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Abstract

The objective of this paper is to analyze the impact of Monetary Integration on portfolio diversification opportunities in European public debt markets. With this aim, we examine the existence of common trends in daily 10 year sovereign yields for EU-15 countries during the period 1994-2008 by means of using multivariate time series techniques. After the introduction of the euro, although we find evidence of multiple cointegration, the results suggest the existence of more than one common trend for the different yields, and thus, the possibility of risk diversification within EU-15 sovereign debt markets. Furthermore, when we analyze solely EMU countries, we find more evidence of interdependence among them, although we cannot still reject the possibility of risk diversification within this group of countries. These findings have important implications for investors, in terms of diversification benefits in a context of a single currency.

JEL Classification Numbers: E44, F36, G15.

Keywords: Monetary integration, sovereign securities markets, risk diversification, cointegration.

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1. Introduction

European Monetary Union (EMU) caused large-scale changes in euro-area sovereign securities markets (see Danthine *et al*. 2001, and the BIS Study group on fixed income markets, 2001). Before the introduction of the euro, yield differentials between European sovereign borrowers were mostly determined by four factors: expectations of exchange rate fluctuations, differences in domestic tax-regimes, differences in credit risk, and differences in market liquidity. The removal of foreign exchange risk in January 1999 and the elimination (or reduction to insignificant levels) of differences in tax treatment during the 1990s eliminated two of these factors, and paved the way for a much more integrated and competitive public debt market.

As a result, euro-area government bond markets began to be considered as a single market, comparable in terms of size to the US or Japanese markets. Nevertheless, segmentation did not disappear completely. In 2009, public debt management is still decentralized under the responsibility of 12 sovereign issuers with differences in rating and a variety of issuing techniques (see Favero, Missale and Piga, 1999). These are features that distinguish the euro-area debt market from its US and Japanese counterparts. One example of this segmentation is the persistence of yield differentials. Gómez-Puig (2006 and 2008) sets out to examine this persistence and to explore what happened to euro-area countries' yield spreads on government bonds after the introduction of the euro[1].

[1] She assesses the impact of EMU on credit risk and market liquidity differences on euro sovereign debt yield differentials. Concretely, on the one hand, she examines whether in the new scenario of increased substitutability between sovereign securities, market liquidity differences may have become a more important component of yield spreads. On the other, she studies whether EMU increased credit risk by denying governments the emergency exit of money creation and by forbidding both the ECB and the EU to bail out troubled governments; or whether, conversely, the maximum threshold that countries had for both their budget deficit and their level of public indebtedness (resulting in broad improvements in budgetary balances) and the possibility that markets did not regard the "no-bail-out" clause as credible, especially in the case of large markets (i.e. that the theory "too big to fail" holds), had resulted in a decrease in perceived credit risk.

The pre-EMU literature speculated that with the elimination of currency risk, yield spreads would narrow and would primarily reflect default risk. Conversely, market participants and member state debt managers appeared to believe that EMU yield differentials would be due mostly to liquidity factors. Therefore, in order to reduce borrowing costs, debt managers introduced substantial innovations that were expected to enhance the liquidity of their bonds.

Actually, the main effects of the introduction of the euro in government bond markets were, on the one hand, an increase in the degree of substitutability among securities issued by different treasuries and higher levels of competition between issuers to attract investors, which led to a certain reorganization of the market structure[2], and on the other, a gain in the importance of credit risk and market liquidity in yield differentials. Before Monetary Union differences in these factors were perhaps not completely priced due to market segmentation.

Therefore, the introduction of the euro reduced segmentation among euro-area government bond markets. The removal of the exchange rate risk brought down an important barrier that had fostered captive domestic markets and had gone some way to explaining the home bias that existed in cross-border investments in the European Union. Adjaouté *et al*. (2000) traced the extent of the home bias, in both the bond and equities markets, for the major European countries -- the UK, France, Germany, Spain, the Netherlands, and Italy -- during the period 1980-1999[3]. The increased substitutability of sovereign securities after EMU intensified the rivalry between sovereign issuers to attract investors, since they were competing directly for the same pool of funding. Nevertheless, as it has been mentioned, ten years after the

[2] Blanco (2001) reports that on the side of the issuers, some significant changes were observed such as the harmonisation of market conventions in the computation of yields, the introduction of a single trading calendar and pre-announced auction calendars, or the increase in issue sizes. In some countries, the creation of large issues was facilitated by the introduction of programmes of exchange of old illiquid bonds for new bonds and by the concentration of issuance activity in a smaller number of benchmark securities. With the aim of attracting more investors, some of the smaller issuers such as Austria, Belgium, the Netherlands and Portugal resorted to syndication procedures. Others such as the French Treasury introduced new instruments such as constant maturity and inflation-indexed bonds.

[3] They report that the United Kingdom held the highest share of foreign assets as a function of total financial wealth (24%); Spain had the smallest (5%), and the Netherlands, Germany and Italy had shares around 17%. Moreover, as expected, for bills and bonds, the level of diversification was substantial only for banks in the UK, France and the Netherlands, i.e. the countries where intermediaries played an important role as market-makers in the eurobond markets. These results are consistent with Tesar and Werner (1995), who present evidence on long-term international investment patterns in Canada, Germany, Japan, the UK, and the US during the 1970-1990 period. At the beginning of the 1990s, the UK led this sample in international portfolio diversification, with foreign security holdings of 32% (compared with 10% in Germany).

introduction of the euro, segmentation did not disappear completely within the EMU, since public debt management is still decentralized under the responsibility of 12 sovereign issuers.

In this scenario, the objective of this paper is to examine the impact of Monetary Integration on portfolio diversification opportunities in European public debt markets, which has important implications for investors, in terms of diversification benefits in a context of a single currency. Several broad categories of possible portfolio allocation should be considered, domestic versus non-domestic investment, debt versus equity investment, and public debt versus private debt investment, among them. Adjaouté and Danthine (2004) analyze diversification opportunities in euro area equity investments. We will focus our analysis to public domestic debt versus public non-domestic debt investment in the European Union-15, though.

With this goal in mind, we apply time series techniques in order to detect the existence of common trends in daily 10 year sovereign yields for EU-15 countries (both EMU and non-EMU participating) during the period 1994-2008 by means of using multivariate cointegration techniques. Our aim is to assess whether, after the introduction of the euro, investors can still benefit from portfolio diversification, not only in the three countries that did not join the EMU in 1999, but also within the euro area. It is worth to note that the essence of cointegration is that the series cannot diverge arbitrarily far from each other, implying that there exists a long-term relationship between these series and that they can be written in an error correction form. By definition, cointegrated markets thus exhibit common stochastic trends. This, in turn, limits the amount of independent variation between these markets. Hence, from the investors' standpoint, markets that are cointegrated will present limited diversification opportunities[4].

To the best of our knowledge, this is the first empirical analysis that studies government yields co-movements within the EU-15, during this long period of time, with the perspective of investor's portfolio allocation. The rest of the paper is organized as follows. Section 2 summarizes the related literature on this topic. The empirical analysis is explained in Section 3 and Section 4 draws the main conclusions.

[4] The requirement for assets that are integrated in an economic sense to share common stochastic factors is an alternative definition of cointegration, as it is pointed out in Chen and Knez (1995).

2. Related Literature

Compared to the large body of literature on international equity market linkages (see Bessler and Yang, 2003 among others) there are few empirical studies on international bond market co-movements. Nevertheless, not only the market capitalization of international bond markets is much larger than that of international equity markets, but also the extent of international bond market linkages does merit investigation as it may have important implications for the possibility of bond portfolio diversification[5].

Conversely, more has been written, on the one hand, on emerging countries, where a very important question in the study of yield co-movements is the analysis of the relative influence of fundamental variables on their behaviour (see Cifarelli and Paladino, 2006), and on the other, on volatility spillovers in international bond markets (see Cappiello *et al.*, 2003; Christiansen, 2003, or Skintzi and Refenes, 2006 among others).

Scarce literature has investigated the co-movements in Government bond markets in the European context. This literature includes: Geyer, Kossmeier and Pischler (2004), Gómez-Puig (2009a and 2009b) or Pagano and von Thadden (2004). Geyer *et al.* (2004) estimate a multi-issuer state-space version of the Cox-Ingersoll-Ross (1985) model of the evolution of bond-yield spreads (over Germany) for four EMU countries (Austria, Belgium, Italy and Spain). Their main findings are (i) one single ("global") factor explains a large part of the movement of all four processes, (ii) idiosyncratic country factors have almost no explanatory power, and (iii) the variation in the single global factor can to a limited extent be explained by EMU corporate-bond risk, but by nothing else. The most striking finding by Geyer *et al.* (2004) is the virtual absence of country-specific yield-spread risk. Pagano and von Thadden (2004), despite the considerable differences in the methodology and data used, also agree that yield differentials under EMU are driven mainly by a common risk (default) factor and suggest that liquidity differences have at best a minor role in the time-series behavior of yield spreads.

Gómez-Puig (2009a and 2009b) estimates panel regressions for two groups of EU-15 countries (EMU and non-EMU) including both domestic (differences in market liquidity and credit risk) and international risk factors. Her results present evidence that it is

[5] The study of international bond markets linkages is also important because it has implications for cost of financing fiscal deficit, monetary policymaking independence, and modelling and forecasting long-term interest rates.

domestic rather than international risk factors that mostly drive the evolution of 10-year yield spread differentials over Germany in all EMU countries during the seven years after the beginning of Monetary Integration. Conversely, in the case of non-EMU countries, adjusted yield spreads are influenced more by world risk factors. The fact that these countries do not share a common Monetary Policy might explain these results, which may show that government bonds from EMU countries have a better safe-haven status compared to non-EMU countries.

These results are sound with the empirical evidence presented by other authors as Cappiello, Hördahl, Kadareja, and Manganelli (2006), who using a completely different methodology investigate whether the introduction of the euro had an impact on the degree of integration of European financial markets. Controlling for the impact of global factors, they document an overall increase in co-movements in euro area financial markets, especially in bond markets, suggesting that integration in the euro-area has progressed since the introduction of the single currency. Finally, there are a number of papers that study financial integration exploiting the implications of asset pricing models. The work by Barr and Priestley (2004) and Hardouvelis *et al*. (2006 and 2007) and Abad, Chuliá and Gómez-Puig (2009) are in this vein. Concretely, Abad et *al.* (2009) adopt the CAPM-based model of Bekaert and Harvey (1995) to compare the differences in the relative importance of two sources of systemic risk (world and Eurozone risk) on Government bond returns, in two groups of countries (EMU and non-EMU) in EU-15. Their results present evidence that euro markets are only partially integrated with the German market.

The aim and methodology used in this paper completely differs from the abovementioned literature, though. In particular, ten years after the introduction of the euro, we examine government's yield co-movements but with the objective of analyzing whether the single currency has cancelled out or still allows the benefits from portfolio diversification in EU-15 public debt markets (both EMU and non-EMU participating) by means of using multivariate time series techniques.

Cointegration techniques have been widely used by the literature to examine co-movements and linkages in international bond markets. Ilmanen (1995) examined the effect of integration of six markets (the US, the UK, Canada France, Germany and Japan) using long-maturity government bonds. He found strong evidence of integration across mature bond markets. On the other hand, Clare, Maras and Thomas (1995) using the daily yield of mature market bonds (the US, UK, West Germany and Japan) found no cointegrating relationship between these markets. Their study focused on bonds with less than 5 year maturity to test market integration through a multivariate cointegration framework. Similarly, Mills and Mills (1991) investigating four major bond markets find no integration. Arshanapalli and Doukas (1994) investigated the temporal relationship between Eurodeposit instruments of five different maturities for different currencies and found several cointegrating factors binding them together for the period between 1986 and 1992. Their multivariate cointegration test for dependency on five maturity sets of seven dimensional system reveals that the cointegrating structure is stronger at the short end rather than at the long end of the maturity spectrum. Kim, Lucey and Wu (2006) examine the time varying level of financial integration of European markets using government bond indices of European economies (Czech Republic, Hungary, Poland, Belgium, France, Ireland, Netherlands, the UK and Germany) in the region. Their test was to see how the Euro zone markets were integrated with Germany. They found strong evidence of linkages between Euro zone markets and Germany. However, a cointegration analysis that studies the nature of financial market integration in EU-15 Government's bond market with the final goal to study risk diversification opportunities is yet to be explored.

3. Empirical Analysis

3.1. A First look at the data

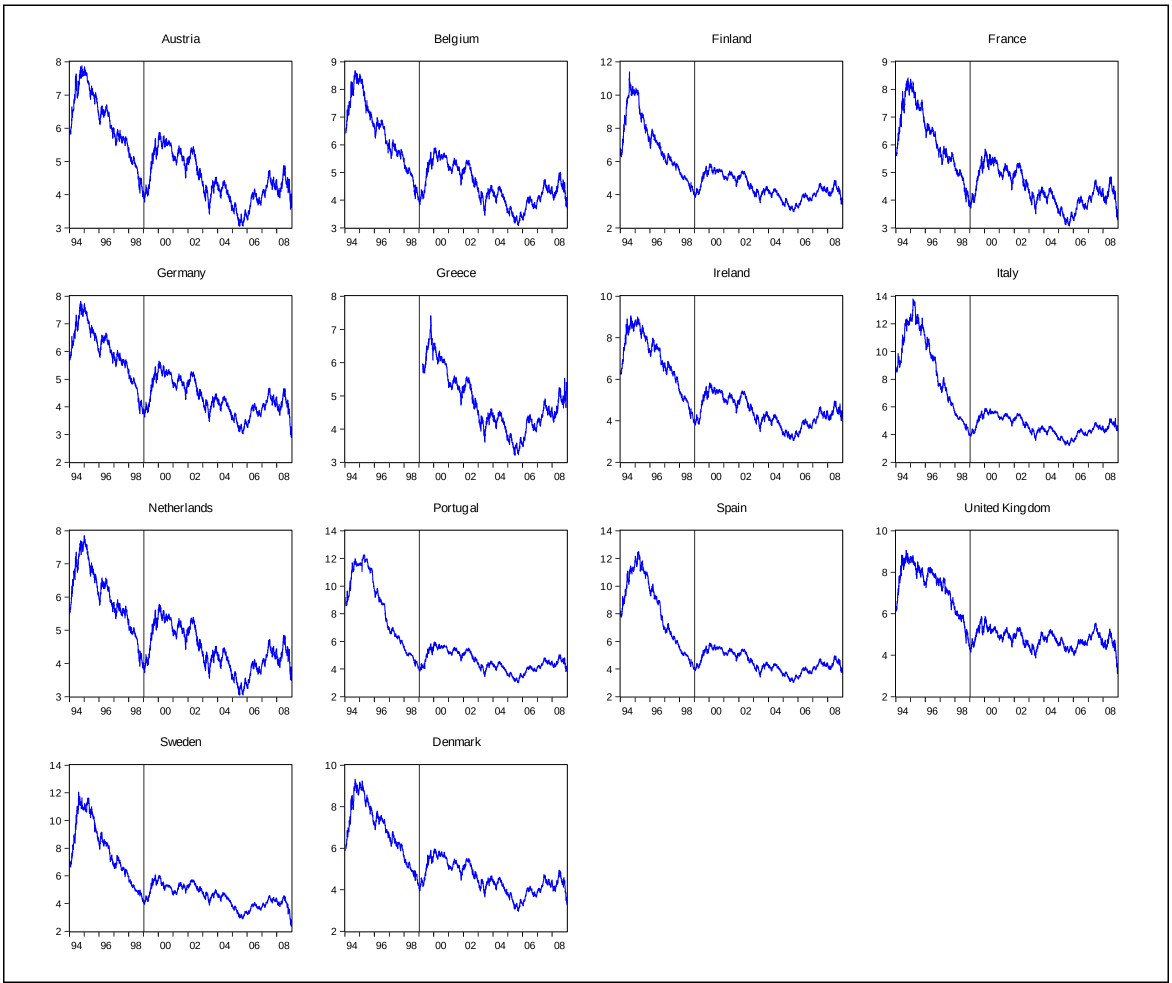
The sample is composed of daily 10-year government yields and includes all EU-15 countries with the exception of Luxembourg (its public debt market is negligible)[6]. Data have been obtained from Datastream and correspond to the "on the run" (benchmark) 10-year issue for each market at every moment of time (they are quoted rates at market close)[7] and span the period January 1994 to the end of December 2008. So, we include daily information that covers five years before the beginning of Currency Union and ten years after the introduction of the euro. Figure 1 shows the temporal evolution of each of the individual yields. It is important to note that the sample period (1994-2008) is split into two subperiods, namely 1994-1998 and 1999-2008, in order to take into account the introduction of a single currency in January 1999.

[6] Since Greece did not join the Monetary Union until January 2001, we first present the results excluding this market from the analysis. Subsequently, the results including Greece are reported.

[7] Datastream creates continuous yield series by taking the yield from the current benchmark in each market and using it to update a separate time series. As a benchmark changes, data are taken from a new stock on the first day of the month.

As mentioned, the removal of foreign exchange risk in January 1999 and the elimination (or reduction to insignificant levels) of differences in tax treatment during the 1990s eliminated two important factors that used to drive yield differentials between European sovereign borrowers, and paved the way for a much more integrated and competitive public debt market[8]. The aforementioned elimination of two of the main components of yield differentials prompted a substantial convergence in EMU 10-year yields during the period January 1999-December 2008. This is clearly reflected in Figure 1. Moreover, non-EMU countries yields, also displayed an important decrease and begun to convergence with euro yields after the introduction of the common currency. In particular, Figure 1 shows that the country with the highest spread over Germany is the United Kingdom, while the country whose government's yields follow those of Germany most closely is Denmark.

Figure 1: 10 Year Governments' Yields



[8] The main factors that drive yield differentials after the introduction of the euro are differences in credit risk and differences in market liquidity.

To obtain a first approximation of the extent of linkages among Government's yields, Table 1 reports the contemporaneous correlation coefficients of all 10 year yields for the whole sample and for each of the two subperiods. A first result from these correlations is the high degree of interdependence among all the Government bond markets along the whole time period. However, the degree of correlation among the UK yields and the rest of European yields appear to be lower, especially for the second subperiod.

Table 1: Contemporaneous Correlation Coefficients (10-Year Governments' Yields)

First period. 01/03/1994 – 12/31/1998

	AT	BE	FI	FR	GR	IE	IT	NL	PT	SP	UK	SW	DK
GE	0.99	0.98	0.95	0.98	--	0.98	0.93	0.99	0.93	0.94	0.97	0.95	0.98
AT		0.99	0.97	0.99	--	0.99	0.95	0.99	0.96	0.96	0.95	0.97	0.99
BE			0.98	0.98	--	0.97	0.94	0.99	0.95	0.95	0.92	0.97	0.97
FI				0.97	--	0.95	0.93	0.97	0.95	0.94	0.90	0.98	0.97
FR						0.98	0.97	0.99	0.97	0.97	0.93	0.98	0.99
IE							0.96	0.98	0.96	0.97	0.97	0.97	0.99
IT								0.94	0.99	0.99	0.90	0.97	0.96
NL									0.94	0.95	0.96	0.97	0.98
PT										0.99	0.89	0.97	0.96
SP											0.91	0.98	0.97
UK												0.92	0.96
SW													0.99

Second period. 01/01/1999 – 12/31/2008

	AT	BE	FI	FR	GR	IE	IT	NL	PT	SP	UK	SW	DK
GE	0.99	0.98	0.99	0.99	0.87	0.96	0.96	0.99	0.98	0.98	0.82	0.94	0.99
AT		0.99	0.99	0.99	0.91	0.99	0.99	0.99	0.99	0.99	0.77	0.91	0.99
BE			0.99	0.99	0.92	0.99	0.99	0.99	0.99	0.99	0.76	0.90	0.99
FI				0.99	0.91	0.99	0.98	0.99	0.99	0.99	0.78	0.92	0.99
FR					0.90	0.98	0.98	0.99	0.99	0.99	0.80	0.92	0.99
GR						0.92	0.91	0.90	0.92	0.92	0.69	0.81	0.92
IE							0.99	0.99	0.99	0.99	0.72	0.88	0.98
IT								0.99	0.99	0.99	0.73	0.87	0.97
NL									0.99	0.99	0.79	0.92	0.99
PT										0.99	0.76	0.89	0.98
SP											0.76	0.90	0.99
UK												0.76	0.78
SW													0.94

Whole sample. 01/03/1994 – 12/31/2008													
	AT	**BE**	**FI**	**FR**	**GR**	**IE**	**IT**	**NL**	**PT**	**SP**	**UK**	**SW**	**DK**
GE	0.99	0.99	0.97	0.99	--	0.98	0.94	0.99	0.95	0.95	0.94	0.96	0.99
AT		0.99	0.97	0.99	--	0.98	0.94	0.99	0.95	0.95	0.92	0.96	0.99
BE			0.99	0.99	--	0.99	0.95	0.99	0.96	0.96	0.93	0.96	0.99
FI				0.98	--	0.98	0.96	0.97	0.98	0.98	0.93	0.98	0.98
FR						0.99	0.96	0.99	0.97	0.97	0.93	0.97	0.99
IE							0.97	0.98	0.97	0.98	0.96	0.97	0.99
IT								0.93	0.99	0.99	0.94	0.98	0.96
NL									0.94	0.95	0.92	0.96	0.99
PT										0.99	0.94	0.98	0.97
SP											0.94	0.98	0.97
UK												0.95	0.95
SW													0.98

3.2. Unit Root Tests

Regression results are likely to be spurious if the variables concerned are not stationary. To determine the integration order of each of the variables, we carry out Augmented Dickey-Fuller (ADF)[9] unit root tests in order to check the integration order of each of the Government's yields[10]. That is, we test the null hypothesis Π=0 based on next equation,

$$\Delta y_t = \alpha_0 + \alpha_1 t + \gamma y_{t-1} + \sum_{j=1}^{k} \theta \Delta y_{t-j} + \varepsilon_t \qquad (1)$$

where y is the Government 10-year yields and k is the number of lagged differences included to capture any autocorrelation. Three ADF unit root tests are carried out (i) with no regressors (Π_0=Π_1=0), (ii) with a constant (Π_1=0) and (iii) with a constant and a linear time trend (see Table 2). The results from the ADF tests are tabulated for the first period (panel 1), second period (panel 2) and the whole period (panel 3). Overall, the findings provide strong evidence in favor of the null hypothesis of unit root for all the interest rates. Furthermore, when ADF unit roots are carried out to the first differences of 10 year yields, we reject the unit root null hypothesis in all the cases, suggesting that 10 year yields follow I(1) processes.

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[9] Alternative approaches to test for unit roots are Phillips and Perron (1988), Kwiatkowski *et al*. (1992) and recently Ng and Perron (2001). The results for those tests are available upon request.

[10] See Dickey and Fuller (1979).

Table 2: ADF Unit Root Tests

Testing the integration order of government yields			
	No regressors	With an intercept	With an intercept and a linear time trend
First period. 01/03/1994- 12/31/1998			
Germany	-0.95	0.41	-3.30*
Austria	-1.03	0.55	-3.51**
Belgium	-1.09	0.50	-4.02**
Finland	-0.91	0.13	-3.58**
France	-0.80	0.25	-3.80**
Greece	--	--	--
Ireland	-1.03	0.78	-3.54**
Italy	-1.12	0.56	-2.95
Netherlands	-0.85	0.26	-3.67**
Portugal	-1.58	1.01	-3.02
Spain	-1.17	0.66	-3.30*
United Kingdom	-0.68	0.29	-3.40*
Sweden	-0.81	0.22	-3.78**
Denmark	-0.77	0.18	-3.48**
Second period. 01/01/1999- 12/31/2008			
Germany	-0.59	-1.12	-2.52
Austria	-0.39	-1.46	-2.50
Belgium	-0.35	-1.42	-2.43
Finland	-0.46	-1.35	-2.50
France	-0.46	-1.51	-2.72
Greece	-0.62	-1.55	-0.89
Ireland	-0.14	-1.64	-2.27
Italy	-0.10	-1.79	-2.47
Netherlands	-0.41	-1.46	-2.59
Portugal	-0.28	-1.57	-2.44
Spain	-0.31	-1.47	-2.49
United Kingdom	-0.66	-1.54	-2.37
Sweden	-0.80	-0.51	-2.49
Denmark	-0.59	-1.18	-2.54
Whole sample. 01/03/1994- 12/31/2008			
Germany	-1.14	-0.77	-2.46
Austria	-1.03	-1.04	-2.29
Belgium	-1.14	-1.03	-1.97
Finland	-1.17	-0.93	-1.78
France	-0.95	-0.92	-2.43
Greece	--	--	--
Ireland	-1.00	-1.00	-1.64
Italy	-1.38	-1.01	-1.03
Netherlands	-0.93	-1.05	-2.53
Portugal	-1.93*	-1.16	-0.85
Spain	-1.40	-0.92	-1.22
United Kingdom	-1.00	-0.55	-2.49
Sweden	-1.26	-0.36	-1.92
Denmark	-1.04	-0.76	-2.37

Note: * and ** mean that we can reject the null hypothesis of unit root at the 10 and 5% significance level.

3.3. Multiple Cointegration

In a next step, we test for multiple cointegration using the Johansen and Juselius (1990) multivariate cointegration technique, that is, we tests whether or not the yields share a common stochastic trend.

In the literature, two primary methods exist to examine the degree of cointegration time series. The first is the Engle–Granger methodology (see Engle and Granger, 1987) which is bivariate, testing for cointegration between pairs of indices. The second is the Johansen–Juselius technique (see Johansen, 1988 and Johansen and Juselius, 1990), which is a multivariate extension and allows for more than one cointegrating vector or common stochastic trend to be present in the data. Although bivariate cointegration procedures capture the dynamics between series, the under dimensionality associated with this testing process introduces bias in the identification and attribution of the common factor. In addition, cointegration is multivariate by nature and the equilibrium dynamics and the common features in the series are best understood when they are analyzed in a multivariate setting (see Hendry and Juselius, 2001). This is the reason why we will use the Johansen-Juselius technique in this study. The main advantage of it this approach is that it allows testing for the number as well as the existence of these common stochastic trends.

As mentioned, cointegration is based on the idea that while a set of variables are individually I(1) nonstationary, a linear combination of these variables might be stationary. While the variables are individually unbounded, the existence of a stationary combination implies that the variables cannot drift arbitrarily far apart. Intuitively, it is the long-run equilibrium relationship that links the cointegrated variables together. We start by considering a vector autoregression of order p:

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + ... + A_p y_{t-p} + Bx_t + \varepsilon_t \qquad (2)$$

where y_t is a k-vector of non-stationary I(1) variables, x_t is a vector of deterministic variables and ε_t a vector of innovations. The above equation can be rewritten as

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-1} + Bx_t + \varepsilon_t \qquad (3)$$

where

$$\Pi = \sum_{i=1}^{p} A_i - I \qquad (4)$$

and

$$\Gamma_i = -\sum_{j=i+1}^{p} A_j \qquad (5)$$

The number of cointegrating relationships is indicated by the rank of Π. If Π has reduced rank (r<k), then there are k-r=n common stochastic trends. There are three possible scenarios depending on the rank of Π. First, if Π is of full rank (r=k), then all elements of y_t are stationary, which implies that the cointegration technique is inappropriate. Second, if the rank of Π equals zero, there are no combinations which are stationary, and, thus, there are no cointegrating vectors. Finally, if the rank of Π is r (0<r<k), then the y_t variables are cointegrated and there exist r cointegrating vectors. In this case, and if the number of common trends is exactly one (n=k-r=1), we conclude that the interest rates are integrated completely and perfectly, since they are driven by the same common stochastic trend. If the number of common stochastic trends is more than one, we conclude that interest rates present certain degree of interdependence, although not complete convergence.

In essence, the Johansen-Juselius approach involves the determination of the rank of a matrix of cointegrating vectors. This technique generates two statistics of primary interest. The first is the λtrace statistic, which (in this instance) is a test of the general question of whether there exist one or more cointegrating vectors. The second is the λmax statistic (maximum eigenvalue), which allows testing of the precise number of cointegrating vectors.

Thus, the output from the approach we employ is two-fold: first, the largest value of the λtrace statistic which tests the general hypothesis of no cointegration versus cointegration, and second, the number of cointegrating vectors given by the λmax or maximum eigenvalue statistic.

The trace statistic for the null hypothesis of r cointegrating vectors is defined as

$$LR_{TR}(r|k) = -T \sum_{i=r+1}^{k} \log(1-\lambda_i) \qquad (6)$$

Where Π_i is the ith largest eigenvalue of Π, r is the number of cointegrating relationships and T is the number of observations. The maximum eigenvalue statistic for the null hypothesis of r cointegrating vectors is expressed as

$$LR_{\max}(r|r+1) = -T\log(1-\lambda_{r+1}) \qquad (7)$$

The results for the multiple cointegration tests are reported in Tables 3.1-3.2 for the whole sample of countries and Tables 4.1 and 4.2 for the EMU countries[11]. As in the previous analysis, cointegration tests have been carried out for the whole period and each of the two subperiods.

Table 3.1: Johansen's Multiple Cointegration Tests

Rank	Eigenvalue	Trace statistic	Max-eigenvalue statistic
First period. 01/03/1994 – 12/31/1998			
0	0.079	529.91	107.55
At most 1	0.064	422.36**	85.81**
At most 2	0.054	336.55**	72.22**
At most 3	0.045	264.34**	59.41
At most 4	0.032	204.93*	42.60
At most 5	0.028	162.33	37.58
At most 6	0.025	124.75	33.60
At most 7	0.022	91.15	29.00
At most 8	0.017	62.15	21.81
At most 9	0.014	40.35	18.64
At most 10	0.010	21.71	13.73
At most 11	0.004	7.98	5.07
At most 12	0.002	2.91	2.91
Second period. 01/01/1999 – 12/31/2008			
0	0.122	1100.656	340.09
At most 1	0.071	760.57**	191.90**
At most 2	0.049	568.67**	131.11**
At most 3	0.044	437.56**	116.76**
At most 4	0.033	320.80**	86.43**
At most 5	0.024	234.37**	63.30**
At most 6	0.019	171.07**	51.00**
At most 7	0.015	120.07**	39.91*
At most 8	0.013	80.16**	35.39**
At most 9	0.009	44.77	24.12
At most 10	0.006	20.66	15.36
At most 11	0.002	5.30	4.00
At most 12	0.001	1.30	1.30
Whole sample. 01/03/1994 – 12/31/2008			
0	0.049	911.15	195.70
At most 1	0.040	715.45**	160.40**
At most 2	0.032	555.05**	128.03**
At most 3	0.031	427.02**	121.38**
At most 4	0.020	305.64**	80.12**
At most 5	0.016	255.52**	61.19**
At most 6	0.014	164.33**	53.97**
At most 7	0.011	110.36**	43.28**
At most 8	0.008	67.08	32.82*
At most 9	0.004	34.26	17.40
At most 10	0.002	16.86	7.49
At most 11	0.002	9.36	7.10
At most 12	0.001	2.27	2.27

Note: * and ** denote that we can reject the null hypothesis of r cointegrating vectors at the 10 and 5% significance level.

[11] Tables 3.1 and 4.1 do not include Greece in the analysis, whilst the results of the estimates including this country are reported in Tables 3.2 and 4.2.

Table 3.2: Johansen's Multiple Cointegration Tests (Including Greece)

Rank	Eigenvalue	Trace Statistic	Max-Eigenvalue Statistic
Second period. 01/01/1999 – 12/31/2008			
0	0.123	1155.22**	333.49**
At most 1	0.067	821.72**	177.66**
At most 2	0.059	644.07**	153.37**
At most 3	0.047	490.70**	123.16**
At most 4	0.034	367.54**	88.39**
At most 5	0.027	279.15**	65.51**
At most 6	0.022	210.64**	55.37**
At most 7	0.017	155.27**	43.24
At most 8	0.015	112.03**	39.37*
At most 9	0.012	72.66	29.75
At most 10	0.008	42.91	21.27
At most 11	0.006	21.64	14.27
At most 12	0.002	7.36	5.79
At most 13	0.001	1.57	1.57

Note: * and ** denote that we can reject the null hypothesis of r cointegrating vectors at the 10 and 5% significance level.

The results presented in these tables may be summarized as follows. First, the number of cointegrating vectors for the first subperiod is lower (9 or 8 depending on whether we use the trace or maximum eigenvalue statistic) than in the second subperiod, which implies that the degree of cointegration or interdependence among long term interest rates is lower in the period before 1999. Second, the number of cointegrating vectors in the first subperiod is the same when analyzing only EMU countries (Table 4.1) and all European countries (Table 3.1), which suggest that the degree of interdependence found among interest rates is limited to EMU countries, while interest rates of non-EMU countries do not share any common trend with the rest of interest rates. Third, the removal of the exchange risk in 1999 increased the number of cointegrating vectors (and the interdependence) among not only EMU countries, but among non-EMU countries as well.

Table 4.1: Johansen's Multiple Cointegration Tests (EMU Countries)

Rank	Eigenvalue	Trace statistic	Max-eigenvalue statistic
First period. 01/03/1994 – 12/31/1998			
0	0.010	426.25**	136.86**
At most 1	0.062	289.39**	82.82**
At most 2	0.047	206.58**	62.35**
At most 3	0.033	144.23**	43.72
At most 4	0.023	100.51	30.66
At most 5	0.019	69.85	25.04
At most 6	0.016	44.81	21.24
At most 7	0.013	23.57	17.04
At most 8	0.004	6.53	4.94
At most 9	0.001	1.60	1.60
Second period. 01/01/1999 – 12/31/2008			
0	0.113	860.92**	313.41**
At most 1	0.065	547.51**	174.76**
At most 2	0.040	372.75**	106.21**
At most 3	0.031	266.54**	81.15**
At most 4	0.026	185.39**	67.46**
At most 5	0.017	117.93**	45.88**
At most 6	0.014	72.05**	36.52**
At most 7	0.009	35.53	23.68
At most 8	0.004	11.85	9.66
At most 9	0.001	2.19	2.19

Whole sample. 01/03/1994 – 12/31/2008			
0	0.052	755.93**	210.05**
At most 1	0.045	545.87**	179.79**
At most 2	0.030	366.09**	119.66**
At most 3	0.021	246.43**	82.39**
At most 4	0.019	164.04**	74.77**
At most 5	0.013	89.27**	51.29**
At most 6	0.005	37.98	19.43
At most 7	0.003	18.55	11.52
At most 8	0.001	7.03	4.33
At most 9	0.001	2.70	2.70

Note: * and ** denote that we can reject the null hypothesis of r cointegrating vectors at the 10 and 5% significance level.

Table 4.2: Johansen's Multiple Cointegration Tests (EMU Countries, Including Greece)

Rank	Eigenvalue	Trace statistic	Max-eigenvalue statistic
Second period. 01/01/1999 – 12/31/2008			
0	0.115	890.57**	311.47**
At most 1	0.062	579.10**	162.09**
At most 2	0.046	417.02**	118.81**
At most 3	0.032	298.21**	82.24**
At most 4	0.026	215.96**	67.62**
At most 5	0.019	148.35**	48.61**
At most 6	0.015	99.74**	37.48**
At most 7	0.011	62.26**	29.00**
At most 8	0.009	33.26*	21.73*
At most 9	0.003	11.53	8.27
At most 10	0.001	3.26	3.26

Note: * and ** denote that we can reject the null hypothesis of r cointegrating vectors at the 10 and 5% significance level.

4. Concluding Remarks

The objective of this paper is to examine the impact of Monetary Integration on portfolio diversification opportunities in European public debt markets. So, we analyze for the first time, the convergence process of EU-15 countries by means of using time-series tests over the period 1994-2008. So, we study whether there are differences in risk diversification opportunities during the five years preceding the introduction of the euro and the ten years after its implementation. In particular, we examine a multivariate framework, using Johansen and Joselius (1988) cointegration test. The results suggest the following.

First, multiple cointegration tests rejects the existence of a unique common trend among the 14 yields that have been analyzed, suggesting the possibility of risk diversification across Europe. Furthermore, when this analysis is carried out only for EMU countries, we also find the existence of more than one common trend for these countries.

However, it is worth to note that there exist differences between EMU and non-EMU countries and between the two periods that have been analyzed. Interdependence is significantly lower during the period that includes the five years before the introduction of the common currency than during the ten years after the euro. Before EMU, there were high opportunities of portfolio diversification, specially, among the countries that did not join the euro in 1999. Actually, during the period 1994-1998, the UK, Denmark and Sweden do not share a common trend with the rest of EU-15 countries. This result is highly reasonable since the countries that stayed out of the euro did not have to fulfill the convergence criteria in long-term interest rates[12].

Nevertheless, the removal of the exchange risk in 1999 increased the number of cointegrating vectors (and the interdependence) not only among EMU countries, but among non-EMU countries as well (meaning that currency union has prompted a convergence of long term interest rates in all EU-15 countries). So, portfolio diversification opportunities have experienced a reduction with the single currency but

[12] In particular, the Treaty stipulated: "the durability of convergence achieved by the Member State ... being reflected in the long-term interest-rate levels". In practice, the nominal long-term interest rate must not exceed by more than 2 percentage points that of, at most, the three best-performing Member States in terms of price stability (that is to say, the same Member States as those in the case of the price stability criterion). The period taken into consideration is the year preceding the examination of the situation in the concerned Member State.

multiple cointegration tests still rejects the existence of a unique common trend among the 14 yields that have been analyzed, which suggests that diversification benefits have not disappeared with EMU.

So, we can conclude that, even though the countries that do not participate in the common currency present higher benefits from diversification, EMU has not eliminated portfolio diversification opportunities in public debt markets' investments. These results are not only sound with the empirical evidence presented by Adjaouté and Danthine (2004) who examine diversification opportunities in euro area equity markets during the period 1999-2001[13], but also with the results presented by Laopodis (2008) and Abad, Chuliá and Gómez-Puig (2009) who study the degree of integration among the EMU bond markets since the beginning of the Currency Union and present evidence that euro markets are only partially integrated with the German market. These findings have important implications for investors in terms of portfolio diversification benefits. Indeed, the removal of the exchange rate barrier fostered convergence in EMU public debt markets (which has been extended to all EU-15), but these markets are not perfectly integrated though. The fact that public debt management is still decentralized under the responsibility of 12 Sovereign issuers (with differences in rating and a variety of issuing techniques) and that there still exists differences in their domestic risk premium (liquidity and default risk)[14] explains their imperfect integration.

To sum up, the results of our cointegration analysis provide evidence that since EU-15 government debt markets are not perfectly integrated, investors should be able to reduce their portfolio-variance-risk without sacrificing expected return by international diversification (Solnik, 1974), consequently benefits from diversification are still possible within EMU public debt markets.

[13] Concretely, their results clearly invalidate the hypothesis that diversification opportunities in the euro-area have been permanently impaired as a consequence of the process of economic and monetary integration. Conversely, they strongly confirm the superiority of a model where diversification is sought after simultaneously across country and sector dimensions over the traditional country allocation model.

[14] See Gómez-Puig (2006 and 2008).

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