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Measuring divergence/convergence within the Economic and Monetary Union

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Abstract

The Economic and Monetary Union was an advance stage towards a complete integration across European countries. We are interested in understand to what extent the common currency has contributed to strengthen the co-movement between Euro area countries. Ehrmann et al.(2011) study convergence by looking at the sovereign bond markets. The authors consider the four Eurozone largest economies, for three different maturities and using high-frequency data. This dissertation extends their research through an updated dataset. As expected we obtain the exact same results for the period we have in common - strong convergence with Euro's introduction. After 2008, the picture changes dramatically. We see a great divergence, which seems to be triggered during the European sovereign debt crisis. This path is reversed in the last part of our dataset, however, the market integration never return to the level experienced during the first nine years of EMU. We innovate this field of analyses through the introduction of a univariate analyses. We conclude that the convergence patterns detected in the zero-coupon yields are to a large extent structural. The great divergence observed after the crisis gave rise to a striking tendency - the formation of two country blocks within the EMU. We discuss possible reasons behind the convergence dynamics observed in the sovereign bond markets and, future implications for the European complete integration goal.

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Keywords: convergence; Euro area; sovereign bond markets; Economic and Monetary Union.

Resumo

A União Económica e Monetária foi um estágio avançado no sentido de uma integração completa entre os países europeus. Estamos interessados em perceber em que medida a moeda comum contribui para o fortalecimento de um movimento concertado entre os países da área do euro. Ehrmann et al. (2011) estuda a convergência, focando-se no mercado de obrigações soberanas. Esta dissertação estende sua investigação através da actualização dos dados. Como esperado, obtemos resultados coincidentes para os períodos que temos em comum - forte convergência depois da introdução do Euro. Depois de 2008, o quadro altera-se drasticamente. Encontramos uma divergência significativa que parece ser desencadeada durante a crise das dívidas soberanas europeias. Este fenómeno é revertido na etapa final contemplada pela nossa amostra, no entanto, a integração experienciada durante os primeiros anos da UEM não volta a acontecer. Com recurso a uma análise univariada verificamos que os padrões de convergência detectados nas *yields* das obrigações de cupão-zero são de facto alterações com fundamentos estruturais. A grande divergência observada após a crise deu origem a uma tendência marcante - a formação de dois blocos de países dentro da UEM. Discutimos possíveis razões para a dinâmica de convergência observada nos mercados de obrigações soberanas e, implicações futuras para o objectivo de ter uma completa integração europeia.

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Palavras chave: convergência; Zona Euro; mercado de obrigações soberanas; União Económica e Monetária.

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1 Introduction

The Economic and Monetary Union (EMU) officially started in 1999 with eleven founding countries. The common currency was an advance stage towards a complete economic integration across European countries. The economic integration pre-supposes an enhanced convergence between European economies. The countries that would share the Euro were supposed to converge in a more rapidly and robust way since they would share the same monetary policy, which in the Euro Zone is ruled by the European Central Bank (ECB). But is this really happening?

Fifteen years after the introduction of the Euro it is important to understand how the common currency is in fact contributing for the convergence among its members. Furthermore, is the convergence process influencing all the members with similar intensities and guiding them to similar directions?

During these first years of the common currency project several measures were used in order to assess convergence within the EMU. The aim of this dissertation is to give insights about this question, looking at the issue from the sovereign bond investor's point of view. The way sovereign bond investors perceived and build expectations about convergence across the EMU countries is translated by their decisions in the sovereign bond market. With the Euro introduction one could expect a higher level of European bond market integration, at least comparing with the period prior to its start. But was this the case?

We follow the work of the Ehrmann et al.(2011) on EMU convergence. Yet, we focus only on their unconditional analysis. The authors use the four major EMU economies (Germany, France, Italy and Spain) with the aim to assess to what extent the sovereign debt market is integrated in the common currency area. Besides the visual representation of the yields on government notes (for several maturities), they also employ three types of statistical measures in order to gauge convergence. Unlike Baele et al.(2004) and Costantini et al.(2014) that address similar matters using monthly data, Ehrmann et al.(2011) analyse EMU convergence considering high-frequency data. They build a high-frequency time series for two different periods: *pre-EMU* and *post-EMU*.

Ehrmann et al.(2011) concludes that there was a very fast, strong and robust convergence (that started even before the Euro introduction) across the EMU sovereign bond market and that co-movement has strengthen along the way (at least until June 2008 when the sample finishes).

We contribute for the literature on this matter by extending of Ehrmann et al. (2011) sample until the end of 2014. This extension will allow us to understand how both the financial and the *European sovereign debt crisis* have affected the EMU bond market integration.

Additionally, it is important to check how structural those Eurozone bond yields behaviour really are. In order to achieve a trustful conclusion regarding this question, we perform a univariate analysis in which the high-frequency time series are decomposed in a cyclical and a permanent component. Therefore, we consider this innovation our main contribution to the literature.

In the EMU's beginning, or even before, papers on these issues find mixed evidences towards convergence across the member economies. Several authors have studied this topic considering different ways to gauge convergence. There are a huge variety of convergence measures depending on which market integration the researchers are interested to assess. Along the literature on this matter we can also find studies that focus in aggregate convergence measures as for instance, inflation differentials, monetary aggregates, unemployment rate, etc... Although all these approaches, we can divide the literature on this subject between papers that analyse the EMU convergence process before and after the financial crisis.

The ones that focus on the early period tend to show evidence of co-movement among EMU states. The price dispersion across traded and non-tradeable goods is a measure employed in order to evaluate the degree of integration within the EMU countries, Rogers(2007) shows that it has diminished in both cases but with a stronger magnitude in the tradable goods market. Pagano and Thadden (2004) observed that spreads have shrunk with Euro introduction. The authors associate this phenomenon with two innovations brought by the EMU: exchange risk elemination and, what the authors called *institutional factors*(Pagano and Thadden, 2004). Costantini et al. (2014) confirmed that the EMU countries spreads on 10 years sovereign bond yields were small until mid-2007 (using Germany as a benchmark). The first Euro area years are also characterized by ”a strong convergence in unemployment rates...” (Estrada et al., 2013:2).

However, convergence isn’t always confirmed. Equity market returns and capital flows are the focus of researchers as, for instance, Fratzscher and Stracca(2009), which do not support the idea that the Euro have decisively contributed for a closer behaviour among the Euro Area economies. Canova, Ciccarelli, and Ortega(2007) find that business cycles among the Euro area members were not more aligned with the common currency emergence. Despite the common monetary policy, Costantini et al.(2014) stress the persistency of the inflation differentials across the EMU members, even in the period previous to the financial crisis. This last fact is corroborated by Estrada et al.(2013).

Real and financial convergence measures are used by Lane(2006) to summarize a general co-movement after the initiation of EMU. Lane(2006) states that the common currency has contributed positively for the economic integration improvement observed across EMU countries. Despite this conclusion, the author argues that only after facing a big crisis or economic downturn in one of its members, the convergence observed in the Eurozone can be completely validated.

The period after the so-called *Great Recession* introduced additional doubts regarding the common currency’s role for the Eurozone economic integration. After 2009, worldwide bond investors begun to put into question the ability of certain EMU governments to meet their debt obligations. Thus, the risk awareness of investors increased and the unbalanced economies started to feel the consequences through the sovereign bond markets. Costantini et al.(2014) discover two groups of countries within the common currency area: an *EMU core* with low levels of sovereign debt and current account balances with no deficit (or, at least, no persistent deficits); and the *EMU periphery* which is composed by Eurozone members with more problematic financial situations.

Looking at the literature on EMU sovereign bond market, one can find several determinants able to influence Eurozone sovereign yields. The works that focus on liquidity risk point to inequalities among the EMU countries which lead to differences in sovereign bond spreads (Jankowitsch et al.,2006). Barrios et al. (2009) confirmed that in the pre-crisis period there was an underestimation of the default risk for some European countries. Attinasi et al.(2010) argued that during the financial crisis the international risk aversion was one of the main drivers for the changes observed in the sovereign bond spreads.

Finally, despite the common monetary policy, the EMU members are individually exposed to real exchange rates appreciations/depreciations which may generate competitiveness gaps within common currency areas and, ultimately give rise to current account deficits and debt problems (De Grauwe and Ji, 2012) and, thereby increasing country specific risks. As suggested in Costantini et al. (2014), when investors have to assign and price sovereign default risk, they take into consideration optimal currency area's (OCA) issues, specially competitiveness divergences among the states of that currency area.[1]

We find evidence of convergence during the first years of the Euro. Around 2009, this dynamic suffers a major setback with European debt crisis. Since there, the integration in the sovereign debt market never returned to the values observed in the early part of the common currency project. As Costantini et al. (2014), we detect a long run tendency towards the formation of two groups within Eurozone. This can be a self-fulfilling process, fuelled by investors' perception and posterior decisions in the sovereign bond market. This conclusion have strong structural foundations. Thus, it seems that will remain in the long run.

The remainder of this dissertation is structured as follows. Section 2 describes the data collected, its estimation and the sub-samples choice. It gives an overview of the statistical methods employed in order to gauge EMU convergence and makes an exhaustive exposition of the univariate analysis methodology. Moreover, we explore and interpret the patterns observed in the data. In Section 3 the main findings are presented. They are divided in three parts: first our results are

[1] See Costantini et al. (2014) for details.

compared with those of Ehrmann et al. (2011), after the additional samples are studied and we end up by presenting the main insights from the decomposed series. We finish with a summary on the main conclusions and some suggestions about alternative avenues of research on this matter.

2 Data and Methodology

The first objective of this thesis is to follow the work of Ehrmann et al. (2011) by considering an updated dataset. However, taking into consideration the same countries, similar maturities and even using the exact same statistical measures in order to gauge convergence across EMU bond markets.

2.1 Yields

The aim of this thesis is to gauge how investors perceived the convergence within the EMU's sovereign bond market which was and still is one of the main goals of the european project. In order to do that we consider the four biggest Eurozone economies: France, Germany, Italy and Spain. With this approach we believe that conclusions can be extended to the Euro area as a whole.

Germany and France can be seen as a representation of the so called *strong northern European economies* and, the other way around, the *less competitive Southern European economies* are represented by Italy and Spain.

Additionally, United Kingdom is the control country. The UK is part of the European Union, however, with it's own independent monetary policy which is under the responsibility of the Bank of England (BOE). Hence, EU common shocks can be seen as perfect situation in order to measure convergence among the EMU countries and compare the results with those obtained between Euro area countries and UK.

Similar to Ehrmann et al. (2011) we opted to use zero-coupon yield curves to understand the level of integration of EMU's bond market mainly because it avoids three important issues which could bias the final results: differences in bond maturities, differences in coupon rates and, (most important) individual idiosyncrasies in the sovereign bond yields (see Grkaynaket al. (2007) for additional information). Thus, this market data ensures an appropriate comparison between the bond yields of the considered countries.

Furthermore, zero-coupon yields usually serve as a benchmark for the valuation of others fixed income instruments.

One of the most important innovations of this research is related with the considered data frequency, which define a high standard for the sovereign bond market convergence. We study the investors perception on EMU integration through daily bond yields. Comparing with, for instance monthly or quarterly data, such high-frequency data are less exposed to cross-country arbitrage that is able to reduce interest rate differentials. It means that one expects to observe more similarities among bond markets yields using low-frequency datasets. However, the findings on daily bond yields are more robust and the conclusions are stronger. Once we are able to prove yield convergence in high-frequency datasets, we can be sure that this convergence will be verified in low-frequency datasets as well.

Regarding the bond maturities, the dataset is built in a wide way with the aim to encompass the investor's sensibilities about the perceived level of integration in the Eurozone sovereign bond market. We consider the evolution of daily yields for three maturities: 2, 5 and 10 years. The first case depicts the short-term bond market, the medium-term is represented by the 5 years yield on government notes, and the 10 years yields reflects the investor's risk perception about the long-term state of the EMU countries.

2.2 Yield computation

The yield curves were computed using interpolated zero yield curves data from Bloomberg Financial Services. The data were collected from the start of 1995 to the end of 2014. The method employed to compute the spot curves (or zero-coupon yield curve) is similar to the one usually used by the central banks worldwide, and this version was first presented by Svensson (1994).[2]

Svensson (1994) features a functional form which is an extended version of the method originally developed by Nelson and Siegel (1987) for the estimation

[2]The spot curves were computed in the R software resorting to the package "YieldCurve" designed by Sergio S. Guirreri (2014).

of forward[3] and spot rates.[4]

Nelson and Siegel (1987) modelled the so-called instantaneous forward rate[5] $f(m)$ through the following parsimonious function

$$f(m,\beta) = \beta_0 + \beta_1 \, exp\left(-\frac{m}{\tau_1}\right) + \beta_2 \left[\left(\frac{m}{\tau_1}\right) exp\left(-\frac{m}{\tau_1}\right)\right], \tag{1}$$

where $\beta = (\beta_0, \beta_1, \beta_2, \tau_1)$ is the vector of parameters (β_0 and τ_1 must be positive), and m stands for time to maturity.

The component, β_0, is a constant which is followed by an exponential term, $\beta_1 \, exp\left(-\frac{m}{\tau_1}\right)$, that is monotonically decreasing/increasing (if β_1 is positive or negative, respectively) towards zero as a function of time to settlement. The third term, $\beta_2 \left[\left(\frac{m}{\tau_1}\right) exp\left(-\frac{m}{\tau_1}\right)\right]$, is responsible for the variety of shapes that this specification is able to capture, as a function of the time to settlement - U-shape if β_2 is positive, or instead, a hump-shape if negative. Finally, the position of the first hump (or the U-shape) on the curve is given by τ_1. When time to settlement tend to zero, the equation tend to becomes a constant like $\beta_0 + \beta_1$, other way around, in case the time to settlement approaches infinity, the forward rate tends to the constant β_0.

The authors describe the spot rate, $s(m)$ as an average of the instantaneous forward rate

$$s(m,\beta) = \frac{1}{m} \int_0^m f(m,\beta) \, dm, \tag{2}$$

The spot rate is then given by the following specification

[3] Forward interest rates are interest rates on investment and loans that will start at a future date, the settlement date, and last to a date further into the future, the maturity date (Svensson, 1994).

[4] Spot and forward rates curves relation resembles to, respectively, the average and marginal cost shapes, assuming time to maturity as quantity produced.

[5] The instantaneous forward rate is the forward rate for a forward contract with an infinitesimal investment period after the settlement date (Svensson, 1994).

$$s\,(m,\beta)\;=\;\beta_0\;+\;\beta 1\;\frac{1-exp\;(-\frac{m}{\tau_1})}{\frac{m}{\tau_1}}\;\beta_2\left[\frac{1-exp\;(-\frac{m}{\tau_1})}{\frac{m}{\tau_1}}\;-\;exp\left(-\frac{m}{\tau_1}\right)\right],\quad(3)$$

The method can generate a considerable amount of possible curves as for instance: U-shapes, S-shapes, monotonic or humped.

Svensson (1994) introduced an important innovation that allows the spot rate to have a second hump-shape (or U-shape) in the curve and, therefore, increasing the curve's flexibility. This is achieved due to the addition of a fourth term (to the previous equation) with two new parameters - β_3 and τ_2 (τ_2 must be positive)[6]

$$\beta_3\left[\frac{1-exp\;(-\frac{m}{\tau_2})}{\frac{m}{\tau_2}}\;-\;exp\left(-\frac{m}{\tau_2}\right)\right],$$

the new parameter vector is given by $\beta=(\beta_0,\beta_1,\beta_2,\tau_1,\beta_3,\tau_2)$.

This last improvement made by Svensson and, the degree of parsimony presented by Nelson and Siegel (1987) in their functional form were the main reasons which justify our methodology option with respect to the computation of the zero-coupon yield curves.

Before having a closer look over the spot rates results, it is important to explore alternative avenues of research suggested by other researchers along the years and present some further arguments that also justify our specification's choice.

Diebold and Li (2006) presented simpler version of the above mentioned original specification. However, this extension increases considerably the potential of dealing with multicollinearity problems.

The aim to solve the multicollinearity problem have motivated several researchers, as for instance Björks and Christensen (1999) and, later on, De Pooter (2007). These economists developed the adjusted Svensson model[7] which has a

[6] β_3 is responsible for the determination of the form and size of the second hump (as does to β_2 for the first hump on the curve) and, τ_2 specifies it's location.

[7] De Pooter suggests to replace $-exp\;(-\frac{m}{\tau_2})$ by the following $-exp\;(-\frac{2m}{\tau_2})$ regarding Svensson's new term.

slight alteration in the fourth term of the equation. As this improvement does not fundamentally modify our results, we decided to follow the Svensson's widely used extension.

It is also worth mentioning the cubic spline methodology firstly shown by McCulloch (1971, 1975) and with great influence in our chosen computation model. However, the lack of simplicity and the handicap regarding the greater degree of unstability in the forward rate's estimates, specially at maturities above 5 years[8], made us rule out this option. Additionally, the parsimony between techniques is sufficiently notorious to justify the choice of Svensson (2004) proposal in detriment of the McCulloch cubic splines method.[9]

2.3 Observed patterns in the spot rates

In Figure 1 we can see the zero-coupon yield series plotted for three different maturities (2, 5 and 10 years). There are five European economies represented in which four of them are EMU founder members (Germany, France, Italy and Spain) and the fifth is part of the EU but chose not to be a Euro Zone country (U.K.) and therefore has both its own currency and independent monetary policy.

Figure 1 and Table 1 show that few years before EMU starts (we start the sample in 1995) we can observe that the yields on government notes for the four countries that were going to share a common currency exhibited a clear divergence. Being Germany perceived as the safest country among those economies, France slightly above and Spain and, particularly Italy as the countries with cheapest bond's prices implying that these were the riskier investments for the *bond players*.

Although the above observations are quite clear, the speed of convergence is striking. After 1997 (only two years after the start of our sample), France arrives very close to Germany and by the end of 1998 the four zero-coupon yields were

[8] This argument is stressed by Shea (1984).

[9] Fisher, Nychka and Zervos (1995) have presented an important extension of McCulloch (1971,1975) but still, far less attractive than the Svesson's method.

at a very similar risk levels. This observation allows us to draw a first conclusion, which is also present in the paper of Ehrmann et al. (2011): the figure leads us to realize that investors expectations regarding EMU's unification was responsible for an unified sovereign bond market among this four economies, even before Eurozone's start. Looking at United Kingdom's bond yield behaviour the last remark is reinforced since at the start of the sample UK behaves closer to France and Germany than Italy and Spain but starting in 1997 this is no longer true and the UK's yields moved away from Germany's yields. Thus, one can state that the four countries convergence was most likely due to the EMU and not because of possible global factors common to all developed countries or regional factors affecting the European Economies.

In the period between the start of EMU and around 2008 the bond market movements across the four biggest EMU Economies were almost indistinguishable. During this period, there was not a single day in which the yield movements has dramatically behaved differently between each other. Figure 1 suggests that the common currency still has an important role for this outcome since the UK's yields were noticeably higher comparing with those of EMU countries.

The period after the global financial crisis draws a completely different picture among the sovereign bond markets, which is well visible in Figure 1. All the considered EMU's yields reached peaks around 2009. Here it is important to stress the Germany's zero-coupon yield's behaviour. It reached a level only comparable with the level observed at the beginning of our sample. However, still being the country with the lowest level of risk from the investors point of view.

This movement was followed by a decrease in the yields for all countries but the intensity of that decrease was noticeably different between the EMU economies, they start to diverge seriously. Furthermore, this movement seems to be caused by a global factor rather to an exclusive phenomena within Eurozone, since UK's spot rates exhibits a very similar movement.

Nonetheless, after 2010 the bond market's tendency seem to show a considerable change. One can see clearly that the EMU countries started to (deeply) diverge. The spreads among the common currency economies surged. Around 2012, Italy experiences spreads, with respect to Germany, similar to the ones observed in 1995. The same happened with Spain but a bit later on (in mid/end 2012). These were the times immediately after the outset of the European sovereign debt crisis, which had a big impact in certain EMU economies.

France, which after 1997 and before 2010 had spot rates very similar to Germany, also suffered a notorious divergence from this path. This implies that France was perceived as a more risky economy comparing with our European benchmark - Germany. This movement starts to become less visible towards the end of our sample (middle of 2014), though never achieving the degree of integration seen at start of the Euro.

The strongest co-movement among the four EMU economies seems to be the one between Italy (green) and Spain (yellow). Their yields were perceived by the financial markets as much more risky than for instance Germany.

After 2010, it appears that two groups of countries are formed within the Euro area: one with lower and more stable yields on government notes, composed by France and Germany (even if France had diverged from Germany for some time), and Italy and Spain forming a second more riskier group. This observation is also suggested by Costantini et al. (2014).

Until the end of our sample (2015), Euro area's convergence does not achieves the extent observed before the world financial crisis. Assuming that a crisis this big could lead to panic responses in the financial markets, this still is an unexpected outcome, as the shock was global and, therefore all EMU countries were exposed to the same impacts. Regarding the above observation, we can guess that there were countries inside the EMU more prepared to deal with some unpredictable events (as the big recession) than others. The asymmetric economic fundamentals was (and still is) understood by investors as a bias in the European monetary Union construction.

The UK yields (once more) support this view since the spot rates between mid 2010 and the beginning of 2014 are much more closer to the ones of Germany and France than to those of Spain or Italy. The latest observation reveals that the response mechanisms and real economic conditions of UK, Germany and France (although France to a lower extent) were much more efficient dealing with the world economic turmoil, at least is our interpretation of the european sovereign bond market's dynamic.

Another insight from Figure 1 is that the financial crisis and after the European sovereign debt crisis surprised the investors. This gave rise to a very strong market answer that can be measured by the widening of the yield spreads among the Euro Zone countries.

Finally, it is important to highlight for differences between the three maturities presented in Figure 1. All the maturities seem to have a very similar behaviour without significant differences to point out. However, there are a few details worth underlining.

During the period of greater convergence, the variations among the countries spot rates are almost invisible for the shorter and medium maturities, and (as expected) more pronounced for the 10 year maturity.

Regarding the period after 2008, characterized by an higher degree of instability, the shorter and medium maturities suffer from a higher volatility if one compares with the longer maturity under study. This let us understand that bond markets are much more sensible to country's economic and financial conditions in the short-run than in the long-run for which they expect a smoothness of this differences.

The solutions found to solve the crisis have calmed down (at some level) the sovereign bond market, however, these responses and solutions appear to have been more effective (although insufficient) in the short-run. For the medium and longer maturities seems that an important structural change has occurred. This is quite clear looking at the level of convergence in the end of the three series: for the 2 years maturity the zero-coupon yield convergence is faster compared with of the 5 and 10 years.

2.4 Sample periods

As stated at the introductory part, this dissertation follows the paper of Ehrmann et al.(2011). Thus, we build the two first sub-samples in a similar way and update their work by adding two additional sub-periods. As a result we split the data into the four sub-samples: pre-EMU (02/01/1995 - 31/12/1998), post-EMU (01/01/2002 - 30/06/2008), between crisis (01/07/2008 - 30/12/2011), and post-crisis (02/01/2012 - 31/12/2014). We will now discuss the reasons behind our sub-sample's choice.

We have to stress that our sample starts at the beginning of 1995 (since we were not able to find data from before that year) whereas Ehrmann et al.(2011) have observation from 1993 on, and so our first sub-sample will be composed by two years less. On the other hand, we use data until the end of 2014 while the mentioned paper considers data only up to June 2008. In our opinion this represents a considerable improvement over our benchmark and leads to more updated conclusions regarding the convergence within the EMU.

In May 1998 the countries eligible for inclusion in the common currency area[10] were announced. At the first of January 1999 those countries exchange rates were fixed and the new currency was introduced. The sample considers a period of three complete years ending in December 1998. Thus, it considers a reasonable period prior to the officially start of EMU.

As Ehrmann et al.(2011), we choose as starting date for the second sub-sample the year of 2002, following the arguments of Goldberg and Klein (2005). At the first years of the common currency and common monetary policy the European Central Bank had to establish its own reputation as a completely new institution. In order to avoid any skewed result, we give a time gap of three years from the end of our first sample. This sub-period ends in June 2008, thus incorporates almost one year of financial crisis effects.

Our sub-sample's choice allows us to compare the convergence results ob-

[10]In order to be eligible to be part of the EMU the countries had to respect several conditions, those conditions were stated in the widespread Maastrich Treaty of February 1992.

tained with those presented in the Ehrmann et al.(2011) since the periods are pretty much the same (with the exception of the the start of the first sub-sample).

As said before, we have extended the sample until the end of 2014. In order to draw more accurate conclusions we decided to divide that additional period in two sub-samples. The aim is to understand how the EMU bond markets have reacted to *the Great Recession* and the European sovereign debt crisis times. On other hand, we also aim to check how persistent those effects were and to what extent they were translated into the risk perception of investors and, subsequent investment decisions concerning the Eurozone's countries.

The third sub-sample starts in July 2008 and ends in the end of 2011. With this option we intend to capture the major period of instability since the birth of the Euro area. The Financial crisis in the United States had branches all over the world, and so, we expect to see a global *flight-to-quality* by the worldwide investors. Having said that, we are expecting a slight increase in divergence and volatility among the EMU bond markets. However, as an unified market the effects should be reduced and the path to convergence is expected to return soon.

The subsequent crisis - the European sovereign debt crisis - is expected (from our point of view) to contribute for a persistent cyclical divergency. Nonetheless, in structural terms one expects that after a period of major global and regional instability the unified market should contribute to specific arbitrage movements that ultimately will point the market into the direction of the convergence levels observed before 2008. In order to confirm this expectations, we build a fourth sub-sample that incorporates the period between 2012 and 2014 (three years). Although, this sub-sample is the smallest amongst the four, we believe that the high frequency of our dataset allows us to draw reliable conclusions.

In order to validate the sub-samples choice we check our option more formally through the multiple structural change model designed by Bai and Perron (2003). Applying this method we can have a clear idea about the exact dates of the structural changes in the EMU countries spot rates.

The test is based on the regression of each considered country's spot rate on a constant and corresponding Germany's yield. The Table 1 is composed by three panels (three considered maturities) each one of them presents the tests results for the three Euro area countries. We can see the number of breaks suggested by the most relevant procedures of this methodology and the exact structural break dates that the chosen procedure detects.

Now we find interesting explain the reasons that justify the preference by one specific procedure over another similarly available method.

The information criteria is an option to chose the exact number and dates of the structural changes. This technique could use the BIC[11] or the LWZ criterion[12] as options to choose both the right number of structural breaks as the exact dates when they occurred. Bai and Perron argue that both information criteria have a weakness as selection procedures, they are unable to take into account potential heterogeneity across segments. Furthermore, BIC works rather well when there are breaks but it faces problems within the null hypothesis (of no breaks), this is specially true when the series under test contains serial correlation. In other way around, the LWZ criterion works better under the null hypothesis whereas the outcome is rather poor in the presence of structural break points.

A more effective option is to make the selection through the sequential procedure as suggested by the model's authors - they clearly state that "...overall, the sequential procedure works better..." (Bai and Perron, 2003:15). It also has the capacity to take into consideration potential heterogeneity across segments unlike the two procedures mentioned before.

The methodology choice (in order to detect formally the exact structural breaks in our series) is one more feature that distinguish our research from the work of Ehrmann et al.(2011) since they use Andrews-Ploberger (1994) break point test.

As our objective is to extend the sample and build more sub-samples, we found that Andrews-Ploberger (1994) break point test is not the most appropriate approach since it only captures one structural change while our option allows for

[11] Also known as Schwarz criterion.

[12] The LWZ is a modified Schwarz criterion and owes its name to the authors responsible for its development - Liu, Wu and Zidek (1997).

multiple structural breaks.

Looking at the Table 1 the first insight is that five out of nine sequential procedure's results (considering all the maturities) point to three breaks. In the case of the results pointing to three structural changes, only in one case (France 5 years maturity) this is not reinforced by the two information criterion. Regarding the other four results, we can see that Spain 2 years and 10 years yield find five break points and Italy 5 years point to four breaks points, however, in those cases the BIC (our second procedure option regarding selection of breaks) suggests three breaks. France 10 years yield is the only series for which none of the procedures suggests three breaks. Nonetheless, the two break points suggested by the sequential procedure matches quite well with our first two sub-samples partitions.

The exact dates for the first break do not vary much among countries and maturities, wherein all of them indicate a date before the end date of our first sub-sample. We are aware that by not choosing an early break point the results will be biased. After perform the test with earlier break points, we realized that under no circumstance the final conclusions will be dramatically different. Furthermore, the results indicate once more that investors have anticipated the unification of the EMU sovereign bond market.

The second breaks results also are within a small range, with the maximum difference being less than one year. The latest break (March 2008) is before the break that both we and Ehrmann et al.(2011) are considering (June 2008), hence they will not affect the third sub-sample's analysis.

In the case of the third chosen break, the sequential procedure indicates breaks dates more far from each other (comparing with the first break chosen), among the countries and maturities (there are cases of more than a year of difference). However, none of the breaks is situated beyond the end of 2011 (when finish our third sub-sample) which ensure us that the fourth sub-sample does not contain any break date and, therefore the analysis regarding that last sub-sample will not be biased.

We can say that the multiple structural change model doesn't indicate a major mistake for our sub-sample options. It advises us that we will bias the results, but after the test we can say that any change in order to follow the exact dates of the breaks would not change any of the conclusions that will be presented in section 3.

Finally, the break point test suggests very close dates for the two first break points tests, which indicates similarities in the yield movements across the EMU economies. This is no longer the case for the last break point test that may imply a weaker co-movement in the Eurozone bond market.

2.5 Measures of convergence employed

In the introductory part of this exposition we have spoken about various types of measures used so far to gauge convergence within the EMU. We opted to use the same statistical measures of Ehrmann et al.(2011) research.

Correlation

The first statistical method employed is the raw correlation across all five countries for which we build the spot rates. The correlations are made between yields of the same maturities. We can take advantage of the analysis of Figure 1 (already presented in Subsection 2.2) in order to give an insight about the intuition behind this method. Thus, we can expect values very close to 1 among the Eurozone countries for the second sub-sample pointing to convergence as the visual representation suggests or, for instance, the correlation between Spain's yields and Germany's yields should be lower in the fourth subperiod comparing with subperiod that follows the start of the common currency.

We test the significance of the results through a method similar to the one used by Ehrmann et al.(2011) but with some adaptations. Ehrmann et al.(2011) test whether the difference in values observed across the two sub-samples is statistically significant.

Contrary to Ehrmann et al.(2011), we deal with four sub-samples, hence, our approach is to test the correlation values of the sub-sample 1 with those of the sub-sample 2, the correlation values of sub-sample 2 with the ones obtained in sub-sample 3, and so forth.

All tests had the same result, the correlation values are statistically different across the sub-samples (at 1% level).

Regression

Regression analysis is our second statistical way to gauge convergence. Ehrmann et al.(2011) argue that Germany and its ancient currency, the Deutsche Mark, functioned as the anchor during the process that gave rise to the Eurozone. Therefore, from our point of view, it makes sense to use Germany as a benchmark for this specific analysis. We calculate regressions for each mentioned country using Germany spot rates as an explanatory variable and also a constant. The regressions are made for the four sub-samples and considering similar maturities for the explanatory and the explained variables.

More formally, our general regression specification is as follows,

$$y_t^{i,j} = \alpha^{i,j} + \beta^{i,j}\, Germany_t^j + \varepsilon_t^{i,j} \tag{4}$$

where $y_t^{i,j}$ denotes the spot rate of country i ($i\ \varepsilon$ {France, Italy, Spain, UK }) for the maturity j ($j\ \varepsilon$ {2, 5, 10} years) on date t, α is a constant, β is the coefficient attach to the spot rates benchmark - Germany - and, ε is the error term.

The results will be deeply analysed later on, however, we find it interesting to expose and explain our expectations after the observation of Figure 1. Thus, in case of strong yield's co-movement between one country and Germany, as for instance the co-movement observed in the second sub-sample for France (in all maturities), we expect values very close to one for the Germany coefficient (β^j), results not far from zero for the constant (α^j) and we should see a high R^2 (not considerably different from one), at least if one compares the France regression results with those of the UK. On other hand, in the period between middle 2010 and 2012 we expect regression results pointing to divergence amongst Italy and Germany sovereign bond yields and, hence, Germany coefficients significantly different from one, a value for the constant much higher then zero and lower R^2.

Before moving to the presentation of the third statistical measure, we would like to stress that the datasets length is particular important for the regression analysis, so the conclusions drawn in the sub-samples with more observations (as the second sub-sample, for example) are more reliable than those resulting from periods with less days considered. Although our four sub-samples are relatively large (this is an issue that will be taken into consideration during Section 4).

Principal component analysis

Finally Ehrmann et al.(2011) suggest that he EMU market integration can also be assessed through the study of a single latent factor that should drive, in case of convergence, the zero-coupon yields (of similar maturities) in direction of market unification. The factors model seems to be a plausible choice for this aim since it is able to break the structure of a set of series into different type of factors: factors common to all series and, factors that differentiate them.

Broadly speaking, this method present two types of models usually characterized as macroeconomic factors models and mathematical factors models. The main distinction between them is related with the possibility to observe the factors. The macroeconomic approach is used when the factors are available (observable)[13]. Following Ehrmann et al.(2011), we opted for a mathematical model.

The principal component analysis (PC)[14] is a widely used mathematical model and, it is the third statistical method employed to gauge the convergence within the EMU sovereign bond markets.

[13]An example of the macroeconomic factors model is the Arbitrage pricing theory model developed by Ross (1976) also known as APT model of Ross.

[14]See Abdi and Williams (2010) for further insights about the principal component analysis.

In our calculus, as in the paper of Ehrmann et al.(2011), the first principal component (first PC) loads uniformly on all spot rates series, whereas the second principal component (second PC) differentiates France and Germany from the other two EMU countries under study. This happens for all sub-samples and maturities.

A third principal component (third PC) is also considered. It is almost irrelevant in the former two periods but gains relevance in the last two sub-samples. This factor's loadings also point to differences among the Eurozone countries.

For the purpose of this study, the first PC indicates convergence depending on its weight (convergency in the case of weight close to 1) and, the second and third PCs are interesting in order to understand in what extent variation in the EMU's sovereign bond market is attributable to diverging subgroups (that have emerged within Euro area).

Formally, we compute the PCA technique using the following baseline equation:

$$X = F\Lambda + \eta \ , \tag{5}$$

X stands for the $T \times 4$ matrix where columns are representing spot rates of same maturities for the different countries considered and rows correspond to days. The $T \times k$ matrix of unobserved factors is represented by F (assuming $k < 4$), Λ is a $k \times 4$ factor loadings factors and the last element of the equation, η, is a $T \times 4$ of white noise noise disturbances. The intuition behind the equation (4) can be explained in the following way: the spot rates for the different maturities are converging within the Eurozone bond market if there exists a $T \times 1$ vector F and a constant λ_i, $i = 1, ..., k$, such that $F \times [\lambda_1, ..., \lambda_k]$ up to white noise is able to describe the matrix X.

We interpret the PCA in the next section (Section 3) when we will be presenting the main findings of our research, however, one can read the results as: closest to 1 is the *First component* (first PC) greater is the convergence within the EMU countries.

Finally, it is important to stress that this analysis is done considering only the Euro area countries (Germany, France, Italy and Spain) given that here, we intend to evaluate the level of the EMU's market unification.

2.6 Univariate time series decomposition

The run-up to monetary union was responsible for a dramatic changes in the investors perception of risk regarding the Eurozone countries. These perceptions may have affected the Euro's sovereign debt market. Figure 1 suggests that the period immediately after the Euro introduction (or even before it) has been characterized by a strong unification among the common currency countries. This appears to have been shaken, initially, by the global crisis and later on the observed divergence has deepened during the so called *European debt crisis*. In the last third of Figure 1 we can clearly see a divergence among the Eurozone's spot rates that achieves their peak (highest divergence) during the year of 2012. After that peak, this undesired movement (from the point view of the monetary union project) is reversed and the spreads begin to shrink again. Yet until the end of our dataset, the EMU sovereign bond market never return to the integration's path observed in the first nine years of common currency.

One of our main goals is to answer the question of whether the dynamics along the different sub-samples are permanent or transitory. The expression permanent is used to say that the convergent or divergent movements are related with structural changes in the EMU bond markets. These changes will have implications for the long run. By transitory we mean the type of dynamics that emerge as responses to some kind of temporary market innovation or shock, that could persist in the market place for some time but will ultimately disappear.

The analysis is based on univariate models since they allow to investigate the time-series features in a simplified environment. These type of models have the problem of not take into account a wide source of information as they are exclusively focused upon past history of the variable of interest. Despite the relevance of this critic, it is not that appropriate in cases where the ultimate objective is not to make predictions but instead discover and exploit variable's patterns.

A pre-requisite of such decomposition is to model the yield series under consideration.

(i) *Model selection*

First we check if the time series are stationary. We use two common unit root tests and a stationary test. The main difference between unit root tests and stationary test is that for the former the default hypothesis testing is pointing to the presence of unit root while for the second case stationarity is the default hypothesis. The joint use of this two type of test is known as *confirmatory data analysis*.

The first unit root test used is the augmented Dickey-Fuller (ADF) which is an extension of the work done by Dickey and Fuller (Fuller, 1976; Dickey and Fuller, 1979) also known as $\tau - test$[15]. We compute the test in levels, considering a maximum of 31 lags ($p = 31$) for the dependent variable since there are not a consensus regarding the optimal number of lags to use in cases of samples composed by high frequency data. We choose the number of lags following the first rule of thumb stated in Brooks (2014): "... the frequency of the data can be used to decide. So, for example, if the data are monthly, use 12 lags, if the data are quarterly, use 4, and so on..." (Brooks, 2014:329). Thus, our option was to choose the total number of days of a month, 31.

The unit root test presented by Phillips and Perron (1988) is our second option to test for the presence of unit roots[16]. As for the ADF test, we perform the test in levels but in this case we assume only 20 lags (the number of working days in a month).

[15]The ADF test avoids the true size of the test (the proportion of times a correct null hypothesis is actually incorrectly rejected) to be higher than the nominal size actually used, which represents an update over the $\tau - test$.

[16]The Phillips and Perron (PP) test is quite similar to the ADF test, the main difference is that it allows for autocorrelation in the residuals through the incorporation of an automatic correction to the Dickey-Fuller method.

In theory, both tests should give the same conclusions and suffer from similar limitations. Thus, it is not a surprise that either ADF and PP tests are usually criticized by the same motives. The most emphasized caveat about these two unit root tests have to do with the lack of power in situations where the unit root is very close to the non-stationary threshold, which may give rise to the no rejection of the null hypothesis (presence of an unit root) when it should be the case.

The above mentioned critic is the main reason that justify our option to jointly use unit root and stationarity tests aiming to get robust conclusions for the sixty sub-samples.

Therefore, we complete our confirmatory data analysis by introducing the KPSS staionary test of Kwaitkowski et al.(1992). As we did for the former two methods, we compute the KPSS test for levels and allowing for a maximum lag of 20 (the justification behind this option is similar to the one used for the Phillips and Perron test). Due to computational power reasons, it is assumed a maximum lag length equal to five either for AR ($p \leq 5$) as for MA ($q \leq 5$).

The three tests results point to the same direction: presence of unit root (in the first two tests) and rejection of the null hypothesis in the KPSS test. This indicates that we have to search for a stationary representation for our time series.[17]

Consequently, we repeat the exact same analytical process but, instead of levels, we now consider first differences. Now, the stationary test does not rejects the null hypothesis and both unit root tests point to the rejection of the presence of unit root. This is the case for each one of the sixty sub-samples subject to the tests. The first conclusion is that all the dependent variables, y_t, are integrated, I(d) (where d stands for the order of integration). Dickey and Pantula (1987) have argued that no financial time series contain more than one unit root and, so, we can assume that all the dependent variables are I(1). Hence, we will deal with an ARIMA(p,1,q) model, where p and q are the length of the autoregressive (AR) and moving average (MA) polynomials.

The next step is to identify the most appropriate model, in other words, ...”de-

[17]Detailed test statistics are available upon request.

termining the order of the model required to capture the dynamic feature of the data..." (Brooks, 2014:230). We achieve this end by the calculation and analysis of the *information criteria*. We compute the Akaike's information criteria (AIC) and the BIC, which are the most commonly used information criteria in order to select univariate models. The root mean squared error (RMSE) is also calculated. The model selected should be the one that minimizes the computed information criteria and the RMSE.

Before the model implementation it is necessary to perform a further step: *model checking*. In this stage we want to check whether the residuals are white noise. In case they are not, we can be sure that the model specification is not the most accurate. We compute the ultimate version of Portmanteau autocorrelation test[18], that is a method widely used to deal with ARIMA models.

We test the hypothesis of *no autocorrelation in the residuals*. In case of rejection of the hypothesis (p-value is less or equal to the specified significance level), we know that there is a dynamic misspecification in terms of autocorrelation.

In order to have a better overview about all hypothesis, we built *diagnosis tables*[19] in order to compare all models possibilities, for all countries and maturities considered.

Our first ideal method regarding the model selection would be to choose those AR and MA lag lengths able to minimize the two information criteria and the RMSE at the same time and, in which the residuals does not show evidence of autocorrelation. However, it does not happen for a single sub-sample.

Therefore, we use a second way to get the best model specifications. We choose the lag lengths that minimize the AIC, the RMSE and, that present the highest p-value in the Portmanteau autocorrelation test. In this second procedure, we opt to drop down the BIC information criteria due to it's lack of efficiency

[18]There are two well-known versions of this kind of autocorrelation test. The original is the Box-Pierce test, developed by Box and Pierce (1970). Later on Ljung and Box (1978) improved the first proposition which today is well-known by Ljun-Box test.

[19]The tables are not presented here due to the lack of space, however, they are available upon request.

when compared with the AIC.[20]

For the cases that the three do not match the necessary conditions, a third method is employed: we choose the model that minimize the AIC and that show evidence of no autocorrelation in residuals (p-value greater than 5%). The size of our sample is the main justification to take out RMSE from this third alternative, as it tends (due to its construction) to choose larger models when the samples are large, which is the case of our sample.

(ii) *Beveridge-Nelson decomposition*

With the purpose of isolating the permanent component of our series we followed the work of Beveridge and Nelson (1981). The Beveridge-Nelson decomposition (B-N decomposition) applies ARIMA methods in order to decompose a non-stationary time series into a long-run component and a cyclical component.[21]

Beveridge and Nelson propose the following definition for the permanent component: "...the value the series would have if it were on that long-run path in the current time period. The permanent component is then the long-run forecast of the series adjusted for its mean rate of change ..." (Beveridge and Nelson, 1981: 156). The authors also interpret the cyclical component as " ...a stationary process which represents the forecastable momentum present at each time period but which is expected to be dissipated as the series tends to its permanent level..." (Beveridge and Nelson, 1981: 158).

Watson (1986) discusses the decomposition methods and stresses that the B-N permanent component is the minimum mean-squared-error estimate of the trend, given data up to some time t, taking into consideration a broader dataset. In practice, the calculation of this trend is complicated in ARIMA models due to the presence of infinite sums of the forecasts.

[20]The average variation of the models orders selected through BIC is greater than those that are obtained using AIC.

[21]See Beveridge and Nelson (1981) for details.

Beveridge and Nelson suggest proceeding by truncating the infinite sum of the forecasts at some adequate large number of times. The proposition works well and is exact only when applied to pure MA(q) process, otherwise this method imply a very heavy computation burden and the result is not exact. Alternatively, Miller (1988) explores a new expression which can be effective in presence of pure AR(p) process. However, in presence of other type of models it requires, once again, the truncation of an infinite sum of forecasts.

As our sixty sub-samples are ARIMA process, we use the Newbold approach which avoids imprecisions and heavy computational burden. Newbold (1990) introduces a new algorithm for a precise computation of the B-N decomposition that is able to give an exact formula for the cyclical component and, subsequently give rise to an exact result for the permanent component.[22] The Newbold algorithm is well implemented in the RATS software[23] and we use it to get the decomposed time-series for all five countries considered here.

Now, it is important to stress some remarks about the B-N decomposition.

In general, innovations in the permanent and transitory components are perfectly negatively correlated. This fact contribute to smooth the actual time-series. Thus, one can expect to observe a higher volatility on the trend component comparing with the original series. However, in cases where theory may suggest that innovations on permanent and cyclical components could have different patterns of correlation, this can lead to outcomes where the perfect negative correlation between them does not apply.

Furthermore, the identification of different stochastic trends in integrated time series is possible, in cases for which additional or alternative restrictions are imposed in the correlation between the trend and the transitory components. This last observation lead us to the same conclusion of Watson (1986) , the B-N decomposition is not unique and so, there are many different stochastic trends that can be drawn through the simple computation of univariate decompositions, as for

[22]See Newbold (1990) for further details on the trend component computation.
[23]The package name is ”bndecom.src”.

instance the Hodrick-Prescott (HP) filter.

We have not opted for the Hodrick-Prescott (HP) filter[24] since it doesn't avoid the problem of non-uniqueness of the decomposition. Furthermore, It is less flexible (regarding the trend's volatility that it can achieve) than the B-N decomposition.[25] So, we believe that the B-N decomposition is the best univariate model available in order to get the most reliable trend component.

The ARIMA(p,1,q) models can be found in Tables 2 and 3. Table 2 present the models that resulted from the model selection procedure extensively explained above. However, it is worth noticing that the RATS software package used to calculate the B-N decompositions have several limitations regarding the length of the models that can actually be computed on it. Thus, some models were changed in order to get results for the decomposition. The ARIMA models considered for the computation of the trend and transitory components are presented in Table 3. The models in Table 3 were chosen after the computation of BN decompositions have failed in RATS, hence, we repeat the calculation with the second best model available (with the aim of select the best models, we used the methods Explained above). We repeat the process until the software is able to run the routine. All the models able to fit in the software routine are statistically significant, at least at the 5% level (no autocorrelation).

From Figure 2 to Figure 16 we present all the decomposed yields calculated for the five countries and three maturities. Each figure presents the decomposed series behaviour along the four sub-samples. We split each sub-sample's representation into two graphs, the first (above) displays the trend B-N component (TC) together with the correspondent country's original spot rate while the second presents the cyclical component (CC) behaviour.[26]

Overall the TC behaves quite close to the original spot rates curve but with a

[24]See Hodrick and Prescott (1997) for details.

[25]The HP filter reaches, as maximum level of volatility, the observed volatility in the original time series.

[26]The TC and CC visual representations are not very clear due to the lack of space. So, we specify the exact upper and lower bound among which the trend and cyclical components have moved in order to give a better overview over the outcomes.

level of volatility reasonably higher. This is attested looking at the second sub-sample of Germany 2 years yield, as well as France for the same period and maturity. However, the biggest TC's volatility is observed for UK 2 years yield in the third sub-sample.

From the above observation we can understand that most of the variation observed in the spot rates (Figure 1) are permanent since the trend components appear to behave very close to the spot rate curves. This means that great part of the patterns detected in the zero-coupon yields within the Euro area have structural base.

The main differences within EMU starts in the third sub-sample and, it is linked to the CC component variation. The transitory components of Germany and France present much less volatility comparing with the CC of Spain and Italy. This could be explained by the economic and financial shocks that occurred at that period. It seems that the last two mentioned countries were less ready to deal with the crisis than the former two. This is confirmed in Figure 1 where we found a visual divergence between this two groups around this same period.

Despite this difference, between the central European countries (France and Germany) and the southern European countries (Italy and Spain), regarding the transitory component variation, it seems that it has a residual influence over the EMU's spot rates behaviour. Thus, this observation reinforces the idea that the divergent movements detected in the spot rates are structural rather than only transitory.

The UK's decomposed yields resembles the behaviour of the less volatile EMU countries, however, with a slightly higher variation of the transitory component. Furthermore, the CC in the third sub-sample (for the 2 years maturity) is the one that achieves the higher bounds of variation. Yet, it returns to its values before crisis in the fourth sub-sample which shows that the variations were (in a great extent) only cyclical.

The answer to the shock verified in Italy and Spain is not as effective as the one observed in UK. The possibility of UK to have its own monetary policy might explain part of the difference about the way investors on sovereign bond markets perceive the economic and financial conditions between those two countries with UK.

It is also worth noticing that the transitory component seems to be more volatile for the shorter maturities. This fact proves that short-run sovereign bond investment is more mobile than those of the long-run.[27] Hence, we can extrapolate that investors react in the short-run maturities, signalling their assessments about the countries economies after the shock has occurred.

2.7 Observed patterns in the B-N decomposed series

As we did in Subsection 2.3, here we will give a brief look at the TC drawn in Figure 17, for the same countries and maturities as Figure 1. Some observations are worth noticing and quite different from the ones we made regarding the original series curves. However, the first conclusion should be that the two series do not present any contradictory information or even a major difference between them. This enables us to say that the integration pattern recorded in the EMU's sovereign bond market (discussed in section 2.3) is essentially structural or permanent.

The decomposed spot rates are presenting an higher level of volatility which, as been said before, is an expected outcome. For instance, one can compare the originally drawn spot rates for Spain, during the period between 2002 and 2008, with the decomposed permanent component of Spain during the same period. We can see a considerable higher level of variation. The same conclusion can be drawn for UK during the period between 1996 and 1998.

In the longer maturities the decomposed spot rates behave in a more constant way and, overall, with greater degree of co-movement. This seems to confirm a long-run tendency towards a higher convergence among the EMU bond markets,

[27]By Investment mobility we mean the ability that investment have to move from one asset to another. This movement could give important clues about the way investors are currently perceiving the long run conditions of the investment opportunities available in the sovereign bond market.

at least if one compares with period before the common currency area have taken place.

Although this recognition, the final period of Figure 17 (around 2009) shows that the convergence levels have weakened in a very rapidly and strong way among the EMU economies, and even after the two crises have elapsed the spreads never returned to the values that characterized the first 9 years of the Euro. This is even more troubling because it is for the longer maturity (investors long-run perceptions) that this divergence has grown the most. Having in mind that the ten years maturity usually is the maturity in which the yields are less volatile, we may guess that the convergence that characterized the beginning of EMU will not be achieved soon.

An interesting detail regarding this first analysis to the spot rates decomposition is related with the behaviour of France's yields. In Figure 17, France's yields series seem co-moving further similarly to the Germany anchor than in Figure 1, which confirms our first idea of two different groups within the Euro area. Also, it looks that Germany and France are positively affected (lower investor's perceived sovereign risk) by the common currency regime. On the contrary, the EMU benefits are not very relevant in case of Spain and Italy since they behave structurally much closer to UK comparing to their Euro peers.

3 Main Findings

We decide to split the results presentation in three main points.

First, we compare our results with those of Ehrmann et al.(2011) regarding the two early sub-samples. As this two periods are common to both studies and the statistical methodologies employed are similar, we do not expect to find significant differences between them. If the results corroborate the previous expectation, the updated data outcomes will have a considerable level of trustfulness.

The additional two sub-samples are analysed in a second subsection where we compare the results of the statistical measures and interpret the major outcomes. The observation of Figure 1 and the break point tests indicated that the co-movement within EMU has deteriorated with the emergence of the global financial crisis first and, after with the European debt crisis. However, the fourth sub-sample starts in 2012 when much of those malignant effects have already vanished. Hence, it allow us to check how the Eurozone's integration has evolved after these major macroeconomic shocks.

We finish this chapter looking at the statistical insights of the B-N decomposed series and making a discussion about the structural integration across EMU's bond market. Even considering that many authors do not consider the European Monetary Union an OCA, we expect some stronger level of long term bond market integration since EMU countries share the same monetary policy and are exposed to the same global and regional economic environment.

The statistical measures employed to gauge convergence across the spot rates are also used here. The results interpretation is similar for the three methodologies.

Yet, there is a results in the PC analysis that is surprising and is worth mentioned before we proceed with the results interpretation. For the 10 years maturity, in the sub-sample 3, the first PC is no longer representing a common factor, instead it differentiates Italy and Spain from Germany and France. In this specific outcome, the common factor is now the second PC. This is happening for the spot rates and for the B-N long run trend.

The correlation results are given from Tables 4 to 7 for the original spot rates and, from Tables 16 to 19 for the decomposed series. The PC's analysis is made in Tables 8 to 11 and 20 to 23 for the spot rates series and the decomposed bond's yields respectively. Together with the components, we present the factor loadings for the three PCs. Tables 9 to 15 show the spot rate's regressions on Germany. The same is made in Tables 24 to 27 for the regressions on B-N trend component of the zero-coupon yields.

3.1 Comparison between empirical results

Ehrmann et al.(2011) found a considerable level of divergence across EMU countries in the period before the common currency have taken place. Our statistical results point to the same conclusions, which confirms observations made in Subsection 2.2 regarding the visual representation of the spot rates (Figure 1).

The quantifications made on the three statistical measures resemble to those in the baseline paper, for all the countries and maturities. The raw correlation (Table 4) states that Spain and Italy are the countries with higher degree of co-movement while Germany and Italy have the lowest value among all the countries. The PC analysis, in Table 8, shows that the second factor explains a non-negligible part of the total variation of the Euro-countries spot rates. The regressions on Germany's yields, presented in Table 12, indicates coefficient values very far from one for the explanatory variable and very far from zero for the constant, whereas the R^2 leaves an important part of the countries zero-coupon yields unexplained.

We must bear in mind that we considered two years less for this first sub-sample if one compares with the paper of Ehrmann et al.(2011). Thus, this result's closeness is quite promising.

Regarding the first years of EMU (until mid 2008), represented in our case by the second sub-sample and by the *post-EMU period* in the baseline paper, convergence have remarkably increased within the Euro area. In Figure 1 we can see that for all maturities the four EMU countries yields are indistinguishable during this period, even during the first year of financial crisis.

The previous idea is reinforced by the values returned by the statistical measures.

In Table 5, the correlations suggest an almost perfect integration across EMU's sovereign bond market. This is even more striking when one compares the correlation result between Italy and Germany or Spain and Germany in the first subsample to those obtained in the second. For instance, Italy and Germany correlation went from a value of 0.672 to a value of 0.995 (in the two years maturity) after the Euro introduction. Moreover, the variation in EMU's sovereign bond market is almost fully explained by the common factor in the PC analysis (table 9). Additionally, the regressions (table 13) also give strong arguments in favour of convergence.

It is also worth noticing that the unification of the Eurozone's sovereign bond market has something to do with the common currency project, since when we compare statistical results of the EMU countries with those of UK (control country) the differences are evident, which was not the case before the Euro.

Overall, the results for this two first sub-sample are in line with those of Ehrmann et al. (2011) which strengthens the credibility of our dataset and the subsequent outcomes concerning the additional sub-samples analysis.

3.2 Main insights after crisis

The EMU bond market convergence falls deeply in our third sub-sample, being at this stage even smaller than the levels observed before the Eurozone start.

The global financial crisis has been a major event and had serious repercussions in the worldwide sovereign bond markets. EMU is not an exception as can be seen in figure 1. Around 2009 the spot rates experience a sharp increase, however this increase is common to all countries (UK included) and temporary. Shortly after, spot rates return to their prior levels (except for the longer maturity) or even arrive to lower values as is the case of Germany and France. Thus, it seems that this unexpected phenomena is not the main explanation for the bond yield divergence across EMU which is clearly proven by the statistical measures for the third sub-sample.

The correlation results, in Table 6, indicate that the previous co-movement weakens deeply among the Euro members. Germany and France are the countries with the highest yield's correlation, although very far way from the value achieved in the first years of EMU. Furthermore, the co-movement of Italy and Spain with Germany is almost nonexistent or even opposite, as the negative correlations for the 5 and 10 years maturities allow us to perceive.

The PC analysis (Table 10) reinforces the insights from the correlations and regression results. Here, the first and third component together are able to explain more than a third of the EMU bond market variation (for the two longest maturities), highlighting a strong divergence within the Euro area's sovereign debt markets. The fact that this is the single sample where there is maturity (10 years) in which the common latent factor is not explaining the majority of the zero-coupon variations. This result clearly highlights a divergence within the Eurozone during the crisis period.

The European sovereign debt crisis appears to be the turning point regarding the behaviour of EMU's spot rates. The convergence at this stage achieved levels bellow those observed in the period before EMU has taken place. Our interpretation of this fact ties in with the conclusion of Barrios et al. (2009) and Attinasi et al. (2010). It seems that with the *Great Recession*, investors have increased their risk aversion impacting in a great extent the sovereign bond yields across EMU. With the emergence of the second crisis (in a short while), investors realized that they were underestimating the sovereign risks of some EMU members. The reaction was extreme and the *weaker countries* start to feel the consequences through the bond markets.

An even more surprising result is related with the behaviour of UK spot rates. The UK yields are those moving closer to Germany's, at least for the 5 and 10 years maturities.

The results for the regression on Germany's yields display a clear approximation between France and UK and, on other hand, a steep divergence of Italy and

Spain's spot rates. We can see in Tables 11 that the coefficient linked to the explanatory variable is quite near to one (convergence) for the spot rates of France and UK. On the contrary, the same coefficients for the yields of Italy and Spain are negatives or very close to zero showing a significant reversion in the convergence patterns of the EMU's spot rates. The previous ideas of divergence are clearly enhanced after looking at the constant's values in the regressions. This last fact is completely new and a quite puzzling one.

From the above statistical observations we can draw two striking findings.

First, It seems that the common monetary policy had little contribution in order to prevent the divergence observed in the bond market across Euro zone countries, given that UK's zero-coupon yields behaved nearest to Germany than Italy or Spain.

Second, the rise of two groups within the EMU space is now evident - Germany and France (that presented movements much closer to UK) and Italy and Spain. The weight detected in Table 10 for the second PC (for the 2 and 5 years maturities), and more important, the rise of the differentiating factor as the main responsible for the 10 years yields' variation is a notorious prove of this internal division. This remark is aligned with one of the main conclusions present in Costantini et al.(2014) paper.

In the fourth sub sample (after the European debt crisis), we can see an improvement in the degree of integration between EMU countries as verified by the PC analysis. However, it resembles more (although smaller for most of the cases) to the movements before the EMU than with the years of convergence verified in the period post Monetary Union. In this sub-sample, the second factor explains a reasonable part of the total variation observed in the EMU sovereign bond market (between 0.165 and 0.302 for the 10 years and 2 years maturities, respectively). This factor still plays a greater role in this period than in the sub-sample 1.

The way for the formation of two groups did not disappear in sub-sample 4, as is clear from the obtained statistical results.

Italy and Spain have the strongest correlation among all the results and for the three maturities. The correlation between the bond yields of Germany and France have experienced a fall, nevertheless, it is the second highest correlation's value (this is true for all maturities). We can say that investors are perceiving the EMU as a union formed by two blocks of countries with considerable differences regarding their sovereign risks.

All the correlation results are confirmed by the regression analysis, for all maturities. The closest regression results are those of Italy and Spain (except for the shorter maturity), despite a slight improvement since the previous sub-sample, they show that the spot rates for the two countries remain away from those of Germany. French rates have suffered a deterioration of its convergence with respect to those of Germany. This is evident through the comparison between regression results of table 15 and those observed in Table 13.

The study of Figure 1 and the argument of Attinasi et al.(2010) could be a possible explanation for the changes visible in the third and fourth sub-samples. The verified surge in the investors risk awareness and risk aversion have two important interlinked consequences. First affects the most unbalanced EMU countries since the investment goes out of their boarders and, as a results the safest countries end up receiving an important part of this capital. The major consequence is a divergency reinforcement.

This may explain the dynamic behind the spot rates behaviour in the last third of Figure 1 where we can see that, despite high variation in the countries yields, Germany not only did not experienced increases in its financing costs but, even saw them fall whereas Italy and Spain experienced sharp increases.

3.3 Structural analysis

Broadly speaking, the statistical measures applied to the B-N decomposed series confirm the results obtained for the spot rates series. Globally, the outcomes are suggesting the same conclusions, which reveals that the convergence's patterns detected in the spot rates across Eurozone have structural bases (they will persist in the long run). We believe that this is our main conclusion taking into account that after the crisis we see a dramatic weakening in the integration across the EMU's sovereign bond market.

The statistical measures, for the first sub-sample, point to the same direction of the results previously presented (on spot rates), for the same period. Indicating a considerable level of structural divergence between (future) EMU countries.

Also in the first sub-sample, the results for the 10 years maturity are those where the divergence is less pronounced, which might indicate that investor have anticipated an integration improvement in the long run. This a quite plausible observation having in mind that at that period the Eurozone project was already well known by investors. The major concern among investors was to understand which European countries would be able to meet the necessary conditions to integrate the common currency.

Comparing the second sub-sample's decomposed series results with those verified for the spot rates, we found much more similarities than differences in the results. The correlation and the regression corroborate the previous results on spot rates (as expected) since there were no major events during the first half of EMU existence.[28] Thus the strong convergence that features the initial period of the Euro seems to have a structural base.

Looking for the decomposed results in the third sub-sample, we can say that EMU is of little help for smoothing structural consequences of major shocks in the European financial markets. It is even possible that EMU has contributed negatively to avoid these consequences since the verified divergence is higher than before the beginning of the Eurozone (first sub-sample).

The PC analysis (Table 22) shows that the second and third factor can explain between a third and almost an half of the total variation in the sovereign bond markets across Euro area (values even higher than those obtained for the results of the spot rates). The most interesting result of this outcome is stamped in the 10 years maturity. The first PC is differentiating the EMU countries and it accounts

[28]We assume that one year of financial crisis is not enough to change the statistical outcomes of a sample that integrates working days of 7 years.

for almost two thirds of the total variation in the trend component (the second PC is the common factor here). This result proves a strong structural divergence in the EMU's sovereign bond market.

This can also be sustained through the observation of UK permanent component that is perceived by the investors as the country closer to Germany during this period of instability, although UK is not an Euro area member.

Both the raw correlation (Table 18) as the regressions (Table 26) suggests that Germany and UK had the strongest co-movement amongst all countries. The sub-sample 3 is the only period (of the four) for which the strongest correlation is between an Eurozone country and a country that does not share the common currency.

In the last sub-sample, the degree of structural convergence in the bond markets that resulted from the three statistical measures applied to the B-N decomposed series, still is quite low (lower than that observed during the period before EMU) and is giving contradictory insights. However, it is possible to note a slight improvement, specially for the longer maturities, if one compares with the decomposed results verified in the previous period.

Italy and Spain are the countries that show the higher level of convergence among all the European states considered (even considering UK). This can easily be check through the observation of Table 19, in which Italy and Spain trend components have the values that are nearest to one, in all maturities.

Also from Table 19, we note a weakening in the co-movement between France and Germany. Yet, the regression exposed in Table 21 shows that, after the third period, France is once again the EMU country that investors perceive as the closest to the European benchmark - Germany.

The first PC (table 23) for the 5 and 10 years maturities, gains importance regarding the explanation of the total structural variation of the EMU's sovereign bond market comparing with the sub-sample 3.

At this stage, UK again becomes the country with the smaller degree of convergence among all countries considered in this dissertation. This is well state in the regression results (Table 27).

The statistical analysis to the B-N decomposed yields shows that the Euro area's convergence is at stake given that instead of a concerted structural movement, the Eurozone sovereign bond market is formed by two groups of countries. Investors perceive the economic and financial conditions of these two groups as very different, which it is translated in the market through the spreads on sovereign bond yields. A possible reason could be related with structural risk aversion triggered after the crisis that made investors pay heightened attention to the economic and financial idiosyncrasies of the EMU members.

Economic and financial weakening signs as persistent inflation differential, competitiveness gaps, default and liquidity risks are nowadays highly scrutinized by worldwide sovereign bond investors. This seems to be an important structural modification regarding the approach investors have to the EMU's sovereign bond market.

4 Conclusions

With the aim to evaluate the convergence within the Eurozone, we focus our study in the sovereign bond yield's dynamics. We extend the unconditional analysis of Ehrmann et al.(2011) by considering an updated dataset. The countries and maturities under study are those that the authors used in their research. Furthermore, we employe similar statistical measures to gauge convergence in the common currency area.

Our high-frequency dataset is divided in a way that allows us to perfectly compare our results to the ones of Ehrmann et al. (2011). Their study goes from 1993 up to mid 2008, which corresponds to our first two sub-samples. As expected, we obtain the same conclusions: the period before EMU was characterized by a divergence among the European countries whereas the first years after the common currency introduction features a strong convergence between EMU countries.

Our main contribution to the literature, besides the updated high-frequency dataset, is to extract the permanent component from the original series in order to assess the structural convergence within the EMU sovereign bond market.

During it's most unstable period, the Euro area has experienced two major macroeconomic events - *the great recession* and *the European sovereign debt crisis*. In order to study their impact for the convergence across EMU bond markets we considered data until the end of 2014.

The integration previously observed in the EMU's bond market falls deeply. It achieves a divergence even bigger than that observed in the period pre-Euro. However, the global financial crisis had not an impact as big as the effect caused by the second crisis. It seems that the Euro had a counter-productive impact in the spreads between member countries, perhaps due to the rigidities imposed by a common monetary policy.

A striking remark coming out of this study is the tendency for the formation of two groups within the Euro area. This fact is also stressed by Costantini et al.(2014). The problem relates to the risk aversion increase experienced after the crisis, which seems to be a structural change in the investors behaviour, which may mean an *investment's funnelling* toward the safest countries, as soon as a small economic instability is suspected to take place. Our statistical results suggest that this is a long run tendency.

The earlier risk underestimation made by investors relative to some European countries together with the above explained investment movement may generate an even greater widening in spreads, since the Euro area is composed by economies in different development stages and, sovereign bond investors are likely to behave in a *over-caution way*. We find evidence that this modification in the worldwide investors is in a great extent structural.

We are aware that our approach it is neither the only one nor the best but it is one that we find interesting to follow and in which we had some room to innovate.

This study could be further developed by introducing the remaining Eurozone countries. Another interesting question is to check how the recent unconventional monetary policy measures have impacted the sovereign bond spreads across EMU countries. A theoretical work on how monetary and fiscal policy can interact in order to prevent or reduce damaging effects for convergence in the sovereign bond yields within the Euro area caused by major macroeconomic shocks, also seems to be a challenging avenue of research.

References

[1] Abdi, H. and Williams, L. J. 2010. Principal component analysis. ***Wiley Interdisciplinary Reviews: Computational Statistics***, 2(4):433-459.

[2] Andrews, D. W. K. and Ploberger, W. 1994. Optimal tests when a nuisance parameter is present only under the alternative. ***Econometrica***, 1383-1414.

[3] Attinasi, M. G. and Checherita-Westphal, C. D. and Nickel, C. 2009. What explains the surge in euro area sovereign spreads during the financial crisis of 2007-09? ***ECB Working Paper***.

[4] Baele, L. and Ferrando, A. and Hrdahl, P. and Krylova, E. and Monnet, C. 2004. Measuring financial integration in the euro area. ***Oxford Review of Economic Policy***, 20(4):509-530.

[5] Bai, J. and Perron, P. 2003. Computation and analysis of multiple structural change models. ***Journal of Applied Econometrics***, 18(1):1-22.

[6] Bai, J. and Perron, P. 2003a. Critical values for multiple structural change tests. ***The Econometrics Journal***, 6(1):72-78.

[7] Barrios, S. and Iversen, P., Lewandowska, M. and Setzer, R. 2009. Determinants of intra-euro area government bond spreads during the financial crisis. ***Directorate General Economic and Monetary Affairs (DG ECFIN), European Commission***.

[8] Beveridge, S. and Nelson, C. R. 1981. A new approach to decomposition of economic time series into permanent and transitory components with particular attention to measurement of the business cycle. ***Journal of Monetary Economics***, 7(2):151-174.

[9] Björk, T. and Christensen, B. J. 1999. Interest rate dynamics and consistent forward rate curves. ***Mathematical Finance***, 9:323-348.

[10] Box, G. E. P. and Pierce, D. A. 1970. Distribution of residual autocorrelations in autoregressive-integrated moving average time series models. ***Journal of the American Statistical Association***, 65(332):1509-1526.

[11] Brooks, C. 2014. ***Introductory econometrics for finance.*** Cambridge university press

[12] Canova, F. and Ciccarelli, M. and Ortega, E. 2007. Similarities and convergence in G-7 cycles. ***Journal of Monetary Economics***, 54(3):850-878.

[13] Costantini, M. and Fragetta, M. and Melina, G. 2014. eterminants of sovereign bond yield spreads in the EMU: An optimal currency area perspective. European Economic Review, 70:337-349.

[14] De Grauwe, P. and Ji, Y. 2012. Mispricing of Sovereign Risk and Macroeconomic Stability in the Eurozone. ***JCMS: Journal of Common Market Studies***, 50(6):866-880.

[15] De Pooter, M. 2007. Examining the Nelson-Siegel class of term structure models: In-sample fit versus out-of-sample forecasting performance. ***Available at SSRN 992748***.

[16] Dickey, D. A. and Fuller, W. A. 1979. Distribution of the estimators for autoregressive time series with a unit root. ***Journal of the American Statistical Association***, 74(366a):427-431.

[17] Dickey, D. A. and Pantula, S. G. 1987. Determining the order of differencing in autoregressive processes. ***Journal of Business & Economic Statistics***, 5(4):455-461.

[18] Diebold, F. X. and Li, C. 2006. Forecasting the term structure of government bond yields. ***Journal of Econometrics***, 130(2):337-364.

[19] Ehrmann, M., Fratzscher, M., Grkaynak, R. S., and Swanson, E. T. 2011. Convergence and anchoring of yield curves in the euro area. ***Review of Economics and Statistics***, 93: 350-364.

[20] Estrada, A., Gal, J. and López-Salido, D. 2013. Patterns of convergence and divergence in the euro area. ***IMF Economic Review***, 61(4):601-630.

[21] Fisher, M. and Nychka, D. W. and Zervos, D. 1995. Fitting the term structure of interest rates with smoothing splines. ***Federal Reserve System Working Paper***.

[22] Fratzscher, M. and Stracca, L. 2009. The political economy under monetary union: Has the euro made a difference? ***Economic Policy***, 24(58):307-348.

[23] Fuller, W. A. 1976. ***Introduction to Statistical Time Series***. John Wiley & Sons.

[24] Goldberg, L. S. and Klein, M. W. 2005. Establishing credibility: evolving perceptions of the European Central Bank. ***National Bureau of Economic Research***.

[25] Guirreri, S. S. 2010. YieldCurve: Modelling and estimation of the yield curve. ***R package version***, 3.

[26] Grkaynak, R. S., Sack, B. and Wright, J. H. 2007. The US Treasury yield curve: 1961 to the present. ***Journal of Monetary Economics***, 54(8):2291–2304.

[27] Hodrick, R. J. and Prescott, E. C. 1997. Postwar US business cycles: an empirical investigation. ***Journal of Money***, Credit, and Banking, 1-16.

[28] Jankowitsch, R. and Msenbacher, H. and Pichler, S. 2006. Measuring the liquidity impact on EMU government bond prices. ***The European Journal of Finance***, 12(2):153-169.

[29] Kwiatkowski, D., Phillips, P. C.B. and Schmidt, P. and Shin, Y. 1992. Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root? ***Journal of Econometrics***, 54(1):159-178.

[30] Lane, P. R. 2006. The Real Effects of European Monetary Union (Digest Summary). ***Journal of Economic Perspectives***, 20(4):47-66.

[31] Liu, J. and Wu, S. and Zidek, J. V. 1997. On segmented multivariate regression. ***Statistica Sinica***, 7(2):497-525.

[32] Ljung, G. M. and Box, G. E. P. 1978. On a measure of lack of fit in time series models. ***Biometrika***, 65(2):297-303.

[33] McCulloch, J. H. 1971. Measuring the term structure of interest rates. ***Journal of Business***, 19-31.

[34] McCulloch, J. H. 1975. The tax-adjusted yield curve. ***Journal of Finance***, 811-830.

[35] Miller, S. M. 1988. The Beveridge-Nelson decomposition of economic time series: Another economical computational method. ***Journal of Monetary Economics***, 21(1):141-142.

[36] Nelson, C. R. and Siegel, A. F. 1987. Parsimonious modeling of yield curves. ***Journal of Business***, 473-489.

[37] Newbold, P. 1990. Precise and efficient computation of the Beveridge-Nelson decomposition of economic time series. ***Journal of Monetary Economics***, 26(3):453-457.

[38] Pagano, M. and Von Thadden, E. 2004. The European bond markets under EMU. ***Oxford Review of Economic Policy***, 20(4):531-554.

[39] Phillips, P. C. B. and Perron, P. 1988. Testing for a unit root in time series regression. ***Biometrika***, 75(2):335-346.

[40] Rogers, J. H. 2007. Monetary union, price level convergence, and inflation: How close is Europe to the USA? ***Journal of Monetary Economics***, 54(3): 785-796.

[41] Ross, S. A. 1976. The arbitrage theory of capital asset pricing. ***Journal of Economic Theory***, 13(3):341-360.

[42] Shea, G. S. 1984. Pitfalls in smoothing interest rate term structure data: Equilibrium models and spline approximations. ***Journal of Financial and Quantitative Analysis***, 19(03):253-269.

[43] Svensson, L. 1994. Estimating and interpreting forward interest rates: Sweden 1992-1994. ***National Bureau of Economic Research***.

[44] Watson, M. W. 1986. Univariate detrending methods with stochastic trends. ***Journal of Monetary Economics***, 18(1):49-75.

Table 1: **Bai-Perron Break Point tests**

2 Years	**Nº Breaks**	**Break dates**				
France						
Sequential	3	01-01-1998*	30-10-2007*	02-09-2011*		
BIC	3					
LWZ	3					
Italy						
Sequential	3	01-01-1998*	05-03-2008*	29-07-2011*		
BIC	3					
LWZ	3					
Spain						
Sequential	5	01-01-1998*	02-04-2001*	29-04-2004*	02-05-2007*	04-05-2010*
BIC	3					
LWZ	2					
5 Years	**Nº Breaks**	**Break dates**				
France						
Sequential	3	18-11-1998*	05-03-2008*	02-09-2011*		
BIC	5					
LWZ	5					
Italy						
Sequential	4	01-01-1998*	06-12-2001*	04-03-2008*	11-07-2011*	
BIC	3					
LWZ	3					
Spain						
Sequential	3	01-01-1998*	02-05-2007*	04-05-2010*		
BIC	3					
LWZ	3					
10 Years	**Nº Breaks**	**Break dates**				
France						
Sequential	2	05-01-1998*	05-03-2008*			
BIC	5					
LWZ	4					
Italy						
Sequential	3	08-01-1998*	05-03-2008*	11-07-2011*		
BIC	3					
LWZ	3					
Spain						
Sequential	5	09-01-1998*	02-04-2001*	02-04-2004*	18-05-2007*	20-05-2010*
BIC	3					
LWZ	3					

The test is based on the regression of each considered county's spot rate on a constant and corresponding Germany's yield.
Notes: Statistics show the number of breaks suggested by two information criteria and sequential procedure. It also specify the exact dates of the break points.
Sequential stands for the sequential procedure.
BIC stands for the information criterion also know as Schwarz criterion.
LWZ stands for the information criterion also know as modified Schwarz criterion.
* statistically significant at the 5% level.
Detailed test-statistics are available from the author upon request.

Table 2: **ARIMA(p,1,q) model selected**

2 Years	**sub-sample 1**	**sub-sample 2**	**sub-sample 3**	**sub-sample 4**
France	(4,1,5)*	(1,1,0)*	(3,1,4)*	(4,1,0)*
Germany	(4,1,5)*	(5,1,5)*	(2,1,4)*	(4,1,5)*
Italy	(3,1,4)*	(4,1,5)*	(4,1,5)*	(5,1,5)*
Spain	(5,1,5)*	(1,1,0)*	(5,1,5)*	(5,1,5)*
UK	(5,1,5)*	(5,1,5)*	(5,1,5)*	(5,1,5)*
5 Years	**sub-sample 1**	**sub-sample 2**	**sub-sample 3**	**sub-sample 4**
France	(4,1,2)*	(3,1,3)*	(5,1,5)*	(5,1,3)*
Germany	(5,1,5)*	(5,1,5)*	(2,1,5)*	(3,1,3)*
Italy	(5,1,5)*	(5,1,5)*	(4,1,4)*	(4,1,5)*
Spain	(5,1,5)*	(2,1,4)*	(5,1,5)*	(5,1,3)*
UK	(5,1,5)*	(3,1,2)*	(5,1,5)*	(5,1,5)*
10 Years	**sub-sample 1**	**sub-sample 2**	**sub-sample 3**	**sub-sample 4**
France	(1,1,3)*	(5,1,5)*	(5,1,5)*	(4,1,4)*
Germany	(2,1,4)*	(5,1,5)*	(2,1,3)*	(5,1,4)*
Italy	(4,1,4)*	(3,1,4)*	(4,1,5)*	(4,1,4)*
Spain	(5,1,5)*	(2,1,2)*	(5,1,5)*	(5,1,5)*
UK	(5,1,5)*	(5,1,5)*	(3,1,5)*	(3,1,4)*

Note: All the ARIMA models found after a *confirmatory data analysis*.
* Portmanteau autocorrelation test indicates no autocorrelation in residuals.
Detailed test-statistics are available from the author upon request.

Table 3: **ARIMA(p,1,q) model employed for the B-N Decomposition computation**

2 Years	**sub-sample 1**	**sub-sample 2**	**sub-sample 3**	**sub-sample 4**
France	(4,1,4)*	(1,1,0)*	(3,1,4)*	(4,1,0)*
Germany	(4,1,4)*	(4,1,4)*	(2,1,3)*	(4,1,4)*
Italy	(3,1,4)*	(4,1,3)*	(4,1,3)*	(4,1,4)*
Spain	(4,1,3)*	(1,1,0)*	(4,1,4)*	(4,1,3)*
UK	(4,1,3)*	(4,1,2)*	(4,1,4)*	(4,1,1)*
5 Years	**sub-sample 1**	**sub-sample 2**	**sub-sample 3**	**sub-sample 4**
France	(4,1,0)*	(3,1,2)*	(4,1,4)*	(4,1,1)*
Germany	(4,1,0)*	(4,1,4)*	(2,1,4)*	(3,1,1)*
Italy	(4,1,4)*	(4,1,4)*	(4,1,2)*	(4,1,4)*
Spain	(4,1,2)*	(2,1,3)*	(4,1,3)*	(4,1,4)*
UK	(4,1,3)*	(3,1,2)*	(4,1,4)*	(4,1,4)*
10 Years	**sub-sample 1**	**sub-sample 2**	**sub-sample 3**	**sub-sample 4**
France	(1,1,3)*	(4,1,4)*	(4,1,1)*	(4,1,4)*
Germany	(2,1,4)*	(4,1,4)*	(2,1,2)*	(4,1,3)*
Italy	(4,1,1)*	(3,1,4)*	(4,1,2)*	(4,1,2)*
Spain	(4,1,0)*	(2,1,1)*	(4,1,3)*	(4,1,3)*
UK	(4,1,3)*	(4,1,2)*	(3,1,4)*	(3,1,3)*

Note: Best ARIMA models able to be well implemented in the RATS package "bndecom.src".
* Portmanteau autocorrelation test indicates no autocorrelation in residuals.
Detailed test-statistics are available from the author upon request.

Table 4: **Correlations of Spot Rates Across Countries, for the sub-sample 1**

2 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.89420	1.00000			
Italy	0.89320	0.67280	1.00000		
Spain	0.92040	0.71900	0.99210	1.00000	
UK	0.62540	0.81040	0.42480	0.44960	1.00000
5 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.96560	1.00000			
Italy	0.96360	0.90080	1.00000		
Spain	0.97320	0.91220	0.99490	1.00000	
UK	0.91430	0.95070	0.89530	0.89160	1.00000
10 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.97540	1.00000			
Italy	0.97540	0.92510	1.00000		
Spain	0.97970	0.93380	0.99740	1.00000	
UK	0.94740	0.97470	0.91750	0.92340	1.00000

All the correlation values are statistically different (1%) from there peers in sub-sample 2.
Detailed test-statistics are available from the author upon request.

Table 5: **Correlations of Spot Rates Across Countries, for the sub-samples 2**

2 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.99680	1.00000			
Italy	0.99810	0.99530	1.00000		
Spain	0.99890	0.99720	0.99910	1.00000	
UK	0.72520	0.74250	0.72910	0.73670	1.00000
5 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.99420	1.00000			
Italy	0.99520	0.99350	1.00000		
Spain	0.99780	0.99640	0.99740	1.00000	
UK	0.73310	0.76370	0.73740	0.74100	1.00000
10 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.98750	1.00000			
Italy	0.98720	0.98330	1.00000		
Spain	0.99700	0.98920	0.99160	1.00000	
UK	0.72090	0.76260	0.74820	0.72380	1.00000

All the correlation values are statistically different (1%) from there peers in sub-sample 1 and 3.
Detailed test-statistics are available from the author upon request.

Table 6: **Correlations of Spot Rates Across Countries, for the sub-sample 3**

2 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.97310	1.00000			
Italy	0.46670	0.27220	1.00000		
Spain	0.47700	0.32030	0.90840	1.00000	
UK	0.94890	0.94580	0.33650	0.32780	1.00000
5 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.93250	1.00000			
Italy	0.25970	-0.07310	1.00000		
Spain	0.19030	-0.04880	0.82440	1.00000	
UK	0.89550	0.95970	-0.10060	-0.14210	1.00000
10 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.89990	1.00000			
Italy	0.06840	-0.31780	1.00000		
Spain	-0.12410	-0.35470	0.77780	1.00000	
UK	0.83920	0.96990	-0.36630	-0.38450	1.00000

All the correlation values are statistically different (1%) from there peers in sub-sample 2 and 4. Detailed test-statistics are available from the author upon request.

Table 7: **Correlations of Spot Rates Across Countries, for the sub-sample 4**

2 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.72550	1.00000			
Italy	0.63730	0.21430	1.00000		
Spain	0.41400	0.10150	0.93350	1.00000	
UK	0.29200	0.05740	-0.03470	-0.25260	1.00000
5 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.80550	1.00000			
Italy	0.79590	0.46260	1.00000		
Spain	0.62730	0.34270	0.94450	1.00000	
UK	-0.10450	0.15380	-0.55890	-0.68300	1.00000
10 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.85660	1.00000			
Italy	0.85370	0.57060	1.00000		
Spain	0.74410	0.47290	0.95040	1.00000	
UK	0.11870	0.44730	-0.31860	-0.45030	1.00000

All the correlation values are statistically different (1%) from there peers in sub-sample 3. Detailed test-statistics are available from the author upon request.

Table 8: **Principal Component Analysis of Spot Rates Across EMU Countries, sub-sample 1**

Contributions of	**2 Years**	**5 Years**	**10 Years**
First PC	0.8884	0.9639	0.9734
Second PC	0.1028	0.0316	0.0239
Third PC	0.0075	0.0035	0.002
Factor Loadings			
First Factor			
France	0.5219	0.5061	0.5047
Germany	0.4598	0.4898	0.4923
Italy	0.503	0.5006	0.5006
Spain	0.513	0.5033	0.5023
Second Factor			
France	0.1664	0.1543	0.1503
Germany	0.7688	0.7568	0.7576
Italy	-0.4835	-0.4888	-0.486
Spain	-0.3841	-0.4056	-0.409
Third Factor			
France	-0.8335	-0.8195	-0.8501
Germany	0.4437	0.4282	0.4264
Italy	0.2759	0.3798	0.2138
Spain	0.1797	0.0295	0.2233

Note: Contributions of the first, second and third principal components (PC) to the cross-sectional variance of the spot rates across the four EMU economies and, respective factor Loadings
The First PC stands for the first factor.
The Second an third PC stands for the second and third factor.

Table 9: **Principal Component Analysis of Spot Rates Across EMU Countries, sub-sample 2**

Contributions of	**2 Years**	**5 Years**	**10 Years**
First PC	0.9982	0.9968	0.992
Second PC	0.0013	0.0017	0.0042
Third PC	0.0004	0.0012	0.0032
Factor Loadings			
First Factor			
France	0.5001	0.5	0.5005
Germany	0.4996	0.4996	0.499
Italy	0.5	0.4998	0.4993
Spain	0.5003	0.5006	0.5012
Second Factor			
France	-0.1326	-0.22	-0.0064
Germany	0.8248	0.8217	0.761
Italy	-0.5233	-0.5193	-0.6384
Spain	-0.1681	-0.0818	-0.1154
Third Factor			
France	-0.8391	-0.7557	-0.6423
Germany	0.2017	0.1871	0.4131
Italy	0.4798	0.6251	0.5577
Spain	0.1579	-0.0561	-0.3254

Note: Contributions of the first, second and third principal components (PC) to the cross-sectional variance of the spot rates across the four EMU economies and, respective factor Loadings
The First PC stands for the first factor.
The Second an third PC stands for the second and third factor.

Table 10: **Principal Component Analysis of Spot Rates Across EMU Countries, sub-sample 3**

Contributions of	**2 Years**	**5 Years**	**10 Years**
First PC	0.6788	0.5166	0.5576
Second PC	0.2966	0.4341	0.3784
Third PC	0.0236	0.0471	0.0599
Factor Loadings			
First Factor			
France	0.5401	0.6096	0.4584
Germany	0.4761	0.4819	0.5919
Italy	0.4853	0.4531	-0.4406
Spain	0.4961	0.4369	-0.4954
Second Factor			
France	-0.4142	-0.3573	0.5845
Germany	-0.5671	-0.5415	0.355
Italy	0.5176	0.5343	0.5623
Spain	0.4888	0.5418	0.465
Third Factor			
France	-0.1573	-0.1819	-0.1752
Germany	0.1181	0.1934	0.2934
Italy	-0.6713	-0.6487	-0.6008
Spain	0.7146	0.7132	0.7227

Note: Contributions of the first, second and third principal components (PC) to the cross-sectional variance of the spot rates across the four EMU economies and, respective factor Loadings
The First PC stands for the first factor.
The Second an third PC stands for the second and third factor.

Table 11: **Principal Component Analysis of Spot Rates Across EMU Countries, sub-sample 4**

Contributions of	**2 Years**	**5 Years**	**10 Years**
First PC	0.6402	0.7532	0.8099
Second PC	0.3021	0.2096	0.1651
Third PC	0.053	0.0332	0.0197
Factor Loadings			
First Factor			
France	0.5353	0.5361	0.5335
Germany	0.3603	0.4225	0.4422
Italy	0.5714	0.5401	0.5255
Spain	0.5072	0.4924	0.4937
Second Factor			
France	0.3746	0.2898	0.248
Germany	0.7	0.7106	0.7253
Italy	-0.3528	-0.3596	-0.3668
Spain	-0.4952	-0.5308	-0.5272
Third Factor			
France	-0.6668	-0.6781	-0.6398
Germany	0.5944	0.5381	0.4794
Italy	-0.1317	-0.1753	-0.2618
Spain	0.4298	0.4689	0.5407

Note: Contributions of the first, second and third principal components (PC) to the cross-sectional variance of the spot rates across the four EMU economies and, respective factor Loadings
The First PC stands for the first factor.
The Second an third PC stands for the second and third factor.

Table 12: **Regression of Spot Rates on Germany Spot Rates for the sub-samples 1**

2 Years	**France**	**Italy**	**Spain**	**UK**
GE	1.34141500***	2.61920100***	2.51873000***	0.63072910***
RSE	(0.02418460)	(0.07577310)	(0.06047900)	(0.01175760)
Constant	-0.93745370***	-3.07596800***	-3.63699300***	4.59604200***
RSE	(0.09538270)	(0.31717210)	(0.25332860)	(0.05561580)
R^2	0.79960000	0.45260000	0.51700000	0.65670000
5 Years	**France**	**Italy**	**Spain**	**UK**
GE	1.29931300***	3.24755800***	2.95086100***	0.88354230***
RSE	(0.01049360)	(0.05215440)	(0.04235200)	(0.00861200)
Constant	-1.37536500***	-8.60948400***	-7.93393000***	2.89028900***
RSE	(0.05139210)	(0.26235660)	(0.21515370)	(0.04813210)
R^2	0.93240000	0.81150000	0.83210000	0.90380000
10 Years	**France**	**Italy**	**Spain**	**UK**
GE	1.16333600***	2.96144800***	2.51571000***	1.10314400***
RSE	(0.00694870)	(0.03895120)	(0.03173020)	(0.00830900)
Constant	-0.85831650***	-9.15402600***	-7.18732800***	1.09789300***
RSE	(0.03976540)	(0.23677030)	(0.19572550)	(0.05290450)
R^2	0.95140000	0.85590000	0.87190000	0.95010000

Note: Sample Size: 1044 observations
GE stands for Germany spot rate.
RSE stands for robust standard errors.
* Significant at 10%; ** Significant at 5%; *** Significant at 1%.
Detailed test-statistics are available from the author upon request.

Table 13: **Regression of Spot Rates on Germany Spot Rates for the sub-samples 2**

2 Years	**France**	**Italy**	**Spain**	**UK**
GE	1.00032100***	1.05262800***	1.01167200***	0.65235280***
RSE	(0.00185520)	(0.00235800)	(0.00171030)	(0.01450030)
Constant	0.02181170***	-0.05102470***	-0.01515860***	2.96460000***
RSE	(0.00588680)	(0.00669780)	(0.00492470)	(0.04917580)
R^2	0.99350000	0.99060000	0.99440000	0.55120000
5 Years	**France**	**Italy**	**Spain**	**UK**
GE	0.98359590***	1.05196500***	1.01703300***	0.65651880***
RSE	(0.00254980)	(0.00270690)	(0.00187590)	(0.01385790)
Constant	0.07832430***	-0.02268620***	-0.01902720***	2.74281800***
RSE	(0.00958300)	(0.00976390)	(0.00706360)	(0.05044870)
R^2	0.98850000	0.98710000	0.99290000	0.58320000
10 Years	**France**	**Italy**	**Spain**	**UK**
GE	0.99590550***	1.04413400***	1.08307200***	0.55738640***
RSE	(0.00299390)	(0.00298830)	(0.00254690)	(0.00907660)
Constant	0.07464190***	0.13047950***	-0.25224920***	2.82458300***
RSE	(0.01233530)	(0.01240940)	(0.01085810)	(0.03620550)
R^2	0.97520000	0.96680000	0.97850000	0.58160000

Note: Sample Size: 1695 observations
GE stands for Germany spot rate.
RSE stands for robust standard errors.
* Significant at 10%; ** Significant at 5%; *** Significant at 1%.
Detailed test-statistics are available from the author upon request.

Table 14: **Regression of Spot Rates on Germany Spot Rates for the sub-sample 3**

2 Years	**France**	**Italy**	**Spain**	**UK**
GE	0.9302906***	0.36572510***	0.3629477***	1.1960190***
RSE	(0.0077758)	(0.0461885)	(0.0327950)	(0.0138250)
Constant	0.3074891***	2.2349450***	2.1492160***	0.4605072***
RSE	(0.0164740)	(0.0952947)	(0.0674048)	(0.0209145)
R^2	0.9469000	0.0741000	0.1026000	0.8945000
5 Years	**France**	**Italy**	**Spain**	**UK**
GE	0.7847471***	-0.0967466***	-0.0502844***	1.1819140***
RSE	(0.0148930)	(0.0626448)	(0.0360854)	(0.0098277)
Constant	0.8334695***	4.0067540***	3.8695770***	0.3806168***
RSE	(0.0394581)	(0.1619893)	(0.0899297)	(0.0228886)
R^2	0.8696000	0.0054000	0.0024000	0.9211000
10 Years	**France**	**Italy**	**Spain**	**UK**
GE	0.6928300***	-0.3533443***	-0.4173524***	1.0368950***
RSE	(0.0173829)	(0.0513627)	(0.0345044)	(0.0095434)
Constant	1.4217060***	5.9000910***	6.0155260***	0.6000566***
RSE	(0.0595891)	(0.1734617)	(0.1144029)	(0.0302268)
R^2	0.8098000	0.1010000	0.1258000	0.9406000

Note: Sample Size: 914 observations
GE stands for Germany spot rate.
RSE stands for robust standard errors.
* Significant at 10%; ** Significant at 5%; *** Significant at 1%.
Detailed test-statistics are available from the author upon request.

Table 15: **Regression of Spot Rates on Germany Spot Rates for the sub-sample 4**

2 Years	**France**	**Italy**	**Spain**	**UK**
GE	1.7401410***	2.6837880***	1.4471320***	0.1475047***
RSE	(0.0573310)	(0.3892675)	(0.4487597)	(0.0860266)
Constant	0.1150831***	1.6273640***	1.9164260***	0.9448560***
RSE	(0.0042693)	(0.0559713)	(0.0742455)	(0.0121694)
R^2	0.5263000	0.0459000	0.0103000	0.0033000
5 Years	**France**	**Italy**	**Spain**	**UK**
GE	1.6050810***	2.6512660***	2.3019680***	0.2670207***
RSE	(0.0416864)	(0.1614738)	(0.1930526)	(0.0523074)
Constant	0.1388089***	1.7159470***	2.0437290***	1.4348560***
RSE	(0.0182883)	(0.1005233)	(0.1340116)	(0.0365376)
R^2	0.6488000	0.2140000	0.1174000	0.0236000
10 Years	**France**	**Italy**	**Spain**	**UK**
GE	1.4048000***	2.0196140***	2.0566620***	0.4849504***
RSE	(0.0248245)	(0.0859857)	(0.1139311)	(0.0268829)
Constant	0.0608662***	1.3411310***	1.4520590***	1.7042710***
RSE	(0.0368574)	(0.1410775)	(0.1953248)	(0.0447257)
R^2	0.7337000	0.3255000	0.2237000	0.2000000

Note: Sample Size: 783 observations
GE stands for Germany spot rate.
RSE stands for robust standard errors.
* Significant at 10%; ** Significant at 5%; *** Significant at 1%.
Detailed test-statistics are available from the author upon request.

Table 16: **B-N Decomposition Correlations of Spot Rates Across Countries, for the sub-samples 1**

2 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.89240	1.00000			
Italy	0.89260	0.66980	1.00000		
Spain	0.91940	0.71540	0.99210	1.00000	
UK	0.61090	0.80130	0.41070	0.43420	1.00000
5 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.96510	1.00000			
Italy	0.96420	0.90230	1.00000		
Spain	0.97720	0.91940	0.99300	1.00000	
UK	0.90840	0.94720	0.89130	0.88870	1.00000
10 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.97450	1.00000			
Italy	0.97570	0.92420	1.00000		
Spain	0.97960	0.93250	0.99740	1.00000	
UK	0.92710	0.95870	0.89850	0.90480	1.00000

All the correlation values are statistically different (1%) from there peers in sub-sample 2.
Detailed test-statistics are available from the author upon request.

Table 17: **B-N Decomposition Correlations of Spot Rates Across Countries, for the sub-samples 2**

2 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.97440	1.00000			
Italy	0.97520	0.98930	1.00000		
Spain	0.99790	0.97560	0.97720	1.00000	
UK	0.70760	0.71390	0.72910	0.71930	1.00000
5 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.99420	1.00000			
Italy	0.99520	0.99350	1.00000		
Spain	0.99790	0.99640	0.99740	1.00000	
UK	0.73190	0.76260	0.73620	0.73980	1.00000
10 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.98710	1.00000			
Italy	0.98730	0.98330	1.00000		
Spain	0.99700	0.98910	0.99210	1.00000	
UK	0.71780	0.75750	0.74220	0.72070	1.00000

All the correlation values are statistically different (1%) from there peers in sub-sample 1 and 3.
Detailed test-statistics are available from the author upon request.

Table 18: **B-N Decomposition Correlations of Spot Rates Across Countries, for the sub-sample 3**

2 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.97100	1.00000			
Italy	0.45100	0.24730	1.00000		
Spain	0.45540	0.29090	0.90450	1.00000	
UK	0.89320	0.87820	0.28940	0.23650	1.00000
5 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.92830	1.00000			
Italy	0.23760	-0.10500	1.00000		
Spain	0.17050	-0.07530	0.82340	1.00000	
UK	0.88860	0.95720	-0.13490	-0.17310	1.00000
10 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.89610	1.00000			
Italy	0.05980	-0.33320	1.00000		
Spain	-0.12930	-0.36300	0.77540	1.00000	
UK	0.83190	0.96880	-0.38630	-0.39570	1.00000

All the correlation values are statistically different (1%) from there peers in sub-sample 2 and 4.
Detailed test-statistics are available from the author upon request.

Table 19: **B-N Decomposition Correlations of Spot Rates Across Countries, for the sub-sample 4**

2 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.72650	1.00000			
Italy	0.60340	0.19170	1.00000		
Spain	0.40250	0.09060	0.94140	1.00000	
UK	0.26090	0.04050	-0.07340	-0.26540	1.00000
5 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.80710	1.00000			
Italy	0.78340	0.44800	1.00000		
Spain	0.63180	0.33490	0.95340	1.00000	
UK	-0.10710	0.16230	-0.57130	-0.67870	1.00000
10 Years	**France**	**Germany**	**Italy**	**Spain**	**UK**
France	1.00000				
Germany	0.86070	1.00000			
Italy	0.84470	0.56370	1.00000		
Spain	0.74610	0.46710	0.95750	1.00000	
UK	0.13290	0.46190	-0.31660	-0.43850	1.00000

All the correlation values are statistically different (1%) from there peers in sub-sample 3.
Detailed test-statistics are available from the author upon request.

Table 20: **Principal Component Analysis of B-N Decomposition of Bond Yields EMU Countries, sub-sample 1**

Contributions of	**2 Years**	**5 Years**	**10 Years**
First PC	0.8872	0.9653	0.9731
Second PC	0.1038	0.0299	0.0243
Third PC	0.0076	0.0036	0.0021
Factor Loadings			
First Factor			
France	0.5221	0.5059	0.5048
Germany	0.4591	0.4902	0.492
Italy	0.5033	0.4999	0.5007
Spain	0.5131	0.5038	0.5023
Second Factor			
France	0.1656	0.1359	0.1442
Germany	0.7698	0.7635	0.7609
Italy	-0.4818	-0.5074	-0.4826
Spain	-0.3847	-0.3758	-0.4092
Third Factor			
France	-0.8335	-0.8019	-0.8511
Germany	0.4427	0.4155	0.4204
Italy	0.277	0.4286	0.2096
Spain	0.1803	-0.0244	0.2346

Note: Contributions of the first, second and third principal components (PC) to the cross-sectional variance of the spot rates across the four EMU economies and, respective factor Loadings
The First PC stands for the first factor.
The Second an third PC stands for the second and third factor.

Table 21: **Principal Component Analysis of B-N Decomposition of Bond Yields EMU Countries, sub-sample 2**

Contributions of	**2 Years**	**5 Years**	**10 Years**
First PC	0.9862	0.9968	0.992
Second PC	0.0106	0.0017	0.0042
Third PC	0.0027	0.0012	0.0032
Factor Loadings			
First Factor			
France	0.5003	0.5	0.5004
Germany	0.4993	0.4996	0.4989
Italy	0.4996	0.4999	0.4993
Spain	0.5008	0.5006	0.5013
Second Factor			
France	-0.5188	-0.2195	-0.0567
Germany	0.5188	0.8217	0.7925
Italy	0.4816	-0.5194	-0.5897
Spain	-0.4794	-0.0822	-0.1448
Third Factor			
France	0.05	-0.7553	-0.656
Germany	0.6936	0.1877	0.3481
Italy	-0.7182	0.6253	0.6027
Spain	-0.025	-0.0573	-0.292

Note: Contributions of the first, second and third principal components (PC) to the cross-sectional variance of the spot rates across the four EMU economies and, respective factor Loadings
The First PC stands for the first factor.
The Second an third PC stands for the second and third factor.

Table 22: **Principal Component Analysis of B-N Decomposition of Bond Yields EMU Countries, sub-sample 3**

Contributions of	**2 Years**	**5 Years**	**10 Years**
First PC	0.6668	0.504	0.5615
Second PC	0.3074	0.446	0.3734
Third PC	0.0247	0.0475	0.0608
Factor Loadings			
First Factor			
France	0.5428	0.6233	0.4549
Germany	0.4745	0.493	0.5907
Italy	0.4855	0.4365	-0.4449
Spain	0.4945	0.4217	-0.4962
Second Factor			
France	-0.4128	-0.3395	0.5903
Germany	-0.5676	-0.5285	0.3545
Italy	0.5153	0.548	0.5586
Spain	0.4918	0.5524	0.4624
Third Factor			
France	-0.1562	-0.1874	-0.1778
Germany	0.1223	0.1975	0.2945
Italy	-0.6717	-0.6452	-0.5981
Spain	0.7137	0.7138	0.7239

Note: Contributions of the first, second and third principal components (PC) to the cross-sectional variance of the spot rates across the four EMU economies and, respective factor Loadings
The First PC stands for the first factor.
The Second an third PC stands for the second and third factor.

Table 23: **Principal Component Analysis of B-N Decomposition of Bond Yields EMU Countries, sub-sample 4**

Contributions of	**2 Years**	**5 Years**	**10 Years**
First PC	0.6314	0.7509	0.8089
Second PC	0.311	0.2143	0.1685
Third PC	0.0524	0.0309	0.0172
Factor Loadings			
First Factor			
France	0.5311	0.5361	0.5335
Germany	0.3554	0.4194	0.4412
Italy	0.572	0.5393	0.5249
Spain	0.5142	0.4958	0.4951
Second Factor			
France	0.389	0.294	0.2542
Germany	0.6968	0.7122	0.723
Italy	-0.3588	-0.3669	-0.3728
Spain	-0.4842	-0.5213	-0.5231
Third Factor			
France	-0.6812	-0.6994	-0.6752
Germany	0.605	0.5437	0.496
Italy	-0.1024	-0.1354	-0.2072
Spain	0.3994	0.4437	0.5051

Note: Contributions of the first, second and third principal components (PC) to the cross-sectional variance of the spot rates across the four EMU economies and, respective factor Loadings
The First PC stands for the first factor.
The Second an third PC stands for the second and third factor.

Table 24: **Regression of B-N Decomposed Bond Yields on B-N Decomposed Germany Yields for the sub-samples 1**

2 Years	France	Italy	Spain	UK
GE	1.36476700***	2.68318000***	2.57404600***	0.63048850***
RSE	(0.02531950)	(0.07877340)	(0.06261040)	(0.01230300)
Constant	-1.02865500***	-3.32360800***	-3.85182500***	4.59837500***
RSE	(0.09961030)	(0.32785350)	(0.26078380)	(0.05754100)
R^2	0.79630000	0.44860000	0.51180000	0.64210000
5 Years	**France**	**Italy**	**Spain**	**UK**
GE	1.3104020***	3.3099090***	3.0150110***	0.8907492***
RSE	(0.0105404)	(0.0511403)	(0.0416405)	(0.0090176)
Constant	-1.4299490***	-8.9156340***	-8.2554960***	2.8552420***
RSE	(0.0516271)	(0.2578345)	(0.2119339)	(0.0502844)
R^2	0.9314000	0.8142000	0.8453000	0.8971000
10 Years	**France**	**Italy**	**Spain**	**UK**
GE	1.1623650***	2.9730660***	2.5217050***	1.1398770***
RSE	(0.0072098)	(0.0397653)	(0.0325108)	(0.0108919)
Constant	-0.8526778***	-9.2195950***	-7.2218000***	0.8860736***
RSE	(0.0411760)	(0.2416520)	(0.2001514)	(0.0680043)
R^2	0.9496000	0.8541000	0.8696000	0.9192000

Note: Sample Size: 1037 observations
GE stands for Germany spot rate.
RSE stands for robust standard errors.
* Significant at 10%; ** Significant at 5%; *** Significant at 1%.
Detailed test-statistics are available from the author upon request.

Table 25: **Regression of B-N Decomposed Bond Yields on B-N Decomposed Germany Yields for the sub-samples 2**

2 Years	France	Italy	Spain	UK
GE	1.02439500***	1.08105400***	1.03516700***	0.64862030***
RSE	(0.00580290)	(0.00395190)	(0.00581450)	(0.01556170)
Constant	-0.05639710***	-0.14352960***	-0.09164550***	2.97499100***
RSE	(0.01803490)	(0.01137170)	(0.01796100)	(0.05189080)
R^2	0.94940000	0.97870000	0.95170000	0.50970000
5 Years	**France**	**Italy**	**Spain**	**UK**
GE	0.9849281***	1.0518560***	1.0175890***	0.6578244***
RSE	(0.0025548)	(0.0027281)	(0.0018865)	(0.0140160)
Constant	0.0738786***	-0.0223940***	-0.0209172***	2.7384360***
RSE	(0.0095945)	(0.0098177)	(0.0070870)	(0.0509158)
R^2	0.9885000	0.9870000	0.9928000	0.5815000
10 Years	**France**	**Italy**	**Spain**	**UK**
GE	1.0004430***	1.0435280***	1.0874650***	0.5588740***
RSE	(0.0030094)	(0.0029446)	(0.0024708)	(0.0094139)
Constant	0.0563891***	0.1333016***	-0.2700931***	2.8186930***
RSE	(0.0123175)	(0.0121869)	(0.0104744)	(0.0374369)
R^2	0.9744000	0.9669000	0.9783000	0.5738000

Note: Sample Size: 1688 observations
GE stands for Germany spot rate.
RSE stands for robust standard errors.
* Significant at 10%; ** Significant at 5%; *** Significant at 1%.
Detailed test-statistics are available from the author upon request.

Table 26: **Regression of B-N Decomposed Bond Yields on B-N Decomposed Germany Yields for the sub-sample 3**

2 Years	**France**	**Italy**	**Spain**	**UK**
GE	0.92793720***	0.34155910***	0.33851290***	1.58737600***
RSE	(0.00825230)	(0.04892770)	(0.03484100)	(0.02348000)
Constant	0.30997610***	2.26141700***	2.17694000***	-0.05720610***
RSE	(0.01691060)	(0.09765680)	(0.06894200)	(0.02987250)
R^2	0.94280000	0.06110000	0.08460000	0.77120000
5 Years	**France**	**Italy**	**Spain**	**UK**
GE	0.7780843***	-0.1439218***	-0.0798630***	1.1751590***
RSE	(0.0154918)	(0.0654689)	(0.0374199)	(0.0102760)
Constant	0.8469234***	4.1045680***	3.9299250***	0.3942334***
RSE	(0.0405505)	(0.1673978)	(0.0921214)	(0.0234721)
R^2	0.8618000	0.0110000	0.0057000	0.9163000
10 Years	**France**	**Italy**	**Spain**	**UK**
GE	0.6877523***	-0.3778762***	-0.4379258***	1.0285730***
RSE	(0.0177567)	(0.0522369)	(0.0354391)	(0.0095776)
Constant	1.4364120***	5.9711430***	6.0753000***	0.6242221***
RSE	(0.0606146)	(0.1758376)	(0.1171118)	(0.0303084)
R^2	0.8030000	0.1110000	0.1318000	0.9386000

Note: Sample Size: 908 observations
GE stands for Germany spot rate.
RSE stands for robust standard errors.
* Significant at 10%; ** Significant at 5%; *** Significant at 1%.
Detailed test-statistics are available from the author upon request.

Table 27: **Regression of B-N Decomposed Bond Yields on B-N Decomposed Germany Yields for the sub-sample 4**

2 Years	**France**	**Italy**	**Spain**	**UK**
GE	1.61254500***	2.27611300***	1.26476900***	0.10071660***
RSE	(0.05346400)	(0.37630480)	(0.44488350)	(0.08351100)
Constant	0.12092840***	1.63839600***	1.92088700***	0.94592270***
RSE	(0.00451180)	(0.05664090)	(0.07431710)	(0.01200210)
R^2	0.52770000	0.03680000	0.00820000	0.00160000
5 Years	**France**	**Italy**	**Spain**	**UK**
GE	1.5640830***	2.5301650***	2.2718270***	0.2851454***
RSE	(0.0391949)	(0.1572574)	(0.1960788)	(0.0531375)
Constant	0.1541732***	1.7623070***	2.0555190***	1.4255740***
RSE	(0.0175760)	(0.1005361)	(0.1354163)	(0.0368031)
R^2	0.6514000	0.2007000	0.1122000	0.0263000
10 Years	**France**	**Italy**	**Spain**	**UK**
GE	1.3962430***	1.9656510***	2.0562550***	0.5084542***
RSE	(0.0236356)	(0.0844623)	(0.1160921)	(0.0272244)
Constant	0.0687779***	1.4091320***	1.4502720***	1.6699980***
RSE	(0.0355034)	(0.1404911)	(0.1984680)	(0.0452614)
R^2	0.7408000	0.3178000	0.2181000	0.2134000

Note: Sample Size: 777 observations
GE stands for Germany spot rate.
RSE stands for robust standard errors.
* Significant at 10%; ** Significant at 5%; *** Significant at 1%.
Detailed test-statistics are available from the author upon request.

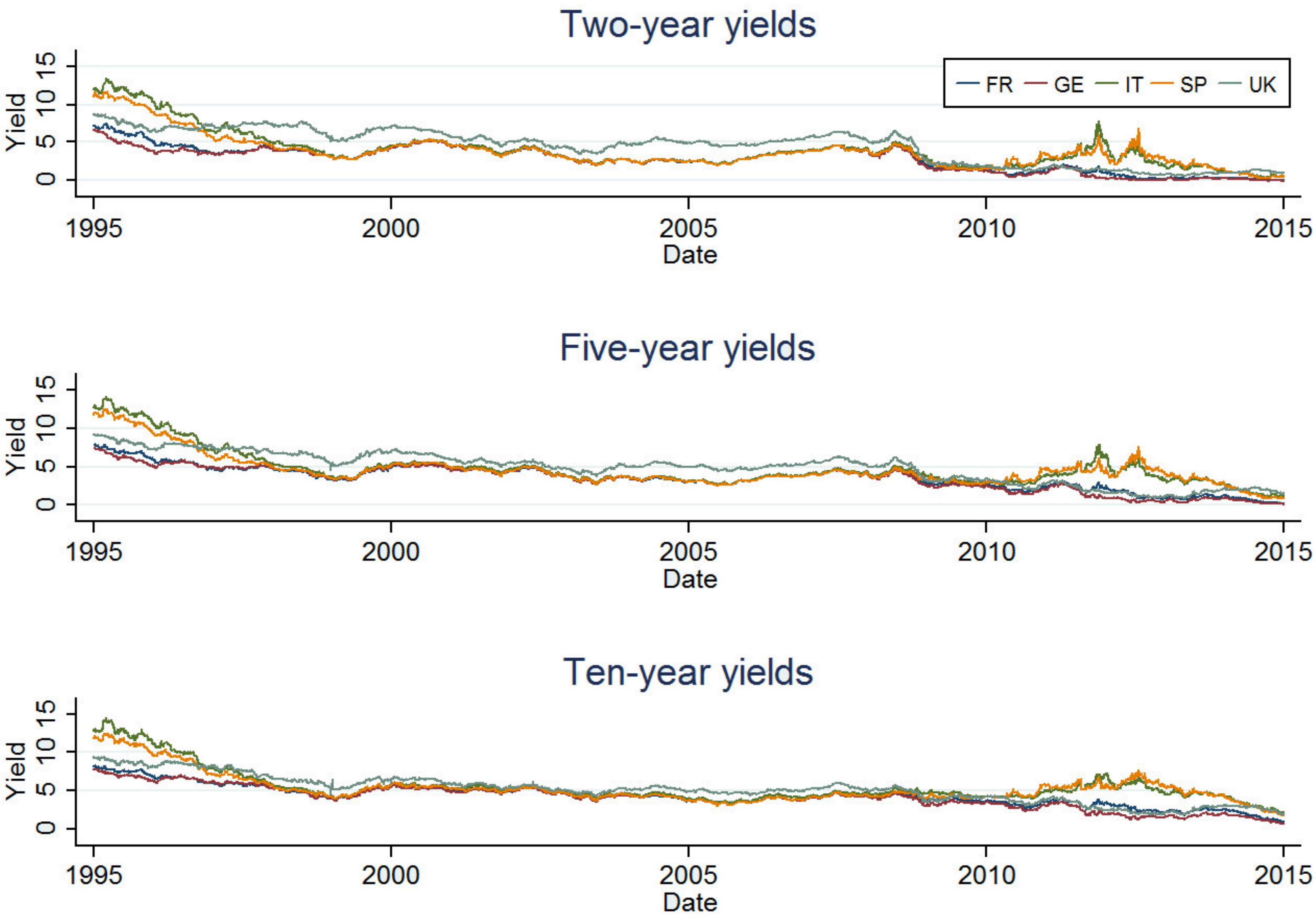
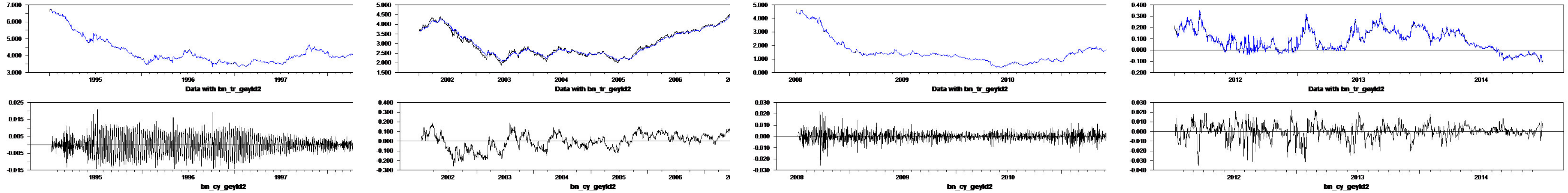


Figure 1: **Spot Rates for the five countries and three maturities**



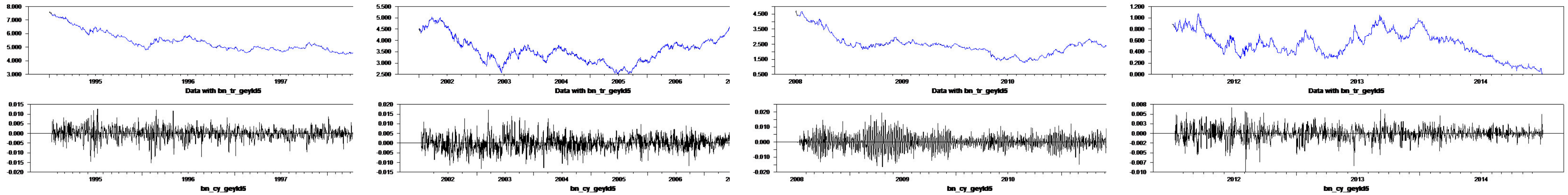
(a) TC's graph range: $3.00 \le TC \le 7.00$
CC's graph range: $-0.015 \le CC \le 0.025$

(b) TC's graph range: $1.50 \le TC \le 5.00$
CC's graph range: $-0.300 \le CC \le 0.400$

(c) TC's graph range: $0.00 \le TC \le 5.00$
CC's graph range: $-0.030 \le CC \le 0.030$

(d) TC's graph range: $-0.20 \le TC \le 0.40$
CC's graph range: $-0.040 \le CC \le 0.030$

Figure 2: Germany 2 years decomposed yields for all sub-samples
First graph draw the original spot rates against the Trend B-N component (TC). Second graph shows the Cyclical component (CC).



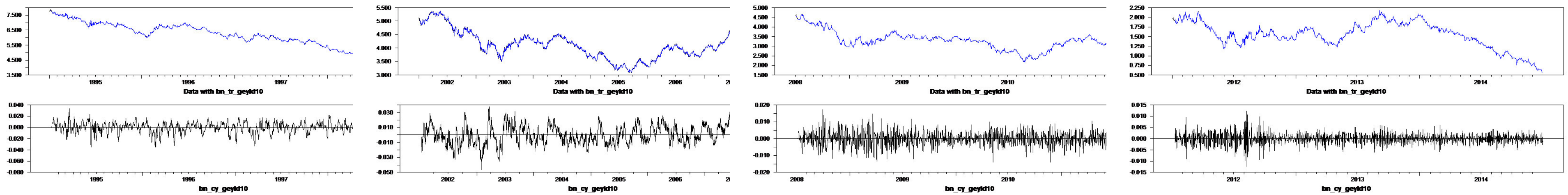
(a) TC's graph range: $-0.020 \le TC \le 0.015$
CC's graph range: $3.00 \le CC \le 8.00$

(b) TC's graph range: $2.50 \le TC \le 5.50$
CC's graph range: $-0.015 \le CC \le 0.020$

(c) TC's graph range: $0.50 \le TC \le 4.50$
CC's graph range: $-0.020 \le CC \le 0.020$

(d) TC's graph range: $0.00 \le TC \le 1.20$
CC's graph range: $-0.010 \le CC \le 0.008$

Figure 3: Germany 5 years decomposed yields for all sub-samples
First graph draw the original spot rates against the Trend B-N component (TC). Second graph shows the Cyclical component (CC).



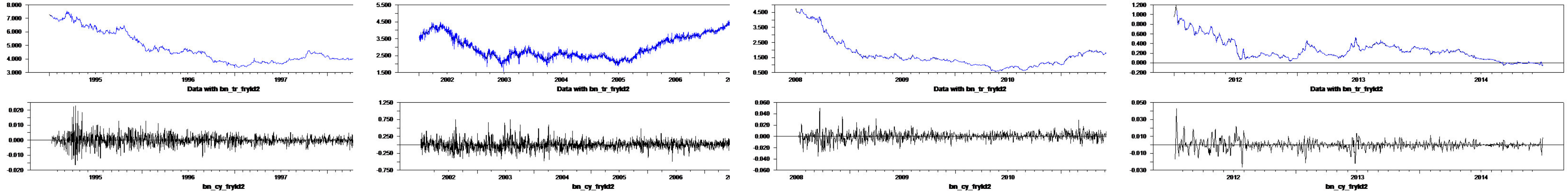
(a) TC's graph range: $3.50 \le TC \le 7.50$
CC's graph range: $-0.080 \le CC \le 0.040$

(b) TC's graph range: $3.00 \le TC \le 5.50$
CC's graph range: $-0.050 \le CC \le 0.030$

(c) TC's graph range: $1.50 \le TC \le 5.00$
CC's graph range: $-0.020 \le CC \le 0.020$

(d) TC's graph range: $0.50 \le TC \le 2.25$
CC's graph range: $-0.015 \le CC \le 0.015$

Figure 4: Germany 10 years decomposed yields for all sub-samples
First graph draw the original spot rates against the Trend B-N component (TC). Second graph shows the Cyclical component (CC).



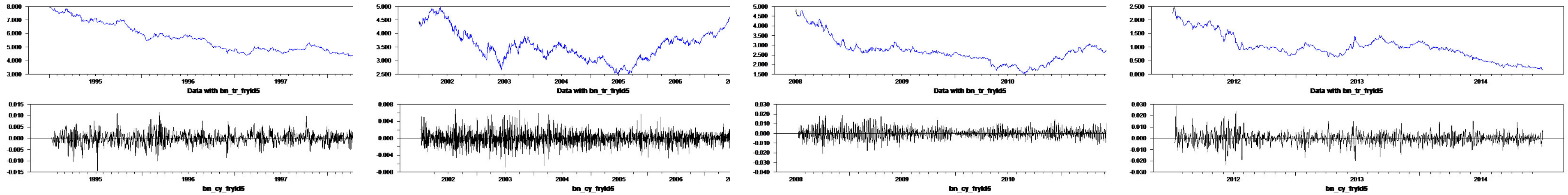
(a) TC's graph range: $3.00 \leq TC \leq 8.00$
CC's graph range: $-0.020 \leq CC \leq 0.020$

(b) TC's graph range: $1.50 \leq TC \leq 5.50$
CC's graph range: $-0.750 \leq CC \leq 1.250$

(c) TC's graph range: $0.50 \leq TC \leq 4.50$
CC's graph range: $-0.060 \leq CC \leq 0.060$

(d) TC's graph range: $-0.20 \leq TC \leq 1.20$
CC's graph range: $-0.030 \leq CC \leq 0.050$

Figure 5: France 2 years decomposed yields for all sub-samples
First graph draw the original spot rates against the Trend B-N component (TC). Second graph shows the Cyclical component (CC).



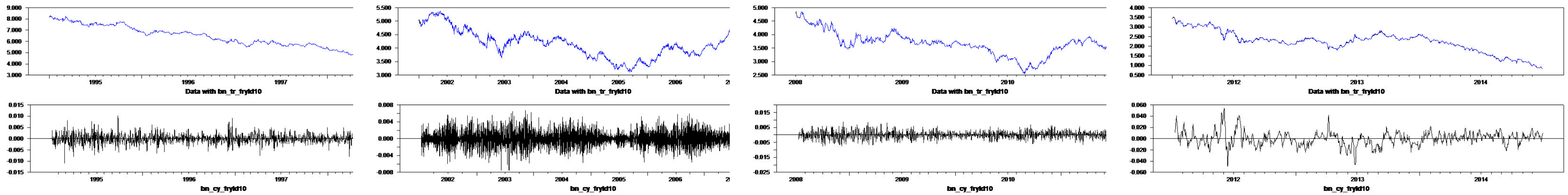
(a) TC's graph range: $3.00 \leq TC \leq 8.00$
CC's graph range: $-0.015 \leq CC \leq 0.015$

(b) TC's graph range: $2.50 \leq TC \leq 5.00$
CC's graph range: $-0.008 \leq CC \leq 0.008$

(c) TC's graph range: $1.50 \leq TC \leq 5.00$
CC's graph range: $-0.040 \leq CC \leq 0.030$

(d) TC's graph range: $0.00 \leq TC \leq 2.50$
CC's graph range: $-0.030 \leq CC \leq 0.030$

Figure 6: France 5 years decomposed yields for all sub-samples
First graph draw the original spot rates against the Trend B-N component (TC). Second graph shows the Cyclical component (CC).



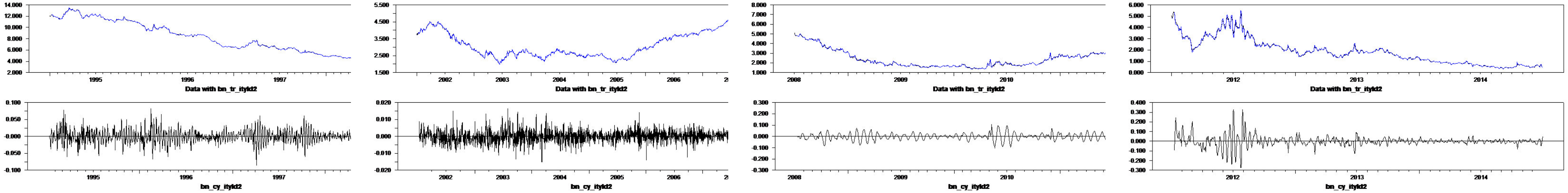
(a) TC's graph range: $3.00 \leq TC \leq 9.00$
CC's graph range: $-0.015 \leq CC \leq 0.015$

(b) TC's graph range: $3.00 \leq TC \leq 5.50$
CC's graph range: $-0.008 \leq CC \leq 0.008$

(c) TC's graph range: $2.50 \leq TC \leq 5.00$
CC's graph range: $-0.025 \leq CC \leq 0.015$

(d) TC's graph range: $0.50 \leq TC \leq 4.00$
CC's graph range: $-0.060 \leq CC \leq 0.060$

Figure 7: France 10 years decomposed yields for all sub-samples
First graph draw the original spot rates against the Trend B-N component (TC). Second graph shows the Cyclical component (CC).



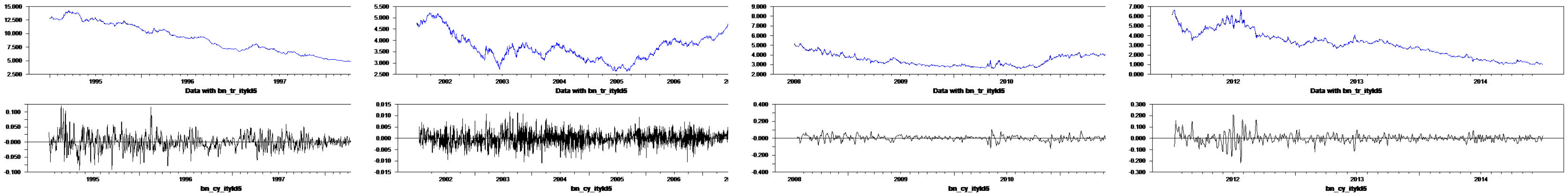
(a) TC's graph range: $2.00 \leq TC \leq 14.00$
CC's graph range: $-0.100 \leq CC \leq 0.100$

(b) TC's graph range: $1.50 \leq TC \leq 5.50$
CC's graph range: $-0.020 \leq CC \leq 0.020$

(c) TC's graph range: $1.00 \leq TC \leq 8.00$
CC's graph range: $-0.300 \leq CC \leq 0.300$

(d) TC's graph range: $0.00 \leq TC \leq 6.00$
CC's graph range: $-0.300 \leq CC \leq 0.400$

Figure 8: Italy 2 years decomposed yields for all sub-samples
First graph draw the original spot rates against the Trend B-N component (TC). Second graph shows the Cyclical component (CC).



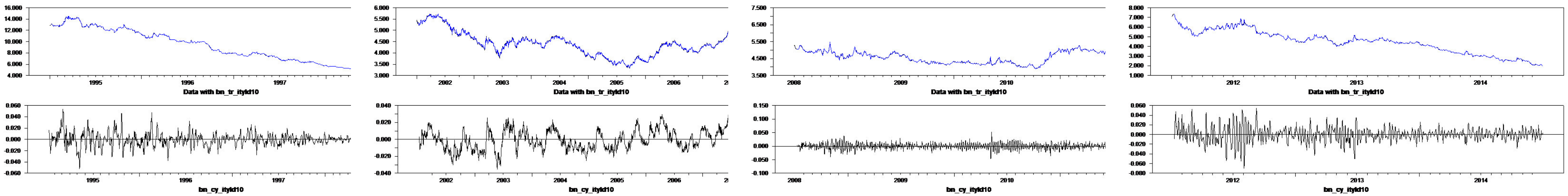
(a) TC's graph range: $2.50 \leq TC \leq 15.00$
CC's graph range: $-0.100 \leq CC \leq 0.100$

(b) TC's graph range: $2.50 \leq TC \leq 5.50$
CC's graph range: $-0.015 \leq CC \leq 0.015$

(c) TC's graph range: $2.00 \leq TC \leq 9.00$
CC's graph range: $-0.400 \leq CC \leq 0.400$

(d) TC's graph range: $0.00 \leq TC \leq 7.00$
CC's graph range: $-0.300 \leq CC \leq 0.300$

Figure 9: Italy 5 years decomposed yields for all sub-samples
First graph draw the original spot rates against the Trend B-N component (TC). Second graph shows the Cyclical component (CC).



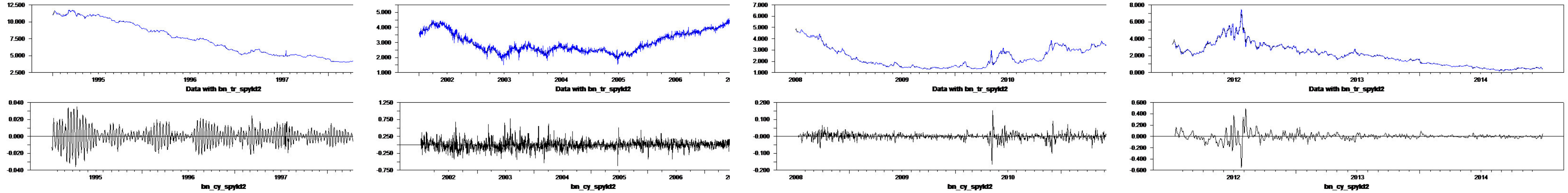
(a) TC's graph range: $4.00 \leq TC \leq 16.00$
CC's graph range: $-0.060 \leq CC \leq 0.060$

(b) TC's graph range: $3.00 \leq TC \leq 6.00$
CC's graph range: $-0.040 \leq CC \leq 0.040$

(c) TC's graph range: $3.50 \leq TC \leq 7.50$
CC's graph range: $-0.100 \leq CC \leq 0.150$

(d) TC's graph range: $1.00 \leq TC \leq 8.00$
CC's graph range: $-0.080 \leq CC \leq 0.060$

Figure 10: Italy 10 years decomposed yields for all sub-samples
First graph draw the original spot rates against the Trend B-N component (TC). Second graph shows the Cyclical component (CC).



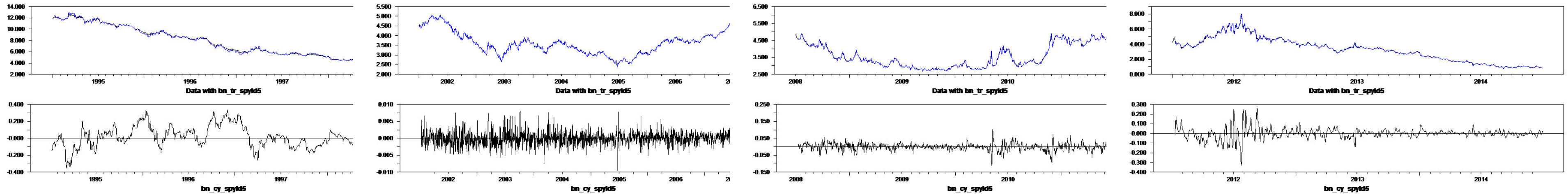
(a) TC's graph range: $2.50 \leq TC \leq 12.50$
CC's graph range: $-0.040 \leq CC \leq 0.040$

(b) TC's graph range: $1.00 \leq TC \leq 5.00$
CC's graph range: $-0.750 \leq CC \leq 1.250$

(c) TC's graph range: $1.00 \leq TC \leq 7.00$
CC's graph range: $-0.200 \leq CC \leq 0.200$

(d) TC's graph range: $0.00 \leq TC \leq 8.00$
CC's graph range: $-0.600 \leq CC \leq 0.600$

Figure 11: Spain 2 years decomposed yields for all sub-samples
First graph draw the original spot rates against the Trend B-N component (TC). Second graph shows the Cyclical component (CC).



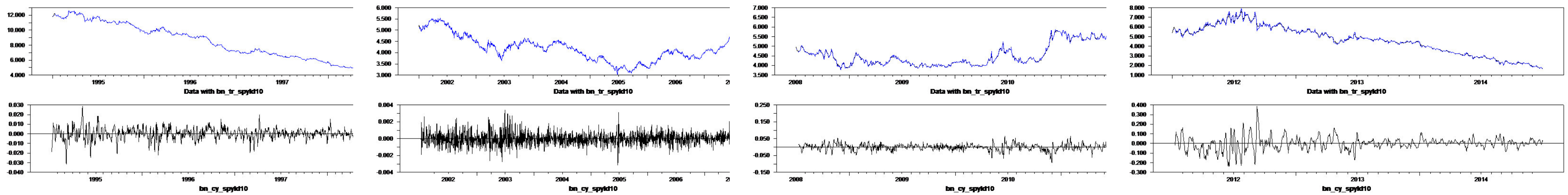
(a) TC's graph range: $2.00 \leq TC \leq 14.00$
CC's graph range: $-0.400 \leq CC \leq 0.400$

(b) TC's graph range: $2.00 \leq TC \leq 5.50$
CC's graph range: $-0.010 \leq CC \leq 0.010$

(c) TC's graph range: $2.50 \leq TC \leq 6.50$
CC's graph range: $-0.150 \leq CC \leq 0.250$

(d) TC's graph range: $0.00 \leq TC \leq 8.00$
CC's graph range: $-0.400 \leq CC \leq 0.300$

Figure 12: Spain 5 years decomposed yields for all sub-samples
First graph draw the original spot rates against the Trend B-N component (TC). Second graph shows the Cyclical component (CC).



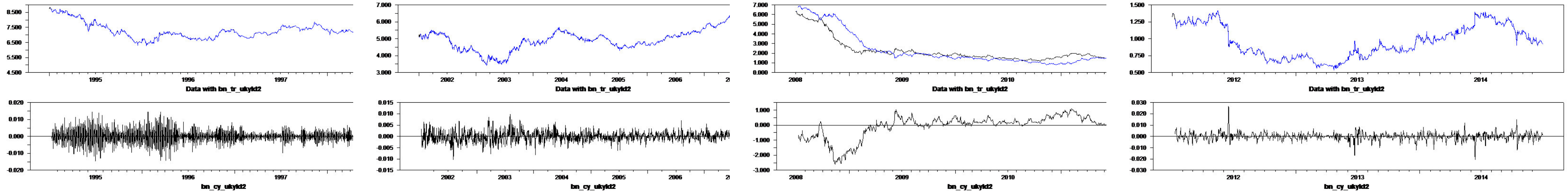
(a) TC's graph range: $4.00 \leq TC \leq 12.00$
CC's graph range: $-0.040 \leq CC \leq 0.030$

(b) TC's graph range: $3.00 \leq TC \leq 6.00$
CC's graph range: $-0.004 \leq CC \leq 0.004$

(c) TC's graph range: $3.50 \leq TC \leq 7.00$
CC's graph range: $-0.150 \leq CC \leq 0.250$

(d) TC's graph range: $1.00 \leq TC \leq 8.00$
CC's graph range: $-0.300 \leq TC \leq 0.400$

Figure 13: Spain 10 years decomposed yields for all sub-samples
First graph draw the original spot rates against the Trend B-N component (TC). Second graph shows the Cyclical component (CC).



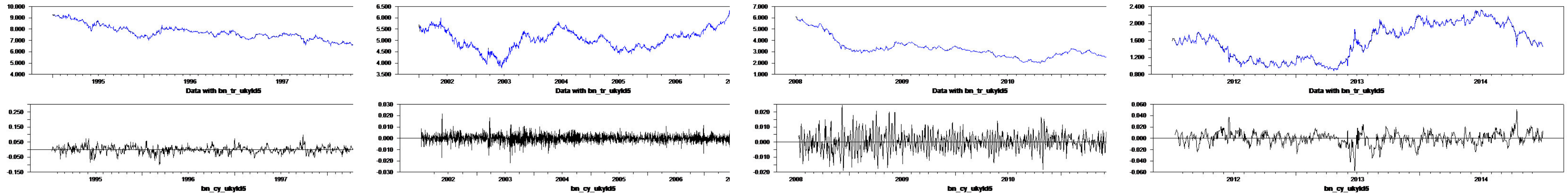
(a) TC's graph range: $4.50 \leq TC \leq 8.50$
CC's graph range: $-0.020 \leq CC \leq 0.020$

(b) TC's graph range: $3.00 \leq TC \leq 7.00$
CC's graph range: $-0.015 \leq CC \leq 0.015$

(c) TC's graph range: $0.00 \leq TC \leq 7.00$
CC's graph range: $-3.000 \leq CC \leq 1.000$

(d) TC's graph range: $0.50 \leq TC \leq 1.50$
CC's graph range: $-0.030 \leq CC \leq 0.030$

Figure 14: UK 2 years decomposed yields for all sub-samples
First graph draw the original spot rates against the Trend B-N component (TC). Second graph shows the Cyclical component (CC).



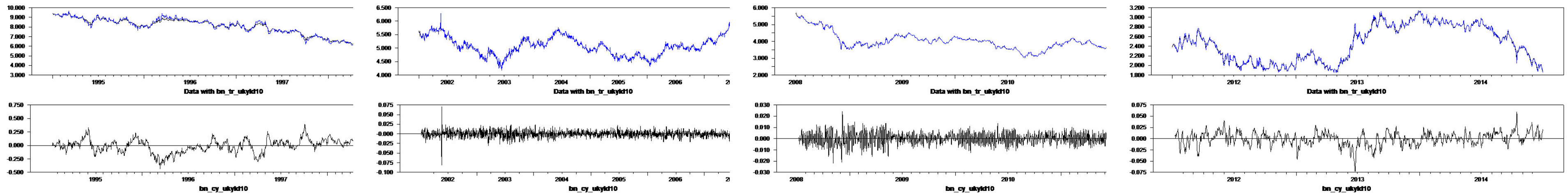
(a) TC's graph range: $4.00 \leq TC \leq 10.00$
CC's graph range: $-0.150 \leq CC \leq 0.250$

(b) TC's graph range: $3.50 \leq TC \leq 6.50$
CC's graph range: $-0.030 \leq CC \leq 0.030$

(c) TC's graph range: $1.00 \leq TC \leq 7.00$
CC's graph range: $-0.020 \leq TC \leq 0.020$

(d) TC's graph range: $0.80 \leq TC \leq 2.40$
CC's graph range: $-0.060 \leq CC \leq 0.060$

Figure 15: UK 5 years decomposed yields for all sub-samples
First graph draw the original spot rates against the Trend B-N component (TC). Second graph shows the Cyclical component (CC).



(a) TC's graph range: $3.00 \leq TC \leq 10.00$
CC's graph range: $-0.500 \leq CC \leq 0.750$

(b) TC's graph range: $4.00 \leq TC \leq 6.50$
CC's graph range: $-0.100 \leq CC \leq 0.075$

(c) TC's graph range: $2.00 \leq TC \leq 6.00$
CC's graph range: $-0.030 \leq CC \leq 0.030$

(d) TC's graph range: $1.80 \leq TC \leq 3.20$
CC's graph range: $-0.075 \leq CC \leq 0.075$

Figure 16: UK 10 years decomposed yields for all sub-samples
First graph draw the original spot rates against the Trend B-N component (TC). Second graph shows the Cyclical component (CC).

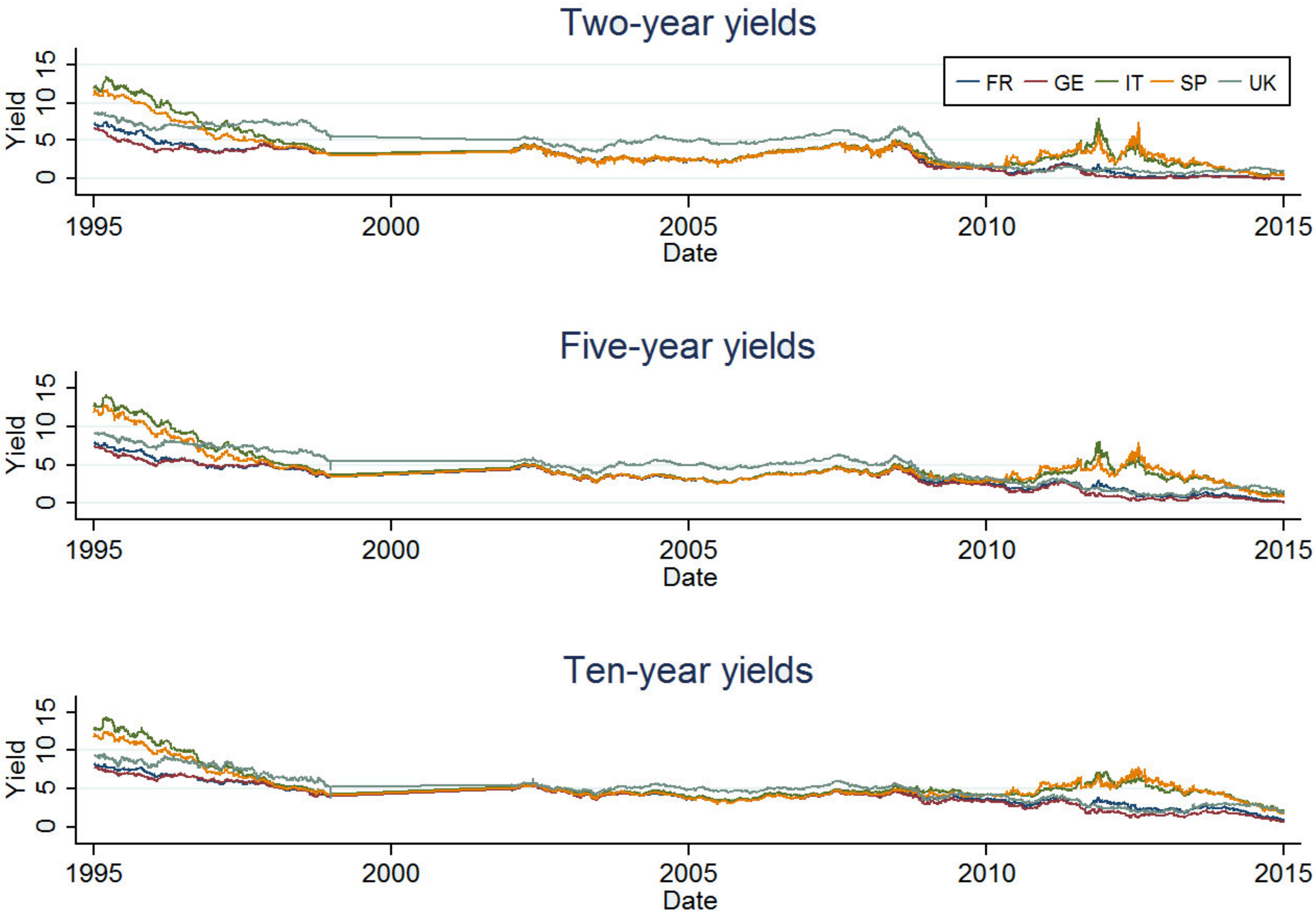


Figure 17: **B-N Permanent component for the five countries and three maturities**