a sample of eleven countries; France, Germany, Italy, Belgium, Netherlands, Ireland, Spain, Portugal, Austria, Finland and Greece. The analysis spans a time period ranging from March 1, 2002 (end of dual circulation period in Greece) until May 2, 2014.

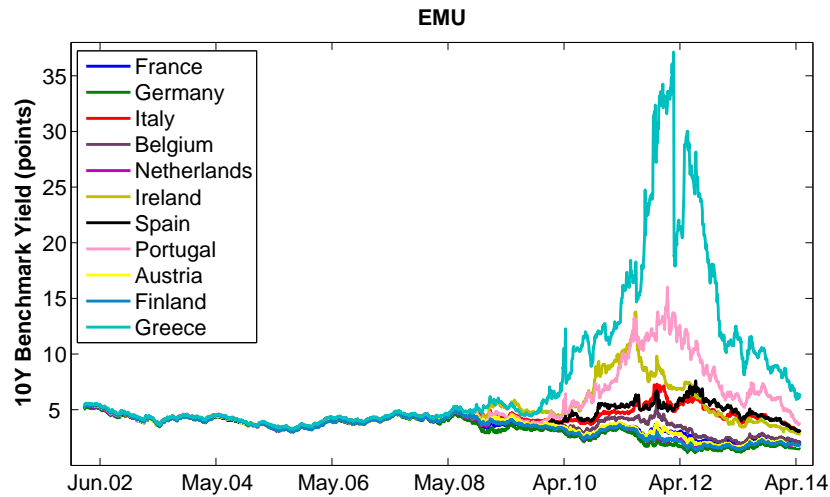


Figure 1: EMU sovereign bond yields from March 2002 to May 2014

Bond yield convergence in EMU is validated by Fig. 1 for the first 10 years of the eurozone. However, it does not tell much about the exact timing and the exact amount of yield co-movements. For that purpose, we apply the consistent dynamic conditional correlation model (cDCC) of Aielli (2013) to track the time-varying co-movement degree. The methodology is explained in the following sub-section.

2.1. Consistent dynamic conditional correlation

The dynamic correlations are estimated by the cDCC. At first, we take the daily changes in bond yields (BY) as the first differences for each member country i i.e.

$$r_{i,t} = \Delta BY_{i,t} = BY_{i,t} - BY_{i,t-1}$$

For a precise model estimation, we take out the days when more than half of the markets are closed. Moreover, the highest and lowest five daily changes of each market are removed from the dataset to get rid of outliers.

To remove the serial correlation effects (which is present in all daily changes) and obtain the zero mean residuals, we first estimate the following mean equation

$$r_t = \mu + \varphi r_{t-1} + \varepsilon_t \quad (1)$$

where $r_t = [r_{1,t}, \dots, r_{n,t}]'$ is the vector of n bond yield daily changes, μ is a vector of constants with length n , φ is the coefficient vector corresponding to autoregressive terms and $\varepsilon_t = [\varepsilon_{1,t}, \dots, \varepsilon_{n,t}]'$ is the vector of residuals.

In the next step, we obtain the conditional volatilities $h_{i,t}$ from the univariate FIAPARCH(1, d ,1) model for an extended flexibility. In particular, we estimate the following

$$h_{i,t}^{\delta/2} = \omega + \{1 - [1 - \beta L]^{-1}(1 - \phi L)(1 - L)^d\}(|\varepsilon_{i,t}| - \gamma \varepsilon_{i,t})^\delta \quad (2)$$

where $\omega \in (0, \infty)$, $|\beta|$ and $|\phi| < 1$, $0 \leq d \leq 1$, γ is the leverage coefficient and δ is the parameter for the power term that takes finite positive values, while $(1 - L)^d$ is the financial differencing operator expressed in terms of a hypergeometric function (see Conrad et al. (2008) for the expression of this function).

To consider cDCC modeling, we start by reviewing the DCC model of Engle (2002). Assume that $E_{t-1}[\varepsilon_t] = 0$ and $E_{t-1}[\varepsilon_t \varepsilon_t'] = H_t$, where $E_t[\cdot]$ is the

conditional expectation on $\varepsilon_t, \varepsilon_{t-1}, \dots$. The asset conditional covariance matrix H_t can be written as

$$H_t = D_t^{1/2} R_t D_t^{1/2} \quad (3)$$

where $R_t = [\rho_{ij,t}]$ is the asset conditional correlation matrix and the diagonal matrix of the asset conditional variances is given by $D_t = \text{diag}(h_{1,t}, \dots, h_{n,t})$. Engle (2002) models the right hand side of Eq.(3) rather than H_t directly and proposes the dynamic correlation structure

$$\begin{aligned} R_t &= \{Q_t^*\}^{-1/2} Q_t \{Q_t^*\}^{-1/2}, \\ Q_t &= (1 - a - b)S + a u_{t-1} u_{t-1}' + b Q_{t-1}, \end{aligned} \quad (4)$$

where $Q_t \equiv [q_{ij,t}]$, $u_t = [u_{1,t}, \dots, u_{n,t}]'$ and $u_{i,t}$ is the transformed residuals i.e. $u_{i,t} = \varepsilon_{i,t}/h_{i,t}$, $S \equiv [s_{ij}] = E[u_t u_t']$ is the $n \times n$ unconditional covariance matrix of u_t , $Q_t^* = \text{diag}\{Q_t\}$ and a, b are non-negative scalars satisfying $a + b < 1$. The resulting model is called DCC.

However, Aielli (2013) shows that the estimation of Q by this way is inconsistent since $E[R_t] \neq E[Q_t]$ and he proposes the following consistent model with the correlation driving process

$$Q_t = (1 - a - b)S + a\{Q_{t-1}^{*1/2} u_{t-1} u_{t-1}' Q_{t-1}^{*1/2}\} + b Q_{t-1} \quad (5)$$

where S is the unconditional covariance matrix of $Q_t^{*1/2} u_t$.

Finally, to consider the time varying group correlation of EMU bond yields, we take the average cDCC i.e.

$$\bar{\rho}_t = \frac{2}{n(n-1)} \sum_{i=1}^{n-1} \sum_{j=i+1}^n \rho_{ij,t} \quad (6)$$

2.2. Correlation based stable networks

If we consider our methodological approach as consisting of two main parts, the first one would be obtaining the dynamic conditional correlation matrix R_t . Following that, the second part is the analysis of networks constructed by the time-varying correlations. During recent years, networks have proven to be an efficient way to characterize and investigate a wide range of complex financial systems including stock, bond, commodity, foreign exchange and interbank lending markets.² Similarly, a correlation based network could be very useful in understanding the integration and segmentation structure of EMU bond markets in our case. Such an approach has not been used in the relevant literature before and we expect it to provide noteworthy implications regarding the subject. To be able to follow our approach, we first need to give some introductory context:

Suppose that an undirected and unweighted network N_t evolves in time and includes at most k nodes from the set $\{n_1, n_2, \dots, n_k\}$ on any given time step t . At that time t , let some (or all) of the nodes in the network be connected to each other according to some t -dependent criterion. As easily understood, in this construction, the nodes included in the network and the edges connecting these nodes need not be stable and are subject to change in time. Now, we introduce the following genuine definitions.

Definition 1: Let N_t be a dynamic network described as above. Let e_{ij} be an edge connecting specific nodes n_i and n_j and time variable t spans the set $\{t_1, t_2, \dots, t_m\}$. Suppose e_{ij} appears in the network s out of m times. Then

²For example, see Iori et al. (2008); Tola et al. (2008); Tumminello et al. (2010); Minoiu and Reyes (2013) for some of the noteworthy studies in recent years.

if $1 \geq \frac{s}{m} \geq p > 0$, e_{ij} is called a *p-stable edge* or *p-stable connection*.³ A network M consisting of only p -stable connections of N_t is called *p-stable network* of N_t .

Definition 2: Let R_t be the cDCC matrix defined in Section 2.1. At time t , let $\bar{\rho}(t)$ be the mean of the lower triangular part of R_t , and $\sigma(t)$ be its standard deviation. A correlation level $\rho_{ij}(t) \in R_t$ is called *c-strong* if $\rho_{ij}(t) \geq \bar{\rho}(t) + c \cdot \sigma(t)$ where the constant $c \geq 0$.^{4,5}

Then our approach is as follows: For a pre-determined strength level c , we construct a dynamic network N_t consisting of nodes connected by only c -strong correlations at time t , where nodes represent the sample countries. Next, for the considered time period, we construct M ; the p -stable network of N_t . For relatively high p values, we can intuitively state that members connected in M are integrated. As c -level is chosen higher, this integration degree gets stronger.

In the following section, we will study the integration/segmentation structure of the EMU bond markets by analyzing the p -stable connections. For the sake of simplicity in our setup, we introduce the following definition which will be our main focus throughout the rest of this study.

³It is clear that every p_1 -stable connection is also p_2 -stable for any $p_2 \leq p_1 \leq 1$.

⁴It would be naive to choose a fixed threshold level to determine if a correlation value is strong or not. Several studies in the literature have shown that correlations are time-varying and tend to increase in turbulent times. Therefore, a fixed choice would most likely introduce a bias depending on the global conditions. With our model, the threshold level is determined endogenously and updated everyday. Thus, possible bias arising due to changing global conditions is minimized.

⁵When $c < 0$, c -strong correlation levels become below the average. In order to consider a reasonable strength concept for correlations, minimum c should be taken as 0.

Definition 3: A network M is called *simply-stable*, if it only consists of p -stable connections of N_t obtained from c -strong correlations where $c = 0$ and $p = 0.5$.

This last definition associates the concept of stability with the observation of an average event at least half of the time which is, indeed, intuitive. (For future studies, the third definition can later be diversified as *super-stable* by imposing stronger connectivity and stability conditions.)

3. Results

Fig. 2 displays the average dynamic correlation between euro area bond yields. Accordingly, the early years of the EMU exhibit an almost perfect bond market integration with an average correlation estimate close to one, an indicator of a gain in importance of aggregated European factors over local country-specific ones. However, things change abruptly in the following years: In Fig. 2, we present two critical dates for the bond market dynamics in EMU. The first one is September 15, 2008, the date when Lehman Brothers collapsed. According to Fig. 1, this event does not have a colossal impact on government bond yields relative to the German Bund, however Fig. 2 clearly shows that the almost perfect correlation among EMU sovereign bond yields starts to deteriorate. The second date is November 5, 2009, the date when the Greek government revealed a revised budget deficit of 12.7% of GDP for 2009, which was double the previous estimate. This time, not only the average correlation deteriorates but also the sovereign yields and spreads relative to the German Bund rise sharply for most of the euro area countries.⁶

3.1. Network analysis

To see the effects of the sovereign debt crisis on the integration/segmentation structure of EMU bond markets, we need to split our time interval as *Phase 1* and *Phase 2*. In this step, we use the aforementioned two critical dates as splitters: Phase 1 is taken as the time interval between March 1, 2002 and September 14, 2008 (6.5 years), whereas Phase 2 covers from November 6, 2009 to May 2, 2014 (4.6 years).

In the following, Fig. 3 displays the simply stable networks in Phase 1 and

⁶Estimated model parameters can be found in Appendix A.

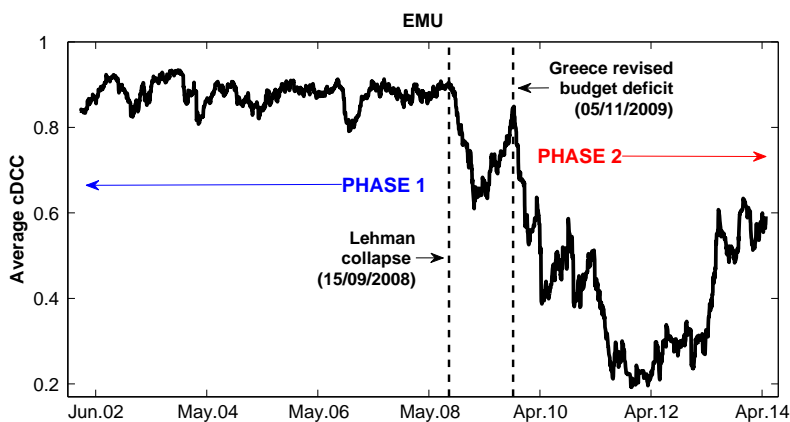


Figure 2: Average dynamic conditional correlation between EMU sovereign bond yields. Vertical lines denote two specific critical dates for the region.

Phase 2.⁷ In Phase 1, a high degree of integration is observed between EMU sovereign debt markets, i.e. almost every member is connected to another. However, strict segmentation is clearly visualized in Phase 2. There are two main clusters where in one of them, the members struggling with debt problems (denoted in red) are present. In the other cluster, we observe the countries with strong fiscal positions during the sovereign debt crisis. Moreover, Belgium, which is one of the two members having relative weak fiscal performances within this cluster (denoted in yellow), serves as a hub in the new segmented structure. Interestingly, Greece is not connected to any other member in Phase 2 which reveals that its debt market no longer belongs to the same asset class with others and currently stands as an outlier in the EMU. Interestingly, simply-stable networks show that the decrease in the overall correlation level in Phase 2 is not due to a general sparsity of EMU members. It is more likely to be

⁷The size of the circles in the figures do not have any economic interpretation and are chosen for optimal allocation purposes when constructing networks.

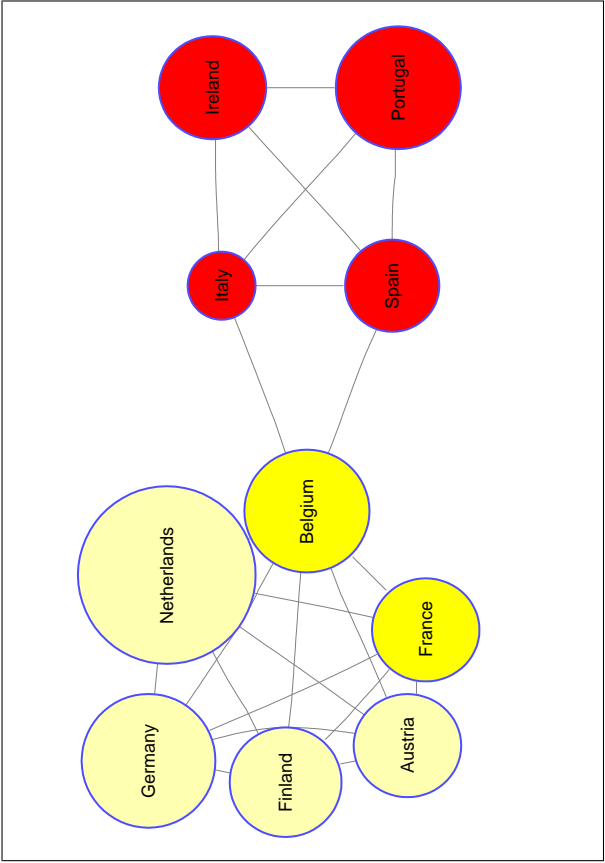
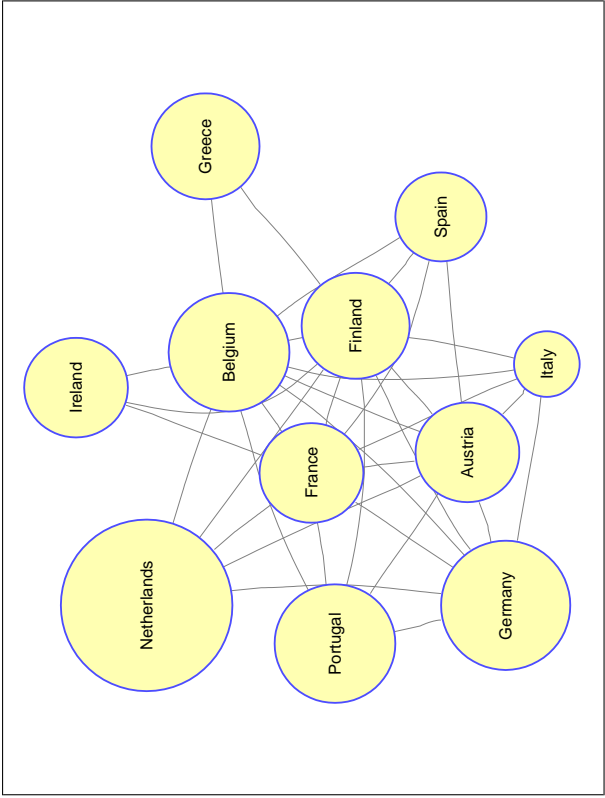


Figure 3: Simply-stable networks in Phase 1 (upper sub-figure) and Phase 2 (lower sub-figure).

caused by clusters of countries that exhibit high within-cluster co-movement but not between-cluster co-movement.

Fig. 3 shows another important point: In our setup, two main clusters are connected through Belgium in Phase 2. Accordingly, if the sovereign debt crisis worsens in the future, the next target of this crisis is most likely Belgium; i.e., the spillover effect will take place through this country first. However, from another point of view, if a recovery is to be observed, it will most likely happen by the convergence of bond yields of struggling members to the yields of Belgium. Therefore, Belgium's sovereign debt market plays a crucial role in monitoring the systemic risk in EMU, and should be tracked by investors and policymakers.

3.2. Path to recovery?

In the previous section, we have given two critical dates for the EMU sovereign debt markets. In this part, we present two additional dates. Starting in 2010 and onwards, bond markets of Greece, Ireland and Portugal and then Spain and Italy had been under intense pressure. Accordingly, the first additional critical date is April 7, 2011, the date when Portugal requested immediate assistance from the European Financial Stability Facility (EFSF) and also the date when the European Central Bank (ECB) increased interest rates by 25 basis points; a very controversial decision considering the euro area's status at that time. After this event, the spreads between the EMU sovereign bonds even expanded and the average correlation hit bottom, hovering around the 0.2 level.

Later, ECB took policy decisions such as lowering interest rates to stimulate economic activities and local policymakers promised structural reforms in these countries. Although these reactions seem to have been effective on spreads (see Fig. 1), Fig. 4 reveals that they are not enough to force EMU bond yields to act as a single asset class as in the pre-Lehman era.

However, starting with 2013, we observe a significant increase in the EMU

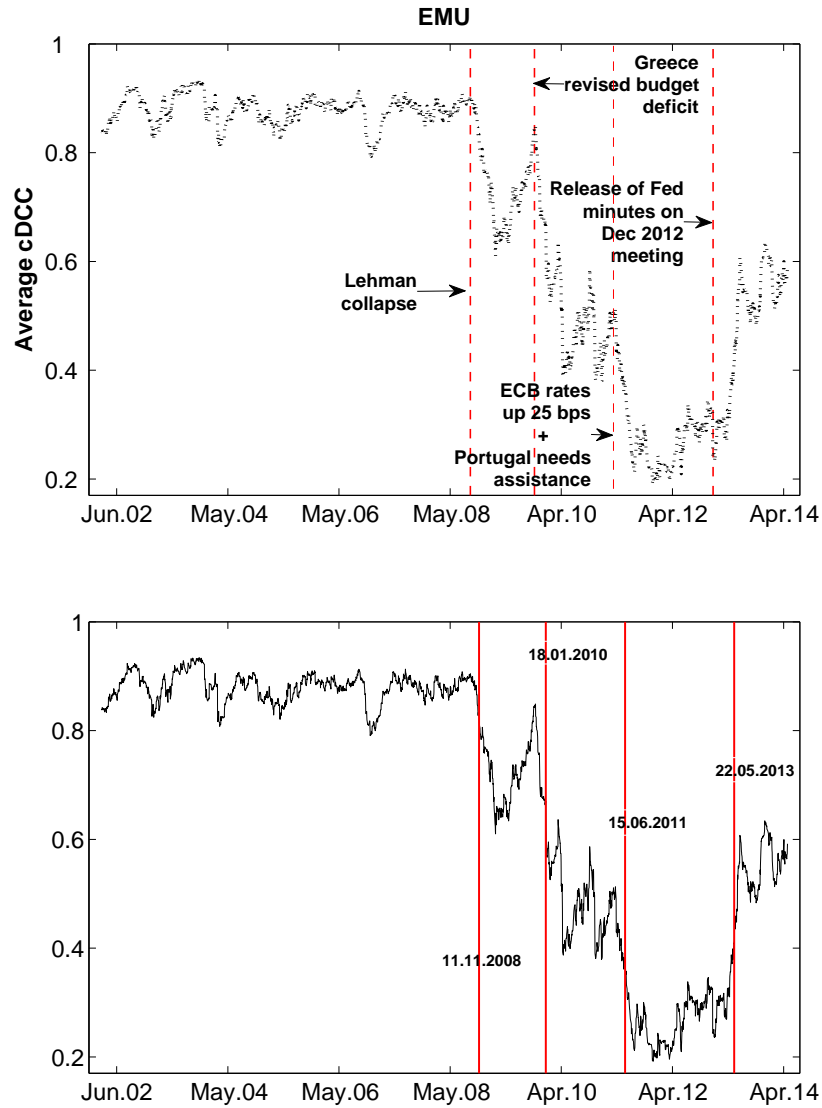


Figure 4: Average dynamic conditional correlation between EMU sovereign bond yields. Vertical lines in the upper sub-figure denote the dates when noteworthy economic incidents occur. Vertical lines in the lower sub-figure denote the dates when dynamic correlation shifts to another mean level according to penalized contrasts.

bond market co-movements with a decreasing trend in their yields (see Fig. 1 and 4). Although we can not say it formally, this situation seems to draw a picture of going back to the pre-Lehman structure. Well, the question to be asked here is that do these changes depend on any fundamentals?

Recent studies show that in the eurozone, fiscal rules, debt, deficits, and debt-service ratios play the main roles in determining the sovereign spreads (Schuknecht et al., 2009; Fatas, 2010; von Hagen et al., 2011; Bernoth et al., 2012; Iara and Wolff, 2014). Therefore, if aforementioned significant changes in sovereign bond yield trends and correlation dynamics are to be observed starting with 2013, then we would expect at least a recovery or signs of recovery in terms of fiscal performances of EMU members prior to 2013; however this is not the case here.

Then, we should ask ourselves why we may have observed such a change? The date of change (second additional critical date) corresponds to Jan 3, 2013, the date which the minutes of the Fed meeting on December 12-13, 2012, were released. The importance of the meeting was that for the first time, there was some disagreement on how long the Fed should keep buying bonds.⁸ Indeed, the so called “Fed tapering” operation that was formally announced by Bernanke on May 22, 2013, seems to be uttered in this meeting.

Although we do not aim to technically prove it, one of the claims of this study is that the public reveal of Fed tapering possibility has the major impact on the changes we consider in EMU bond markets, and this impact is transmitted through the mechanism of “flight-to-quality”: When differences in government bond yields have sharply increased in the euro area for the first time, the main explanation was that the market players have been shaken through a wake-up

⁸<http://news.yahoo.com/fed-minutes-show-concerns-bond-190130672.html>.

call triggered by the global financial crisis and started to distinguish between the different EMU members (Beber et al., 2009). Now, in the case of Fed tapering and the vanishing excess liquidity environment, the flight-to-quality mechanism again seems to be in the works, however this time, the address of quality is the developed markets worldwide, whereas flight is from emerging countries.⁹ The problem is that in the previous case, low and high quality addresses were mainly based on solid fiscal performances (Schuknecht et al., 2009; von Hagen et al., 2011; Bernoth et al., 2012; Iara and Wolff, 2014). However in the current case, emerging countries, where the flight takes off, are better off in terms of these fiscal performances in general, compared to the target addresses i.e. EMU members including the problematic ones.¹⁰ Overall, the situation after Fed tapering rumors suggests that during the recent recovery period in EMU, not the quality but the “illusion of quality” (probably due to fiscal history of developed and emerging countries) takes a big role. Of course, one could argue that the main influence was originated from the heightened confidence in distressed governments’ commitment towards sustainable fiscal policies,¹¹ and the forthcoming macropudential regulations of ECB. However, it should be kept in mind that commitments from governments and policy responses from ECB

⁹We observe severe capital outflows from emerging markets during this period. Due to these outflows, currencies of Chile, India, Brazil, Turkey, South Africa and Indonesia experienced depreciations ranging between 10% and 26% in 2013. Similarly, several emerging sovereign bond yields shot up and equity markets in some of these countries loss up to 30% of their values.

¹⁰For example, developed countries worldwide were averaging about 100% debt to GDP ratio while in the emerging countries this ratio was averaging around only about 40% by the end of 2012. Similar considerable differences in other fiscal indicators were also observed.

¹¹For example, see Codogno et al. (2003); Barrios et al. (2009) for earlier studies on the subject.

took place occasionally during 2009-2012 and both did not seem to be enough for a healthy recovery and did not force these yields to act as a single asset class back then.¹²

Finally, by using the penalized contrast function methodology of Lavielle (2005), we formally present the dates when the average correlation shifts to different mean levels in Fig.4.¹³ We can see that within short time intervals, the aforementioned critical events triggered structural changes in the correlation dynamics.

So, what happens next? Currently, EMU members seem to benefit from the illusion of quality as the upward pressure on their bond yields' spreads have loosened and the coherency in the bond yield movements has been improving significantly. Therefore, struggling members have time to implement structural reforms until the next excess liquidity environment for whatever the reason. Moreover, a shift in expectations due to this illusion can lead to a further self-fulfilling wave of cross-border capital flows, which would definitely support EMU members on this path.¹⁴

¹²Although it is not the scope of this paper, further research could seek answer to the rhetorical question of "do we need any other central banks then Fed?". Naturally, the answer would be "yes" but the idea is to stress on the challenges faced with other central banks when one clearly dominates the others.

¹³The main advantage of this methodology is that it does not impose any condition on the dependency and distribution of the data. For details, see Appendix B.

¹⁴See Masson (1999) for theoretical support to this argument.

4. Conclusion

This paper focuses on the recent developments observed in the EMU sovereign debt markets. First, we try to clarify the integration and segmentation of the EMU sovereign debt markets before and after the crisis from a novel perspective. Accordingly, an almost perfect integration is observed in the pre-crisis era. However, with the collapse of Lehman Brothers and the following fiscal problems in Greece, the integration structure is severely damaged, yielding an all time low group correlation level in the EMU. By introducing the simply-stable network concept, we show that the decrease in the overall correlation level after the financial crisis is not due to a general sparsity of EMU members. It is caused by clusters of countries that exhibit high within-cluster co-movement but not between-cluster co-movement. Accordingly, in its new form, EMU sovereign debt markets are segmented into two main parts where fiscal performance seems to be the main reason in this segmentation. Moreover, these two main parts are connected through only one member, Belgium, in our setup. This situation suggests that the path to recovery in a positive future or transmission of crisis in a negative one will take place through this member and its debt market should be monitored by policymakers and investors.

In the second part, we try to shed a light on the recovery signals and in particular, the increased harmony observed in EMU bond markets recently. It is argued that fundamental indicators did not play a role in this case as they were in a much worse situation compared to pre-crisis levels and did not even show promising performances up until the start of this process. Alternatively, transitions were mainly attributed to the Fed tapering rumors originated in early 2013 and the following diminishing excess liquidity environment which eventually created an instinct of “need to flight-to-quality” from emerging countries to developed ones, even though fiscal performances tell that a different story should

have been written. The results naturally bring out the following question: If the turmoil observed during 2008-2009 was a self-correction in financial markets then, were EMU bond markets overvalued pre-2008 or are they undervalued post-2009?

References

- Aielli, G. P., 2013. Dynamic conditional correlation: on properties and estimation. *Journal of Business & Economic Statistics* 31, 282–299.
- Barrios, S., Iversen, P., Lewandowska, M., Setzer, R., 2009. Determinants of intra-euro area government bond spreads during the financial crisis. *European Commission Economic Papers* 388.
- Beber, A., Brandt, M. W., Kavajecz, K. A., 2009. Flight-to-quality or flight-to-liquidity? Evidence from the Euro-area bond market. *Review of Financial Studies* 22, 925–957.
- Beirne, J., Fratscher, M., 2013. The pricing of sovereign risk and contagion during the European sovereign debt crisis. *Journal of International Money and Finance* 34, 60–82.
- Bernoth, K., von Hagen, J., Schuknecht, L., 2012. Sovereign risk premiums in the European government bond market. *Journal of International Money and Finance* 31, 975–995.
- Codogno, L., Favero, C., Missale, A., 2003. Yield spreads on EMU government bonds. *Economic Policy* 37, 527–529.
- Conrad, C., Karanasos, M., Zeng, N., 2008. Multivariate fractionally integrated APARCH modeling of stock market volatility: A multi-country study. Discussion Paper Series, University of Heidelberg.
- Cukierman, A., Lippi, F., 1999. Central bank independence, centralization of wage bargaining, inflation and unemployment - theory and some evidence. *European Economic Review* 43, 1395–1434.

- Ehrmann, M., Fratzcher, M., Gurkaynak, R., Swanson, E. T., 2011. Convergence and anchoring of yield curves in the Euro area. *Review of Economics and Statistics* 93, 350–364.
- Engle, R. F., 2002. Dynamic conditional correlation: a simple class of multivariate generalized autoregressive conditional heteroskedasticity models. *Journal of Business & Economic Statistics* 20, 339–350.
- Fatas, A., 2010. The economics of achieving fiscal sustainability. Paper presented at the Academic Consultants Meeting - Board of Governors, Federal Reserve.
- Gruner, H. P., 2010. Why EMU is not a failure? *European Journal of Political Economy* 26, 1–11.
- Gruner, H. P., Hefeker, C., 1999. How will EMU effect inflation and unemployment in Europe? *Scandinavian Journal of Economics* 101, 33–47.
- Iara, A., Wolff, G. B., 2014. Rules and risk in the Euro area. *European Journal of Political Economy* 34, 222–236.
- Iori, G., De Masi, G., Precup, O., Gabbi, G., Caldarelli, G., 2008. A network analysis of the Italian overnight money market. *Journal of Economic Dynamics and Control* 32, 259–278.
- Lavielle, M., 2005. Using penalized contrasts for the change-point problem. *Signal Processing* 85, 1501–1510.
- Masson, P., 1999. Contagion: macroeconomic models with multiple equilibria. *Journal of International Money and Finance* 18, 587–602.
- Minoiu, C., Reyes, J. A., 2013. A network analysis of global banking: 1978-2010. *Journal of Financial Stability* 9, 168–184.

- Schuknecht, L., von Hagen, J., Wolswijk, G., 2009. Government risk premiums in the bond market: EMU and Canada. *European Journal of Political Economy* 25, 371–384.
- Sibbertsen, P., Wegener, C., Basse, T., 2014. Testing for a break in the persistence in yield spreads of EMU government bonds. *Journal of Banking & Finance* 41, 109–118.
- Tola, V., Lillo, F., Gallegati, M., Mantegna, R. N., 2008. Cluster analysis for portfolio optimization. *Journal of Economic Dynamics and Control* 32, 235–258.
- Tumminello, M., Lillo, F., Mantegna, R. N., 2010. Correlation, hierarchies, and networks in financial markets. *Journal of Economic Behavior & Organization* 75, 40–58.
- von Hagen, J., Schuknecht, L., Wolswijk, G., 2011. Government bond risk premiums in the EU revisited: The impact of the financial crisis. *European Journal of Political Economy* 27, 36–43.

Appendix A. Parameter estimates

The following Table A.1 presents the estimated parameters for the model used in this paper.

Table A.1: Parameter estimates for AR(1)-FIAPARCH(1, d ,1) and cDCC(1,1) process

	φ	$\omega \times 10^4$	d	ϕ	β	γ	δ
France	0.076*** (0.000)	1.353 (0.647)	0.343*** (0.000)	0.372*** (0.000)	0.664*** (0.000)	0.111 (0.244)	1.791*** (0.000)
Germany	0.128*** (0.000)	0.368 (0.724)	0.328*** (0.001)	0.360*** (0.000)	0.672*** (0.001)	0.101 (0.377)	2.016*** (0.000)
Italy	0.079*** (0.000)	0.883 (0.406)	0.249** (0.049)	0.131 (0.875)	0.289 (0.760)	-0.287* (0.087)	1.992*** (0.000)
Belgium	0.137*** (0.000)	6.441 (0.463)	0.335*** (0.000)	0.365*** (0.004)	0.586*** (0.000)	-0.051 (0.626)	1.512*** (0.000)
Netherlands	0.102*** (0.000)	5.714 (0.729)	0.373*** (0.000)	0.371*** (0.000)	0.703*** (0.000)	0.146 (0.280)	1.435** (0.037)
Ireland	0.084*** (0.000)	2.119 (0.359)	0.486*** (0.000)	0.437*** (0.000)	0.771*** (0.000)	-0.135 (0.259)	1.653*** (0.000)
Spain	0.091*** (0.000)	0.796 (0.416)	0.346*** (0.000)	0.358*** (0.000)	0.625*** (0.000)	-0.298** (0.019)	1.840*** (0.000)
Portugal	0.168*** (0.000)	0.158 (0.676)	0.467*** (0.000)	0.383*** (0.000)	0.729*** (0.000)	-0.280*** (0.003)	1.838*** (0.000)
Austria	0.111*** (0.000)	1.263 (0.679)	0.363*** (0.004)	0.381*** (0.000)	0.705*** (0.000)	0.080 (0.341)	1.772*** (0.002)
Finland	0.112*** (0.000)	2.661 (0.596)	0.425*** (0.001)	0.354*** (0.000)	0.749*** (0.000)	0.156 (0.136)	1.551*** (0.001)
Greece	0.206*** (0.000)	0.643 (0.284)	0.585*** (0.000)	0.202* (0.098)	0.619*** (0.000)	-0.148* (0.062)	1.802*** (0.000)

cDCC parameters	
a	b
0.027*** (0.000)	0.964*** (0.000)

1. The values in the parentheses are p -values obtained from robust standard errors.
2. *, ** and *** denote significance at 10%, 5% and 1% levels respectively.

Appendix B. Detection of mean shifts in the dynamic correlation

To detect the dates of mean shifts in the dynamic correlation level, we use penalized contrasts. To prevent misunderstandings, the reader is asked to consider the mathematical notations in Appendix B independent from the other parts of this manuscript.

Consider a sequence of random variables Y_1, \dots, Y_n that take values in \mathbb{R}^p . Assume that $\theta \in \Theta$ is a parameter denoting the characteristics of the Y_i 's that changes abruptly and remains constant between two changes. Change occurs at some instants $\tau_1^\star < \tau_2^\star < \dots < \tau_{K^\star-1}^\star$. Here $K^\star - 1$ is the number of change points hence we have K^\star number of segments where \star is used to denote the true value. Now, let K be some integer and let $\tau = (\tau_1, \tau_2, \dots, \tau_{K-1})$ be a sequence of integers satisfying $0 < \tau_1 < \tau_2 < \dots < \tau_{K-1} < n$. For any $1 \leq k \leq K$, let $U(Y_{\tau_{k-1}+1}, \dots, Y_{\tau_k}; \theta)$ be a contrast function useful for estimating the unknown true value of the parameter in the segment k ; i.e. the minimum contrast estimate $\hat{\theta}(Y_{\tau_{k-1}+1}, \dots, Y_{\tau_k})$, computed on segment k of τ , is defined as a solution of the following minimization problem:

$$U(Y_{\tau_{k-1}+1}, \dots, Y_{\tau_k}; \hat{\theta}(Y_{\tau_{k-1}+1}, \dots, Y_{\tau_k})) \leq U(Y_{\tau_{k-1}+1}, \dots, Y_{\tau_k}; \theta), \quad \forall \theta \in \Theta, \quad (\text{B.1})$$

For any $1 \leq k \leq K$, let G be

$$G(Y_{\tau_{k-1}+1}, \dots, Y_{\tau_k}) = U(Y_{\tau_{k-1}+1}, \dots, Y_{\tau_k}; \hat{\theta}(Y_{\tau_{k-1}+1}, \dots, Y_{\tau_k})) \quad (\text{B.2})$$

then define the contrast function $J(\tau, \mathbf{y})$ as

$$J(\tau, \mathbf{y}) = \frac{1}{n} \sum_{k=1}^K G(Y_{\tau_{k-1}+1}, \dots, Y_{\tau_k}) \quad (\text{B.3})$$

where $\tau_0 = 0$ and $\tau_k = n$. When true number K^\star segments is known, for any

$1 \leq k \leq K^*$, the sequence $\hat{\tau}_n$ of change point instants that minimizes this kind of contrast has the property that

$$\Pr(|\hat{\tau}_{n,k} - \tau_k^*| > \delta) \rightarrow 0, \text{ when } \delta \rightarrow \infty \text{ and } n \rightarrow \infty \quad (\text{B.4})$$

In particular, this result holds for weak or strong dependent processes. We consider the model $Y_i = \mu_i + \sigma_i \varepsilon_i$, $1 \leq i \leq n$, where (ε_i) is a sequence zero-mean random variables with unit variance. In the case of detecting changes in the mean, we assume that (μ_i) is a piecewise constant sequence and (σ_i) is a constant sequence. Now, even if (ε_i) is not normally distributed, a Gaussian log-likelihood can be used to define the contrast function. Let

$$U(Y_{\tau_{k-1}+1}, \dots, Y_{\tau_k}; \mu) = \sum_{i=\tau_{k-1}+1}^{\tau_k} (Y_i - \mu)^2 \quad (\text{B.5})$$

then

$$G(Y_{\tau_{k-1}+1}, \dots, Y_{\tau_k}) = \sum_{i=\tau_{k-1}+1}^{\tau_k} (Y_i - \bar{Y}_{\tau_{k-1}+1:\tau_k})^2 \quad (\text{B.6})$$

where $\bar{Y}_{\tau_{k-1}+1:\tau_k}$ is the empirical mean of $(Y_{\tau_{k-1}+1}, \dots, Y_{\tau_k})$.

When the number of shift points is unknown, it is estimated by minimizing a penalized version of $J(\boldsymbol{\tau}, \mathbf{y})$. For any sequence of change point instants $\boldsymbol{\tau}$, let $pen(\boldsymbol{\tau})$ be a function of $\boldsymbol{\tau}$ that increases with the number $K(\boldsymbol{\tau})$ of segments of $\boldsymbol{\tau}$. Then, let $\hat{\tau}_n$ be the sequence of change point instants that minimizes

$$F(\boldsymbol{\tau}) = J(\boldsymbol{\tau}, \mathbf{y}) + \varphi pen(\boldsymbol{\tau}) \quad (\text{B.7})$$

where φ is a function of n that goes to zero at an appropriate rate as n goes to infinity. The estimated number of segments $K(\hat{\tau}_n)$ converges in probability to K^* . The proper $pen(\boldsymbol{\tau})$ and the penalization parameter φ are chosen according to Lavielle (2005). For further details, refer to Lavielle (2005).