BGPE Discussion Paper

No. 125

Government bond market integration and the EMU: Correlation based evidence

Sebastian Missio

September 2012

ISSN 1863-5733

Editor: Prof. Regina T. Riphahn, Ph.D.
Friedrich-Alexander-University Erlangen-Nuremberg

BGPE Discussion Paper Series

Government bond market integration and the EMU: Correlation based evidence

Sebastian Missio[a]

[a] Ludwig-Maximilian-University of Munich, Seminar for Macroeconomics, Ludwigstr. 28, 80539 München, Germany, and Bavarian Graduate Program in Economics, Lange Gasse 20, 90403 Nuremberg, Germany. Email: sebastian.missio@lrz.uni-muenchen.de
Tel.: +49 (0) 89 / 2180 – 6935, Fax: +49 (0) 89 / 2180 - 13521

August 2012

Abstract

In July 1990, the project of the European Monetary Union (EMU) started and finally led to the introduction of the Euro in January 1999. This paper analyses the development of the government bond market integration during the three stages of the EMU.
Based on the results from dynamic conditional correlation (DCC) models, the study shows that the integration process was highly advanced but not completed at any point in time and that the degree of integration differentiated between geographical and political regions.
It is confirmed statistically that the first, the second and the third stage of the EMU each contributed as a whole to the integration process and that each beginning of a new stage triggered an own wave of government bond market integration progress.
Finally, a comparison of government bond market integration with equity market integration is proposed in order to identify the particular reason for the bond market integration in Europe. The results demonstrate that the expectation of real harmonization of fundamental values as opposed to an expectation that countries of the Euro Area will be saved once there is financial distress drives the European government bond market integration.

JEL classification: E44, E65, F36, C58
Keywords: Bond market integration, European Monetary Union, Dynamic conditional correlation

1. Introduction

The European Monetary Union (EMU) represents a supranational construction which used to have beneficial effects on the financial stance of each of its members. The history of the EMU is characterized by years of strong government bond yield convergence, which rendered the debt servicing less costly. This development however came to an abrupt ending with the start of the European debt crisis and the thereof resulting strong increase of interest rates on sovereign debt of some member countries.

For seven member countries, an overview of the history of the bond yield development since the early EMU is provided in Figure 1.[1] During the 1990's the bond yields generally started to decline and to converge. With the 2000's, this convergence process was almost completed and bond yields remained at strongly decreased borrowing costs. This scheme was only interrupted by the outbreak of the European debt crisis in late 2009.

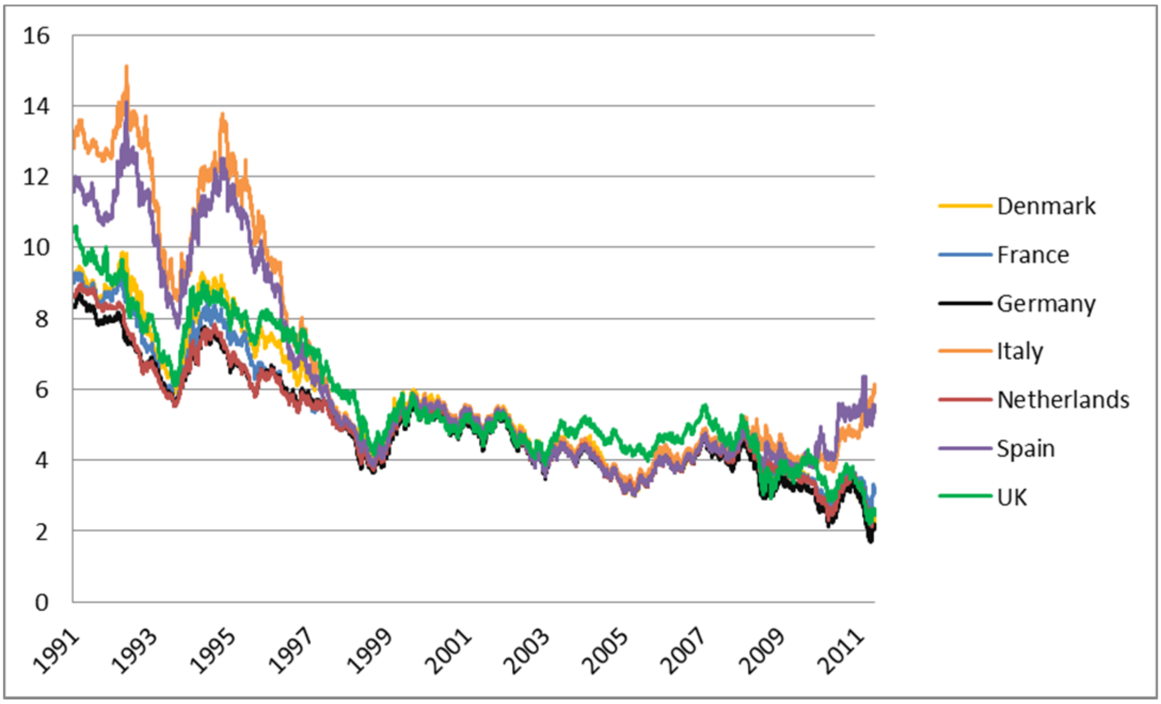

Figure 1: Percentage 10-year benchmark government bond yields of seven EMU founding members, Denmark, France, Germany, Italy, the Netherlands, Spain and the UK.

[1] The countries used in Figure 1 are identical to those used in the analysis. All data used throughout the analysis is provided on Datastream.

The intra-EMU yield convergence is referred to several causes. A non-exhaustive literature list includes Blanco (2002), who stresses the disappearing exchange rate risk, Pagano and von Thadden (2004), who address liquidity and the reduced segmentation of the institutional framework for governmental bonds, or Côté and Graham (2004), who account for the shared fiscal standards and monetary cooperation.

In comparison to examining convergence, this paper analyses if also a synchronization of bond yield movements can be identified. Bond yield convergence means that spreads between single government bonds decreased in mean, but it says nothing about the exact timing and the exact amount of yield movements. Given the undisputed yield convergence within the EMU, identification of a higher parallelism of yield movements provides even stronger evidence for bond market integration.

If there is synchronization of the timing, the direction and the degree of yield movements, not only a high degree of bond yield convergence, but also a significant increase in correlations between sovereign debt yields should be observed. Therefore, this paper applies the dynamic conditional correlation analysis (DCC) proposed by Engle (2002) and Engle and Sheppard (2001).[2]

Based on estimated time series of correlation coefficients between bond yields of EMU countries, the integration process is documented. The DCC methodology is considered highly suitable for an analysis of financial market integration. The dynamic nature of the correlation estimates allows for a detailed observation of the chronological development of the integration process. Additionally, heteroskedasticity adjustment guarantees that changes in the level of correlations are not solely driven by changes in volatility.

Applying correlations as measure of market integration is not new to the literature. Bertero and Mayer (1990) investigate interdependences between markets by static correlation coefficients. According to Forbes and Rigobon (2002), a persistently high level of correlations between two countries' financial assets implies strong interdependence as economic interconnections lead to strong comovement of assets.

[2] For an introduction to the dynamic conditional correlation (DCC) model and the model specification according to the data applied in this analysis refer to Appendices A and B.

Cappiello et al. (2006a) provide evidence that correlation based measures of bond market integration are highly adequate. Arguing that after a successful integration process, yield movements should be more attributable to global factors versus idiosyncratic factors, the authors develop a factor model which distinguishes between common and local drivers of financial assets. The observation of an increase in correlations signifies that the financial markets started to pay more attention on information which concerns the integrated area as a whole. Country specific events which affect the yields idiosyncratically and therefore lead to less correlation are less relied upon.

Also the integration process of the EMU has been analysed with measures of bond yield comovements as indicators of a gain in importance of aggregated European shocks over local country specific factors. Baele et al. (2004) investigate, which extent of bond yield movements can be attributed to the movement of the German 10-year benchmark government bond yield, which is assumed to proxy EMU wide shocks. The remaining bond fluctuation is referred to regional information. It is found that during the European integration process idiosyncratic shocks became significantly less important for yield movements as compared to high explanatory power of common factors.

Ehrmann et al. (2011) use a comparable factorization of global and regional information and additionally unconditional static correlations as measures to analyse the bond market integration during the European integration process. Strong integration is identified, which is primarily referred to the common monetary policy and the elimination of exchange rate risk. Abad et al. (2010) refer to a CAPM based analysis and also provide evidence that since the adoption of the single currency, intra-EMU information became the more important bond yield driver as compared to either global or local effects.

Finally, Cappiello et al. (2006b) also apply the DCC methodology to examining the integration process of the EMU. Using weekly data of Euro Area and non-Euro Area countries, correlation time series are estimated and integration is confirmed visually.

The aforementioned studies are providing results favouring a strong EMU integration process. In this study, all major results are replicated, statistically confirmed and enhanced, however completely based on the results of the DCC methodology.

Firstly, this study agrees on earlier results that the integration process was highly advanced but not completed at any point in time and that the degree of integration differentiated between geographical and political regions.

Secondly, it is confirmed statistically that the first, the second and the third stage of the EMU contributed significantly to the integration process. Additionally, a test procedure investigating the exact timing of significant and permanent upswings of bond market integration is developed.

Earlier studies found either the exact date of monetary unification in 1999 or some earlier date from which on the subsequent unification could be expected as single break point in the European bond yield development. This study reveals that besides the Euro introduction in 1999, in fact also the beginning of the monetary unification process in 1990 and beginning of the second stage of the monetary unification process in 1994 each triggered a new wave of integration increases. The European bond yield development thus shows three distinct break points each fostering the integration process itself.

Thirdly, the study shows that the particular reason for the bond market integration in Europe is the financial market's expectation of European integration in the fundamental data. Bond market integration and convergence is driven by financial market's belief that there is harmonization of the single countries' risk factors.

A belief in the harmonization of risk factors in the Euro Area can be caused by two major aspects: First, there is a belief in real integration, i.e. the financial market believes that countries of the Euro Area become more similar because of economic and judicial prerequisites for EMU membership. Second, there is an ex ante expectation in a potential bail-out, i.e. the financial market believes that countries of the Euro Area will be saved once there is severe financial distress. The former harmonizes fundamental factors, the latter guarantees that in the absence of fundamental harmonization, country specific risk is distributed among all Euro Area countries.

While the bail-out argument only works for bond markets, a belief in real integration is also valid for equities. Dynamic conditional correlations applied to major equity indices of the seven countries reveal comparable results as seen in the bond market analysis. This favours that the belief in real integration is the main driver of bond market integration in Europe.

The paper is structured as follows. Section 2 shows the development towards stronger EMU bond market integration and regional characteristics. In Section 3, the relevance of the three stages of the EMU for the integration process is elaborated. Section 4 draws attention on the similarities of bond yield correlation in comparison to equity index correlation. Section 5 concludes.

2. EMU bond market integration

In July 1990 the first stage of the EMU was launched. From January 1994 until December 1998, the second stage of the EMU served as preparation for the final monetary unification. The introduction of the Euro in January 1999 marked the beginning of the third stage of the EMU.

In this section, the DCC based correlation analysis is carried out for seven countries which participated in the foundation of the EMU. Subsection 2.1 describes the data used, Subsection 2.2 analyses the dynamic correlation development and its implications for the integration success.

2.1 Yield data

In order to investigate the harmonization of bond yield movements since the implementation of the EMU, week daily 10-year benchmark government bond yields for a sample of seven countries, Denmark, France, Germany, Italy, the Netherlands, Spain and the UK are used.

The analysis spans a time period ranging from January 1987 until December 2003 for Denmark, France, Germany and the UK and from January 1992 until December 2003 for Italy and Spain. A lack of data availability renders it impossible that also the calculations for the latter two countries completely comprise all three stages of the EMU. After four years of the third stage of the EMU, the time span stops by the end of 2003 as the integration process is almost completed by then and remains on comparably high levels in the subsequent years.

Prolonging the time period would only further aggravate all results regarding the third stage of the EMU.

The restriction to the seven countries is chosen according to data availability and in order to support intra-EMU comparisons of different country groups.

Germany is the biggest and most solid economy within the EMU. In the following, each other country's dynamic bond yield correlations are calculated against the German bond yields. Rising correlations indicate a stronger integration of the other six countries with the German government bond market.

With France and the Netherlands, two countries highly equivalent to Germany are analysed. Both Northern European economies are financially similarly solid. Major problems remained absent even in the wake of the European debt crisis.

Denmark and the UK also represent two financially solid founding members which however did not participate in the third stage of the EMU due to their opting out decisions. Therefore, the two countries are confined to the others for political reasons regarding the unification process.

Finally, Italy and Spain are members of the distressed Southern European country block. Since late 2009, the two countries are massively attacked by the financial market and suffer from strongly increasing borrowing costs. While also participating in the Euro Area, Italy and Spain are far more distinct to Germany as compared to France and the Netherlands.[3]

2.2 Correlation development

The estimated correlation dynamics are used to analyse the degree of the EMU integration process. If the EMU countries become more integrated, European information gains in importance as driver of bond yield movements as compared to country specific information. A stronger parallelism of bond yield developments is therefore acknowledged as evidence for

[3] In an additional analysis, the bond market integration of Hungary and Poland with Germany is evaluated before and after the accession to the EU. Appendix C shows results of the comparison between the integration development of the two Eastern European countries around the time of the EU accession and Western European countries around the time of the EMU foundation.

stronger bond market integration. An increase in parallelism between the German government bond yields with the other six countries comes along with an increase of correlation coefficients between the respective bond yields over time.

The development of the six countries' correlations with the German benchmark bond yields is shown in Figure (2). The time varying lines depict the estimated dynamic conditional correlation series. The vertical lines indicate the beginning of the stages of the EMU process in July 1990, January 1994 and January 1999.[4]

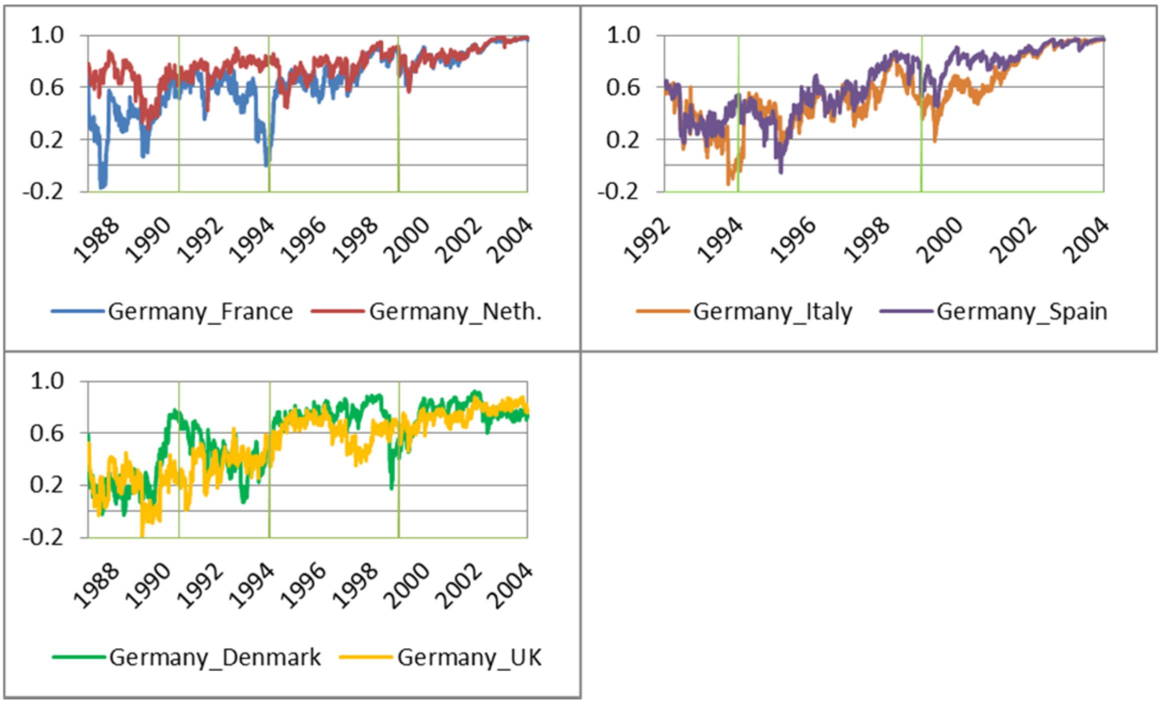

Figure 2: Dynamic conditional correlation estimates of 10-year benchmark government bond yields between Germany vis-à-vis France and the Netherlands (upper left subplot), Denmark and the UK (lower left subplot) and Italy and Spain (upper right subplot). Vertical lines indicate the stages of the EMU.

The graphical results lead to three initial results all in line with the literature. First, for all country groups, a strong tendency for rising bond yield correlations can be recognized. This development draws the clear conclusion that the EMU process fostered stronger bond market integration of all six countries with the German counterpart.

[4] As the time series for Italy and Spain begin in 1992, the upper right subplot only indicates the beginning of the second and third stage of the EMU.

A second insight from the visual inspection is the regional differentiation between the different members of the EMU. The average correlations of the Northern European countries' bond yields vis-à-vis the German bond yields are the highest in the sample of all six countries. France and the Netherlands display the strongest integration with the German government bond market.

The Southern European countries start from the lowest average correlations in the early 1990's, but the subsequent development describes an immense catch up process. Only a few years after the introduction of the Euro, Italy and Spain reach highly identical integration degrees as Northern Europe.

Interestingly, this last aspect is not true for Denmark and the UK. While rising correlations also favour stronger integration with German bond markets, the average correlations of the two non-Euro Area countries after the introduction of the single currency fall short as compared to the Euro Area.

Third, the Euro Area countries reach almost perfect bond market integration with correlation estimates close but short to one. Reasons for the failure of perfectly complete bond market integration are diverse. Arguments contain differences in country specific credit risk (Codogno et al., 2003; Schuknecht et al., 2009), differences in liquidity risk (Adjaouté and Danthine, 2003; Favero et al., 2010; Gomez-Puig, 2006; Jankowitsch et al., 2006), or a combination thereof (Bernoth et al., 2004; Manganelli and Wolswijk, 2009).

The descriptive overview of the graphical results is summarized in Table (1). Average correlations pre stage one and within each of the three stages of the EMU are provided. Additionally, the percentage stage to stage growth rates of average correlations and the percentage two stage growth rates are displayed.

Correlation Series		pre Stage 1	Stage 1	Stage 2	Stage 3
Germany-France	Ø-Correlation	0.365	0.547	0.690	0.865
	Stage %-Growth		50%	26%	25%
	2-Stage %-Growth			89%	58%
Germany-Netherlands	Ø-Correlation	0.642	0.754	0.767	0.875
	Stage %-Growth		17%	2%	14%
	2-Stage %-Growth			19%	16%
Germany-Denmark	Ø-Correlation	0.263	0.444	0.726	0.760
	Stage %-Growth		69%	64%	5%
	2-Stage %-Growth			176%	71%
Germany-UK	Ø-Correlation	0.193	0.363	0.616	0.746
	Stage %-Growth		89%	70%	21%
	2-Stage %-Growth			220%	105%
Germany-Italy	Ø-Correlation		0.298	0.483	0.746
	Stage %-Growth			62%	54%
	2-Stage %-Growth				150%
Germany-Spain	Ø-Correlation		0.388	0.537	0.844
	Stage %-Growth			38%	57%
	2-Stage %-Growth				118%

Table 1: Descriptive statistics for correlation estimates of the French, Dutch, Danish, British, Italian and Spanish vis-à-vis the German 10-year benchmark government bond yields. For each correlation series, the first row shows the average correlation before the first stage and within the three stages of the EMU, the second row shows the percentage growth of average correlations from stage to stage and the third row shows the percentage correlation growth from pre stage one to stage two and from stage one to stage three.

3. The role of the EMU stages for bond market integration

The graphical analysis showed a general trend towards higher integration of the EMU bond markets. In this section the role of the single stages of the monetary unification process for the bond market integration is evaluated. Subsection 3.1 measures that each stage as a whole contributed to higher integration in general. In Subsection 3.2 it is shown that specifically the beginning of each stage triggered a separate wave of the integration progress and marks an own break point in the bond yield development.

3.1 EMU stages contribute to bond market integration

For testing the hypothesis that the different stages of the EMU did have a statistically significant impact on bond market integration, the following dummy regression is proposed.

The estimated correlation time series from Subsection 2.2, i.e. the dynamic conditional correlations between German government bond yields vis-à-vis the other six countries' bond yields, are applied to an AR(1) model. Dummy parameters representing the single stages of the EMU are implemented into this regression equation provided in (1).

$$\rho_t = \varphi + \kappa\rho_{t-1} + \eta D_{1,t} + \mu D_{2,t} + \omega D_{3,t} + u_t \tag{1}$$

The autoregressive parameters ρ_t are the dynamic conditional correlation estimates of Subsection 2.2, $D_{1,t}$, $D_{2,t}$ and $D_{3,t}$ represent stage dummies, φ, κ, η, μ, ω and η the parameters to be estimated and u_t the error term.

The composition of the dummy variables depends on the specific stage to be tested. Exemplarily, in order to test whether the first stage of the EMU significantly contributed to the bond market integration, the time span before the first stage is taken as base scenario and no dummy for that time period is included into equation (1).

Accordingly, the first dummy variable $D_{1,t}$ then represents the first stage of the EMU and takes a value of one between 01.07.1990 and 31.12.1993 and zero otherwise. The second dummy variable $D_{2,t}$ represents the second stage and takes a value of one between 01.01.1994 and 31.12.1998, the dummy representing the third stage, $D_{3,t}$, takes a value of one between 01.01.1999 and the end of the sample on 31.12.2003.

As long as the first stage of the EMU did significantly contribute to the bond market integration, the parameter of $D_{1,t}$ must be significantly positive. If the parameter is significantly positive, there is statistical evidence that the average correlation level increased during stage one as compared to the time pre stage one, i.e. the base period.

Testing the impact of the other two stages on the bond market integration runs accordingly. In order to evaluate the contribution of stage two of the EMU, the first stage represents the base scenario and is not included as dummy in equation (1). The three dummies capture the time periods pre stage one, stage two and stage three. The coefficient of $D_{2,t}$ is tested for positive significance. For testing stage three of the EMU, the second stage is the base scenario and the coefficient of $D_{3,t}$ needs to be evaluated.

Regression equation (1) is calculated for the six countries' bond yield correlations with Germany. Table (2) shows the coefficient estimates described above, which are relevant for evaluating the contribution of the single stages of the EMU to the bond market integration.[5]

Correlation Series	Stage 1	Stage 2	Stage 3
Germany-France	0.004***	0.004***	0.003*
	(3.517)	*(4.269)*	*(1.894)*
Germany-Netherlands	0.003	0.000	0.003***
	(0.283)	*(0.202)*	*(7.370)*
Germany-Denmark	0.004	0.007***	0.001***
	(1.440)	*(13.146)*	*(3.957)*
Germany-UK	0.010***	0.014	0.007***
	(4.566)	*(0.348)*	*(14.218)*
Germany-Italy		0.005***	0.005***
		(3.486)	*(5.100)*
Germany-Spain		0.003**	0.006***
		(2.315)	*(21.890)*

Table 2: EMU stage dummy regression estimates: Dummy parameter estimates testing the contribution of the single stages of the EMU to the bond market integration from equation (1) are shown for dynamic conditional correlation series of French, Dutch, Danish, British, Italian and Spanish 10-year benchmark government bond yields vis-à-vis German 10-year benchmark government bond yields. Significantly positive coefficients indicate a positive impact of the EMU stage for the bond market integration between Germany and the respective counterpart. Upper numbers refer to the coefficient estimates. *, ** and * denote rejection of H0 (the parameter being equal to zero) and statistical significance at the 10%, 5% and 1% confidence level, Wald t-statistics derived from heteroskedasticity-robust standard errors are presented in parentheses.**

The statistical analysis confirms a contribution of the stages of the EMU to the bond market integration in most cases.

For the French-German correlations exemplarily, the first stage dummy coefficient takes a value of 0.004 and is highly significantly positive. Thus, the average correlation increased during the first stage of the EMU as compared to the period pre first stage. With a value of again 0.004, also the second stage dummy is significantly positive and the average correlation during the second stage increased as compared to the first stage. Finally, with a significant coefficient of 0.003, the average correlation again increased during the third stage as compared to the second stage.

[5] As the time series for Italy and Spain only begin in 1992, equation (1) is estimated with only two dummy variables for these two countries. Because of space reasons, results are restricted to those coefficient estimates, which can be interpreted with regard to the question of contribution to the bond market integration. All other estimation results can be obtained from the author on demand.

All three stages of the EMU did have a positive impact on the bond market integration between France and Germany. A significant contribution of all three stages to the bond market integration with Germany is not confirmed for the other countries. A significantly positive effect of the first stage however also applies for the UK and of the second stage for Denmark, Italy and Spain.

Interestingly, the third stage fostered bond market integration for all six countries, even for the two countries not participating in the Euro Area. This might be due to the fact that even though the single currency was not initiated, Denmark and the UK nevertheless still participated in the European Union. Thus integration still advanced, however at a potentially slower pace.

3.2 Beginnings of EMU stages trigger bond market integration

The single stages of the EMU each introduced economic and judicial standards, which affected the seven countries in a similar way. The contribution to bond market integration therefore is reasonable.

Now it is demonstrated that not only the three stages as a whole positively affected the integration progress, but that actually with the beginning of each stage a new wave of increased correlations was triggered. Each starting point of a new stage of the EMU thus represents an own break point in the bond yield development of the analysed countries.

Identifying periods triggering the integration process is more complicated as compared to evaluating the contribution of the stages of the EMU. A convention of what is meant by a trigger needs to be derived initially.

A period can only function as trigger for bond market integration, if it displays a significant increase of average correlations after one or more years of stable or decreasing correlations. As however observed in Figure 2, the dynamic correlations of the different country pairs are erratic. Upswings and downswings take turn regularly. Consequently, it is not conducive to identify an integration trigger each time the correlations increase for a short term.

A long term increase of average correlations changes the situation. If an upswing is sustained more permanently, i.e. if not only the current year displays a significant increase of average correlations, but this increase is either kept or augmented during the next years, a sustainable integration trigger can be identified. A suchlike triggered wave of integration comes to an end once an already reached level of average correlation significantly decreases again.

The test procedure proposed for identification of the moments triggering the integration progress again applies the estimated correlation series from Subsection 2.2 in an AR(1) model which is enhanced by dummy variables. The estimation equation is provided in (2).

$$\rho_t = \varsigma + \lambda\rho_{t-1} + \Sigma_i\theta_i D_{i,t} + u_t \qquad (2)$$

This time the dummy variables are not representing the stages of the EMU, but the years between 1987 and 2003. The time span of the dummy variables is reduced in order to narrow down the periods which triggered upswings of bond market integration.

The composition of the dummy variables again depends on the specific time period to be tested. If it is to be tested whether the year of 1988 triggered a permanent surge in correlations, the year of 1987 works as the base scenario and has no dummy in equation (2). The 16 years from 1988 until 2003 are captured by 16 dummy variables which take a value of one during their respective year and a value of zero otherwise.

The test procedure investigating trigger periods of bond market integration involves several steps. Given that the year 1988 is triggering an integration wave, the parameter of $D_{1,t}$ must be significantly positive, i.e. the average correlations significantly increased in 1988 as compared to the base year of 1987.

A significantly positive coefficient of $D_{1,t}$ however only confirms that the year 1988 generated a short term increase of correlation. So far, nothing can be said about the sustainability of that integration upswing. Therefore the coefficient of $D_{2,t}$ is tested for positive significance in the next step. If that test result is also positive, then the average correlations remained at an increased level in 1989 as compared to the base year of 1987. An immediate reverse of the integration process can thus be rejected.

As long as the average correlations persist on a level significantly higher as compared to the base year of 1987, the dummies representing the further years are tested in the same way. By means of that it can be revealed, if a long term integration wave is triggered and for how many years it endures.

The test procedure which evaluates if the other 16 years trigger integration waves is systematically carried out in the same way. Exemplarily, in order to test if the year 1989 serves as a trigger year, the base year switches from 1987 to 1988 and the 16 dummy variables account for all other years. Confirming positive significance for the dummies capturing the years after the base scenario 1988 reveals the length of a potential integration wave triggered in 1989.

The results of the trigger regression (2) for all countries are provided in Table 3.[6] The base years are listed in the rows. Year numbers followed by a plus sign refer to the length of a positive integration wave. Year numbers followed by a minus sign refer to the length of a disintegration period with decreasing average correlations. If base years are marked by an X, the subsequent year neither initiated a period of higher nor lower correlations.

		Correlation Series					
		France	**Netherlands**	**Denmark**	**UK**	**Italy**	**Spain**
Base Year	**1987**	X	X	X	X		
	1988	X	1 year -	X	1 year -		
	1989	**3 years +**	**14 years +**	**3 years +**	**14 years +**		
	1990	X	X	3 years -	X		
	1991	X	2 years +	1 year -	12 years +		
	1992	1 year -	X	X	X	1 year -	X
	1993	X	4 years -	X	2 years +	**10 years +**	X
	1994	X	**9 years +**	**3 years +**	2 years +	X	X
	1995	X	3 years +	2 years +	4 years -	2 years +	**8 years +**
	1996	1 year +	X	X	1 year -	X	7 years +
	1997	X	1 year +	2 years -	6 years +	1 year +	6 years +
	1998	X	3 years -	X	5 years +	1 year -	1 year -
	1999	X	**4 years +**	**4 years +**	**4 years +**	X	X
	2000	**3 years +**	3 years +	X	X	**3 years +**	X

Table 3: Trigger dummy regression estimates: Estimation results refer to equation (2). Year numbers indicate the length of the period a significant increase (+) or decrease (-) of average dynamic conditional correlations of French, Dutch, Danish, British, Italian and Spanish 10-year benchmark government bond yields vis-à-vis German 10-year benchmark government bond yields sustained as compared to the respective base year. An X indicates that neither average

[6] Also the trigger regressions for Italy and Spain are reduced because bond yield data only starts in 1992. For the two countries, equation (3) is calculated with 11 instead of 16 year dummies.

correlations increased nor decreased as compared to the base year. Statistical significance is confirmed for confidence levels of 10% or below, Wald t-statistics derived from heteroskedasticity-robust standard errors are used.

In most cases, the dummy analysis reveals that not only the three stages of the EMU contributed as a whole to the integration progress, but that predominantly the time around the beginning of each new stage triggered an integration wave of its own. Consequently, each beginning of a new stage of the EMU marked a break point in the bond yield development.

This conclusion can especially clearly be described based on the Dutch results. The average correlation between the Dutch and the German government bond yields did not rise significantly between 1987 and 1989. Starting in 1990, a significant upswing in correlations as compared to the base year of 1989 can be recognized. This integration wave lasted for 14 years, i.e. for the whole sample period the correlation did not drop back to its average level of 1989. The year of 1990, i.e. the year the first stage of the EMU began, triggered the first long term integration wave.

After 1990, there was a short term upswing, a downswing and two neutral years. Especially the decrease in average correlations set a preliminary end to the integration progress. Only in 1995, i.e. one year after the second stage of the EMU started, a second wave of integration began. Average correlations rose significantly above the level of the base period in 1994 and remained at least that high for 9 years until the sample period ended.

The subsequent development led to years of minor integration progress and to a year of decreasing average correlation. This period of disintegration marked the end of the second wave of bond market integration. In the year 2000 however, i.e. one year after the third stage of the EMU began, the bond market integration was again accelerated. A third wave of increased average correlation lasting for the next four years until the end of the sample period can be confirmed.

Though not as strong as for the Netherlands, also the results for the other countries are in line with the argument that the stages of the EMU each caused an own break point in the bond yield development and thereby fostered the bond market integration.

The boldly highlighted years of Table 3 show that for Denmark also a break point at each stage can be confirmed. For France and the UK, the beginning of first and the third stage marked an integration trigger, for Italy the same is true for the second and the third stage. In the Spanish case, the second stage led to a long term upswing in bond market integration. Though integration upswings are not always triggered exactly at the time a new EMU stage start, a chronological connection is acceptably clear.

4. Reasons for bond market integration

Bond markets become more integrated, if the risk of the single countries converges. Once that is the case, European information gains in importance over country specific information. Besides bond yield convergence, also a harmonization of bond yield movements is then observable.

Perceived convergence of country specific risk inside the Euro Area can be caused by two distinct factors: Either fundamentals converge and there is integration in real values, or it is expected ex ante that distressed economies receive help from the rest of the Euro Area.

In this section, the DCC analysis from Section 2 is applied to major equity indices of the same seven countries. As the results for equity markets is comparable to the bond market results, an ex ante expectation of bail out provision inside the Euro Area can be ruled out. A financial market's perception of integration in real values is shown to be the likely reason for bond market integration.

In Subsection 4.1 the data is presented, Subsection 4.2 provides an overview of the estimation results. The estimation procedure is identical to Section 2.

4.1 Equity data

The harmonization of movements of equity indices is investigated for the same set of countries, Denmark, France, Germany, Italy, the Netherlands, Spain and the UK. In all cases, a major performance index is applied to the analysis.[7] Clearly the composition of the equity indices varies from country to country, but nevertheless they serve a reasonable approximation for the evaluation of equity market integration.

[7] The equity indices are Copenhagen KFX for Denmark, CAC 40 for France, DAX 30 for Germany, FTSE Italia for Italy, AEX for the Netherlands, IBEX 35 for Spain and FTSE 100 for the UK.

The time span of the equity analysis starts in January 1992 and ends in December 2003 for all seven countries. Matching the time range to the bond market analysis is not possible for each country due to data availability. Additionally, the August Putsch of 1991 in the Soviet Union shows an extreme influence on the development in the equity markets. In order to avoid this deviation which does not show up in the bond market development, this anomaly is excluded.

4.2 EMU equity market integration

Comparable to Section 2.2, dynamic conditional correlations of the six countries' equity indices vis-à-vis the German DAX 30 are estimated according to the DCC model. The correlation development is presented in Figure (3).

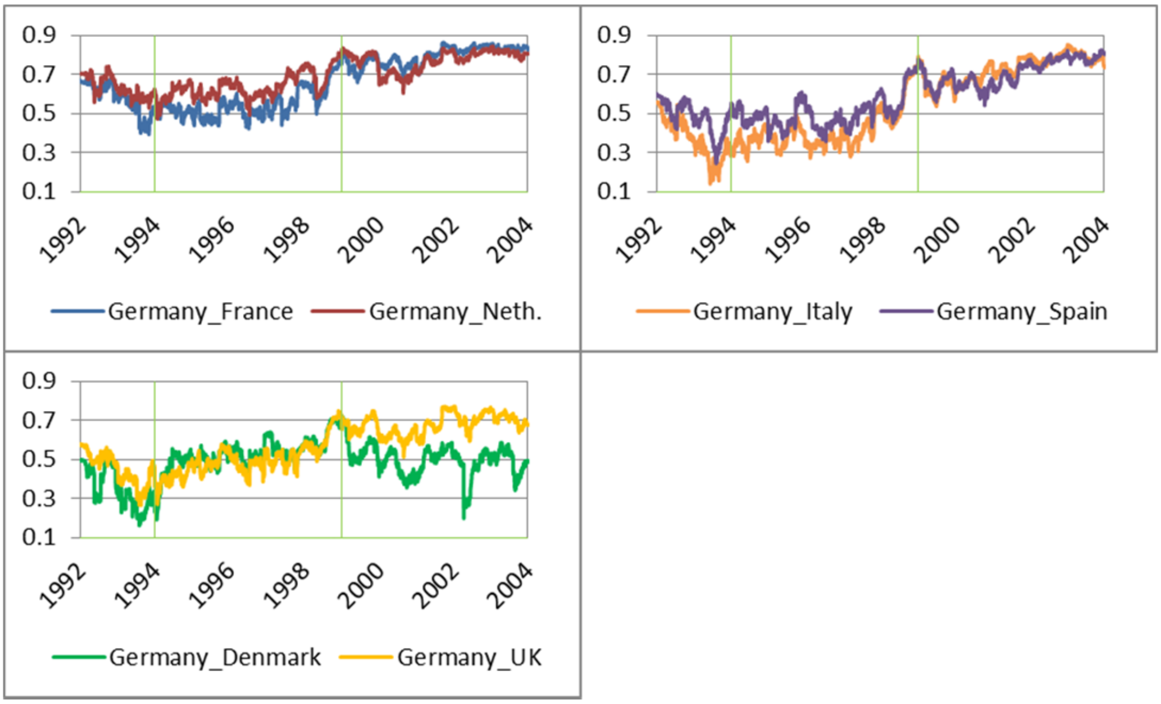

Figure 3: Dynamic conditional correlation estimates of major equity indices between Germany vis-à-vis France and the Netherlands (upper left subplot), Denmark and the UK (lower left subplot) and Italy and Spain (upper right subplot). Vertical lines indicate the stages of the EMU.

The graphical results demonstrate equity market integration. With the exception of Denmark since the beginning of the third stage of the EMU, a general increase in correlation coefficients can be confirmed. The Danish development might be reasonably linked to the opting out decision regarding the Euro.

If the integration of the bond markets is only driven by an ex ante believe that distressed countries can rely on immediate help of other countries of the Euro Area, a similar integration progress should not be observable for the equity markets. As for equity markets a bail out is not expectable, integration should limit itself to the bond markets.

As however the conclusion in favour of integration is also valid for equities, the financial market is not relying on a bail out, but is more likely to perceive convergence in fundamental values. The cause of bond market integration thus lies in real integration as opposed to an anticipated multilateral rescue provision within the Euro Area.

The descriptive overview of the dynamic conditional correlation estimates of the equity indices is shown in Table 4.

Correlation Series		**Stage 1**	**Stage 2**	**Stage 3**
Germany-France	Ø-Correlation	0.580	0.547	0.796
	Stage %-Growth		-6%	45%
	2-Stage %-Growth			37%
Germany-Netherlands	Ø-Correlation	0.634	0.639	0.774
	Stage %-Growth		1%	21%
	2-Stage %-Growth			22%
Germany-Denmark	Ø-Correlation	0.353	0.530	0.496
	Stage %-Growth		50%	-6%
	2-Stage %-Growth			41%
Germany-UK	Ø-Correlation	0.451	0.497	0.679
	Stage %-Growth		10%	37%
	2-Stage %-Growth			51%
Germany-Italy	Ø-Correlation	0.367	0.415	0.730
	Stage %-Growth		13%	76%
	2-Stage %-Growth			99%
Germany-Spain	Ø-Correlation	0.482	0.503	0.710
	Stage %-Growth		4%	41%
	2-Stage %-Growth			47%

Table 4: Descriptive statistics for correlation estimates of the French, Dutch, Danish, British, Italian and Spanish vis-à-vis the German major equity indices. For each correlation series, the first row shows the average correlation within the three stages of the EMU, the second row shows the percentage growth of average correlations from stage to stage and the third row shows the percentage correlation growth from stage one to stage three.

5. Conclusion

The analysis provides further insights regarding the bond market integration during the EMU process. DCC models are estimated in order to evaluate the degree of European bond market integration. A clear development towards greater bond market integration is confirmed. The results also depict that integration fall short from being complete and that regional differences in the degree and pace of integration remain.

Additional calculations show that each stage of the EMU positively influenced the integration process. Both the stages as a whole contributed to higher bond market integration and the beginning of each stage triggered an own wave of integration. The bond yield development during the EMU process displays three distinct break points.

Finally, the analysis sheds light on the reason for the bond market integration. Ex ante expectations of bail outs within the Euro Area are dismissed as cause for the bond market integration. Financial market perception of convergence in real values is advocated instead. The evidence is derived from the similarity of equity market integration as compared to bond market integration.

Appendix A. Dynamic conditional correlation (DCC) models

DCC models estimate time varying correlation coefficients. Dynamic correlations are especially useful when analysing correlation developments over time.

DCC modelling requires two-step estimation. In the first step, conditional variances $h_{i,t}$ are estimated with univariate GARCH models. In the second step, the conditional correlation matrix $\mathbf{R_t}$ is estimated. The input vector $\mathbf{r_t}$ is characterized according to (A.1) with the covariance matrix $\mathbf{H_t}$ specified in (A.2).

$$\mathbf{r_t} \sim N(0, \mathbf{H_t}) \tag{A.1}$$

$$\mathbf{H_t} = \mathbf{D_t}\,\mathbf{R_t}\,\mathbf{D_t} \tag{A.2}$$

$\mathbf{R_t}$ represents the time variant correlation matrix. Non-diagonal elements are correlation coefficients between the different elements of the input vector $\mathbf{r_t}$. $\mathbf{D_t}$ is diagonal with the square roots of the conditional variances of the input vector $\mathbf{r_t}$, $h_{i,t}$, as elements.

The conditional variances for the $i=1,\dots,N$ elements of the input vector $\mathbf{r_t}$ are estimated with N univariate GARCH models according to (A.3).

$$h_{i,t} = \omega_i + \Sigma_p\, \alpha_{i,p}\, r^2_{i,t-p} + \Sigma_q\, \beta_{i,q}\, h_{i,t-q} \tag{A.3}$$

From the estimated conditional variances $h_{i,t}$, the standardized GARCH residuals $\boldsymbol{\varepsilon}_\mathbf{t}$ are subsequently derived according to (A.4).

$$\boldsymbol{\varepsilon}_\mathbf{t} = \mathbf{D^{-1}_t}\,\mathbf{r_t} \tag{A.4}$$

The volatility adjusted residuals $\boldsymbol{\varepsilon}_\mathbf{t}$ are applied to the multivariate GARCH equation. Comparable to the conditional variances in (A.3), the conditional covariance $\mathbf{Q_t}$ depends on lagged realizations of the residual vector $\boldsymbol{\varepsilon}_\mathbf{t}$ and lagged conditional covariance. The multivariate GARCH equation is provided in (A.5)

$$\mathbf{Q_t} = (1 - \Sigma_m\, \gamma_m - \Sigma_n\, \delta_n)\,\mathbf{\hat{O}} + \Sigma_m\, \gamma_m\, (\boldsymbol{\varepsilon}_\mathbf{t-m}\, \boldsymbol{\varepsilon}'_\mathbf{t-m}) + \Sigma_n\, \delta_n\, \mathbf{Q_{t-n}} \tag{A.5}$$

The unconditional covariance of the standardized residuals $\boldsymbol{\varepsilon}_t$, i.e. the term Ô, ensures that the multivariate estimation generates well defined conditional covariance matrices. The unconditional covariance matrix Ô is positive definite and guarantees together with the positive semidefinite lagged shock $\boldsymbol{\varepsilon}_{t-m}\boldsymbol{\varepsilon}'_{t-m}$ the generation of a positive definite conditional covariance matrix $\mathbf{Q}_t$.

With the normalization shown in (A.6), the conditional covariance matrix is finally transformed to the conditional correlation matrix $\mathbf{R}_t$, in which the auxiliary matrix $\mathbf{Q}^*_t$ is diagonal with the square roots of the diagonal elements of the conditional covariance matrix $\mathbf{Q}_t$ as its elements.

$$\mathbf{R}_t = \mathbf{Q}^*_{t-1}\, \mathbf{Q}_t\, \mathbf{Q}^*_{t-1} \qquad \text{(A.6)}$$

The two-step DCC estimation is calculated with maximum likelihood estimation or quasi maximum likelihood if the input vector $\mathbf{r}_t$ is not multivariate normal. Under very general conditions, the (quasi) maximum likelihood estimates are consistent and asymptotically normal.

Appendix B. DCC model specification

DCC modelling requires stationary mean zero input variables according to (A.1). All data applied to the model is filtered for unit roots by differencing, the resulting stationary variables are subsequently demeaned.

In the next step, the lag order of the univariate GARCH-equations (A.3) needs to be specified according to the modified input data. A general version of each conditional volatility model is estimated and GARCH-coefficients are evaluated with Wald t-tests. Removing all insignificant lags reveals the final specification.

The adequacy of the GARCH-specifications is tested with the ARCH-LM test. A sufficiently high F-statistic leads to rejection of the null hypothesis of no remaining heteroskedasticity.

The final step requires identification of the lag order of the multivariate GARCH-equation of (A.5). As in the univariate case, Wald t-tests are applied to the coefficients of a general version of the conditional covariance model. Modified standard errors need to be used, as t-statistics are otherwise inconsistent, as documented in Engle and Sheppard (2001).

The suitability of estimating a dynamic correlation process depends on the properties of the correlation structure. If correlations between assets are constant as assumed in Bollerslev (1990), estimation of a dynamic structure becomes redundant.

It is thus essential to investigate if the data allows for the estimation of correlation dynamics. An OLS based test procedure proposed by Engle and Sheppard (2001) is applied to confirm the adequacy of estimating dynamic conditional correlations. A sufficiently high F-statistic rejects the null hypothesis of constant correlations.

The DCC specification and the diagnostic test results for the dynamic bond yield correlation are shown in Table B.1, for the dynamic equity index correlation in Table B.2.

	ARCH 1	GARCH 1	GARCH 2
Germany	0.061***	0.923***	X
(0.322)	*(6.027)*	*(70.453)*	
France	0.074***	0.902***	X
(0.811)	*(5.996)*	*(53.596)*	
Netherlands	0.086***	0.894***	X
(0.463)	*(4.661)*	*(40.039)*	
Denmark	0.088***	0.894***	X
(0.265)	*(4.318)*	*(36.754)*	
UK	0.071***	0.348**	0.567***
(0.105)	*(3.418)*	*(2.168)*	*(3.756)*
DCC	0.031***	0.257***	0.712***
*(723.074)****	*(6.167)*	*(5.563)*	*(15.126)*
Italy	0.097***	0.903***	X
(0.992)	*(5.157)*	*(48.034)*	
Spain	0.078***	0.920***	X
(0.864)	*(3.637)*	*(44.881)*	
DCC	0.033***	0.281***	0.685***
*(1150.305)****	*(10.330)*	*(5.736)*	*(14.016)*

Table 5: DCC specification and diagnostic test results for dynamic bond yield correlation: Rows 1-6 refer to the sample ranging from January 1987 to December 2003, rows 7-9 to the sample ranging from January 1992 to December 2003.

Rows 1-5 and 7-8 display ARCH and GARCH coefficients for the univariate conditional volatility equation (5) for Germany, France, the Netherlands, Denmark, the UK, Italy and Spain. Upper numbers refer to coefficient estimates, Wald t-statistics derived from heteroskedasticity-robust standard errors are presented in parentheses. Lower numbers in parentheses below the country name refer to F-statistics derived from the ARCH-LM test. A sufficiently high F-statistic leads to rejection of the H0 of no remaining ARCH.

Row 6 and 9 display ARCH and GARCH coefficients for the multivariate conditional covariance equation (7). Upper numbers refer to coefficient estimates, Wald t-statistics derived from modified standard errors are presented in parentheses. Lower numbers in parentheses below "DCC" refer to F-statistics derived from the OLS-test for constant conditional correlation. A sufficiently high F-statistic leads to rejection of the H0 of constant conditional correlation.

***, ** and *** denote rejection of H0 and statistical significance at the 10%, 5% and 1% confidence level.**

	ARCH 1	ARCH 2	GARCH 1	GARCH 2
Germany	0.094***	X	0.906***	X
(0.631)	*(9.382)*		*(92.964)*	
France	0.056***	X	0.944***	X
(0.717)	*(7.728)*		*(137.808)*	
Netherlands	0.039**	0.062***	0.898***	X
(0.969)	*(2.203)*	*(3.030)*	*(89.320)*	
Denmark	0.072***	X	0.928***	X
(1.734)	*(5.183)*		*(61.886)*	
UK	0.069***	X	0.930***	X
(0.183)	*(5.940)*		*(80.420)*	
Italy	0.099***	0.074***	0.067**	0.760***
(2.100)	*(5.583)*	*(3.654)*	*(2.007)*	*(23.714)*
Spain	0.041***	0.046**	0.913***	X
(0.791)	*(2.666)*	*(2.207)*	*(67.085)*	
DCC	0.015***	X	0.557***	0.426***
*(160.091)****	*(5.505)*		*(4.766)*	*(3.658)*

Table 6: DCC specification and diagnostic test results for equity index correlation: All rows refer to the sample ranging from January 1992 to December 2003.

Rows 1-7 display ARCH and GARCH coefficients for the univariate conditional volatility equation (5) for Germany, France, the Netherlands, Denmark, the UK, Italy and Spain. Upper numbers refer to coefficient estimates, Wald t-statistics derived from heteroskedasticity-robust standard errors are presented in parentheses. Lower numbers in parentheses below the country name refer to F-statistics derived from the ARCH-LM test. A sufficiently high F-statistic leads to rejection of the H0 of no remaining ARCH.

Row 8 displays ARCH and GARCH coefficients for the multivariate conditional covariance equation (7). Upper numbers refer to coefficient estimates, Wald t-statistics derived from modified standard errors are presented in parentheses. The lower number in parentheses below "DCC" refers to the F-statistic derived from the OLS-test for constant conditional correlation. A sufficiently high F-statistic leads to rejection of the H0 of constant conditional correlation.

***, ** and *** denote rejection of H0 and statistical significance at the 10%, 5% and 1% confidence level.**

An X marks that for the particular time series, the relevant ARCH or GARCH parameter is insignificant and dropped from the equation. As for the bond yield analysis no ARCH 2 coefficient is significant, the whole column is dropped for space reasons. All other parameter coefficients are significant. For each univariate conditional volatility equation, the null hypothesis of no remaining heteroskedasticity is not rejected. For the multivariate conditional covariance equation, the null hypothesis of constant conditional correlation is clearly rejected. The DCC specification is acceptable.

Appendix C. Bond market integration of EU accession countries of 2004

In May 2004, the biggest enlargement of the EU was completed. While far from being an identical situation, the accession is comparable to the first two stages of the EMU.

With entering into the EU, the accession countries contractually agreed on developing the own economies in order to meet the prerequisites for the introduction of the single currency. The EMU countries worked towards the same goal during the time before the Euro. The contractual counterpart to the Treaty of the Accession formed the Treaty on the European Union (Maastricht Treaty), which came into force in November 1993, i.e. two months before the second stage of the EMU began.

A major difference between the two situations is to be mentioned: While the exact timing of the Euro introduction in January 1999 was publicly announced during the second stage of the EMU, the time of the Euro introduction for the accession countries remained indeterminate. The countries analysed in the following, Hungary and Poland, even by today did not yet introduce the Euro.

A comparison of the bond market integration during the time of the foundation of the EMU and the time of the EU accession is nevertheless interesting for two reasons:

First, non-participation in the Euro Area also applies for Denmark and the UK. Differences in the development of the bond market integration between those two countries and the accession countries are thus not solely attributable to the lack of the single currency or the uncertainty regarding the introduction of it.

Second, at the beginning of the EMU process it was not yet determined, at which time the single currency will be introduced. Additionally, it was not guaranteed, which countries will join the Euro. As the same is true for Hungary and Poland, it is worth analysing, if the developments for the accession countries are similar.

The DCC analysis for the accession countries is conducted with week daily 10-year benchmark government bond yields of Hungary and Poland. The yield series start in January 2001 and end in December 2006.

The countries and the starting point of the time series are chosen according to data availability and the economic importance and size of the selected economies. The time series are terminated early enough to ensure that the subsequent financial crisis did not have any impact on the yield development.

Figure C.1 shows the dynamic conditional correlations. For means of comparison, additionally the earlier presented correlation estimates for Denmark and the UK are shown as well. Those two countries represent the closest fit to the two accession countries for the reasons explained above.

In order to render the observation periods comparable, only the subperiod between January 1991 and December 1996 is presented for Denmark and the UK. For all four countries, the correlation series have a length of six years, which approximately capture three years before and after the accession for Hungary and Poland and three years before and after the second stage of the EMU for Denmark and the UK.

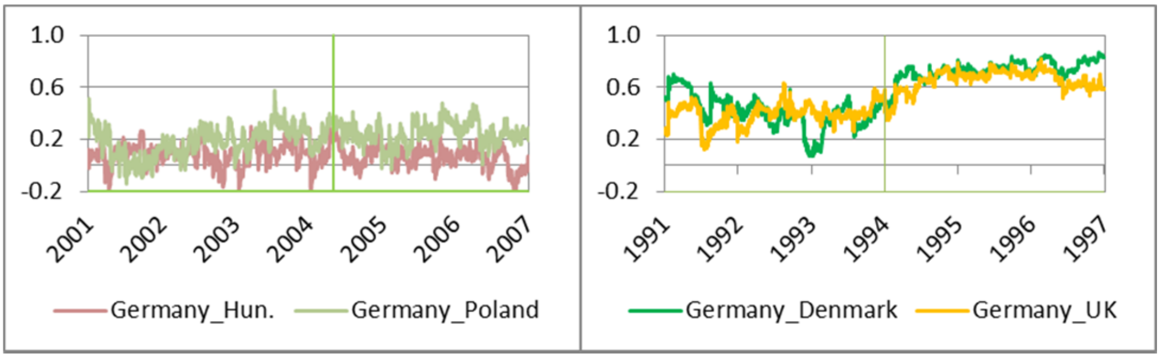

Figure 4: Dynamic conditional correlation estimates of 10-year benchmark government bond yields between Germany vis-à-vis Hungary and Poland (left subplot) and Denmark and the UK (right subplot). The vertical line on the left subplot indicates the EU accession, the vertical line on the right subplot the second stage of the EMU.

The comparison allows two immediate conclusions. First, the bond market integration of the accession countries displays a highly lower degree. This is both true for the time before the major contractual agreements, i.e. the Treaty of the Accession and the Maastricht Treaty, were ratified and the time afterwards.

Second, even though all four countries did not have any specified timeline for introducing the single currency, a major upswing of the bond market integration can be confirmed for Denmark and the UK, while a similar strong development failed to appear for Poland and did not appear at all for Hungary.

The impact of the EU accession for the bond market integration is highly distinct as compared to the impact of the EMU. Even though, both events are at least to some degree comparable, a comparable behaviour of the yield development is not identified. The descriptive overview of the results from Figure C.1, presented in Table C.1, further confirms this impression.

Correlation Series EU		**pre EU**	**EU**
Germany-Hungary	Ø-Correlation	0.083	0.064
	Stage %-Growth		-23%
Germany-Poland	Ø-Correlation	0.182	0.247
	Stage %-Growth		35%
Correlation Series EMU		**Stage 1**	**Stage 2**
Germany-Denmark	Ø-Correlation	0.411	0.729
	Stage %-Growth		77%
Germany-UK	Ø-Correlation	0.393	0.654
	Stage %-Growth		67%

Table 7: Descriptive statistics for correlation estimates of the Hungarian and Polish (upper half) and the Danish and British (lower half) vis-à-vis the German 10-year benchmark government bond yields. For each correlation series, the first row shows the average correlation before and after the EU accession and accordingly before and after the second stage of the EMU. The second row shows the percentage growth of average correlations in between the two periods.

Literature

Adjaouté, K., Danthine, J.-P., 2003. European financial integration and equity returns: A theory-based assessment, in: Gaspar, V., Hartmann, P., Sleijpen, O., (Eds), The transformation of the European financial system. ECB, Frankfurt, pp. 186-245.

Abad, P., Chuliá, H., Gómez-Puig, M., 2010. EMU and European government bond market integration. Journal of Banking & Finance, 34, 2851-2860.

Baele, L., Ferrando, A., Hördahl, P., Krylova, E., Monnet, C., 2004. Measuring financial integration in the Euro area. ECB Occasional Paper Series, 14.

Bernoth, K., von Hagen, J., Schuknecht, L., 2004. Sovereign risk premia in the European government bond market. ECB Working Paper Series, 369.

Bertero, E., Mayer, C., 1990. Structure and performance: Global interdependence of stock markets around the crash of October 1987. European Economic Review, 34, 1155-1180.

Blanco, R., 2002. The Euro-Area government securities market. Recent developments and implications for market functioning, in: Market functioning and central bank policy. BIS, Basel, pp. 65-85.

Bollerslev, T., 1990. Modelling the coherence in short-run nominal exchange rates: A multivariate generalized ARCH model. Review of Economics and Statistics, 72, 498–505.

Cappiello, L.,Gérard, B., Kadareja, A., Manganelli, S., 2006a. Financial integration of new EU member states. ECB Working Paper Series, 683.

Cappiello, L., Hordahl, P., Kadareja, A., Manganelli, S., 2006b. The impact of the Euro on financial markets. ECB Working Paper Series, 598.

Codogno L., Favero, C., Missale, A., 2003. Yield spreads on EMU government bonds. Economic Policy, 18, 503-532.

Côté, D., Graham, C., 2004. Convergence of government bond yields in the Euro zone: The role of policy harmonization. Bank of Canada Working Paper Series, 04-23.

Ehrmann, M., Fratzscher, M., Güürkaynak, R.S., Swanson, E.T., 2011. Convergence and anchoring of yield curves in the Euro Area. Review of Economics and Statistics, 93, 350-364.

Engle, R.F., 2002. Dynamic conditional correlation: A simple class of multivariate generalized autoregressive conditional heteroskedasticity models. Journal of Business and Economic Statistics, 20, 339–350.

Engle, R.F., Sheppard, K., 2001. Theoretical and empirical properties of dynamic conditional correlation multivariate GARCH. NBER Working Papers, w8554.

Favero, C., Pagano, M., von Thadden, E.-L., 2010. How does liquidity affect government bond yields? Journal of Financial and Quantitative Analysis, 45, 107–134.

Forbes, K., Rigobon, R., 2002. No contagion, only interdependence: Measuring stock market co-movements. Journal of Finance, 57, 2223-2261.

Gomez-Puig, M., 2006. Size matters for liquidity: Evidence from EMU sovereign yield spreads. Economics Letters, 90, 156–162.

Jankowitsch, R., Mösenbacher, H., Pichler, S., 2006. Measuring the liquidity impact on EMU government bond prices. European Journal of Finance, 12, 153–169.

Manganelli, S., Wolswijk, G., 2009. What drives spreads in the Euro area government bond market? Economic Policy, 24, 191–240.

Pagano, M., von Thadden, E.-L., 2004. The European bond markets under EMU. Oxford Review of Economic Policy, 20, 531-554.

Schuknecht, L., von Hagen, J., Wolswijk, G., 2009. Government risk premiums in the bond market: EMU and Canada. European Journal of Political Economy, 25, 371-384.