

# Spillover effects on government bond yields in euro zone. Does full financial integration exist in European government bond markets?

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**Abstract** This paper examines the time varying nature of European government bond market integration by employing multivariate GARCH models. We state that unlike other bond markets, in euro markets the default(credit) risk factor and other macroeconomic and fiscal indicators are not able to explain the sovereign bond yields after the beginning of monetary union. This fact might be counted as a signal for perfect financial integration. However, we also find that the global shocks affect Germany and the rest of euro bond markets in various levels, creating particular discrepancies in asset prices even we take into account the market specific factors. Different level responses of each euro market to the global shocks reveal that euro bond markets are not fully integrated with each other unlike the recent literature claimed. Besides, we explore that the global factors are effective for the volatility of yield differentials among euro government bonds.

**Keywords** Financial Integration · Multivariate GARCH Models · Euro Bond Markets · Spillover Effects · Asset Pricing

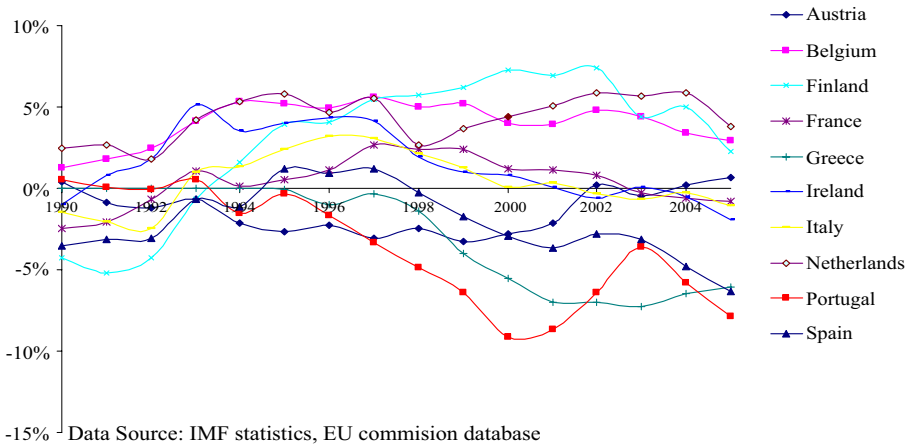
**JEL Classification** F15 · G12

## 1 Introduction

Recently, international portfolio holders began to focus on other factors instead of standard factors-default (credit) risk, exchange rate risk, or liquidity premium risk factors-when they were holding euro denominated government

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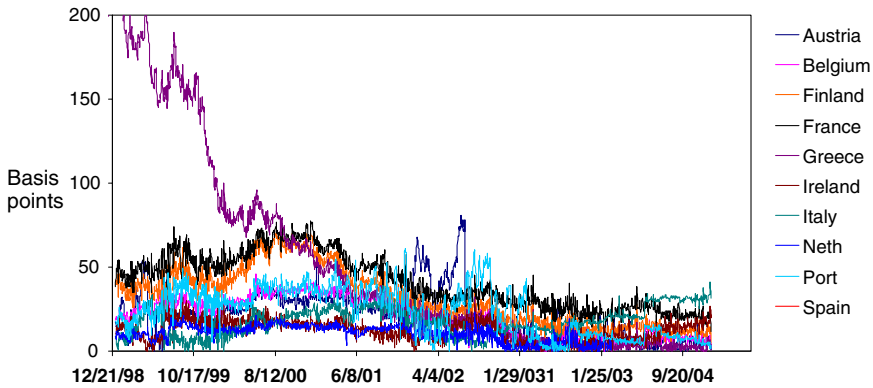
**Fig. 1** Current account to GDP ratio of EMU members

bonds. The main reason behind the change in investors' decision is the recent adjustments in the formation of euro bond markets. Why does remarkable change take place in European markets while we can not observe such a change in the rest of the Organisation for Economic Co-operation and Development (OECD) bond markets? The fundamentally transformed structure of the European bond markets has been triggered by the Maastricht treaty. In the content of the treaty, the prospective monetary union [European monetary union (EMU)] member aimed to satisfy certain fiscal and macroeconomic standards to converge upon each other economically and financially by the beginning of the currency union. To quickly summarize the criteria, the members should have public debt levels below the Maastricht ceiling of 60% of their gross domestic product (GDP), plus the budget deficits of central governments should not exceed 3% of GDP. Added to these, member countries were supposed to hold annual domestic inflation rates under 2% per annum. Expectedly, the outcome of these policies were observed as more integrated financial markets since the mid 1990s in the euro region. Besides, both elimination of exchange rate risks and the significant decreases in intra-euro market frictions like trading costs, brokerage commission transaction fees, and taxes have led to a more integrated financial environment since the beginning of monetary union.

In the first point of view, accelerated financial integration among euro bond markets has been widely expected, since the macroeconomic and fiscal indicators have shown incredible improvement for the "higher risk"<sup>1</sup> euro markets, creating a potential for those members to converge with "lower risk"

<sup>1</sup>"Higher risk" members are euro members that are in relatively vulnerable fiscal positions and have higher current account deficits. When we check Fig. 1 it is clearly observed the diversity on the current account positions of EMU members. Besides, the "high risk" definition refers to either higher default risk of the euro members or poor credit rated members.

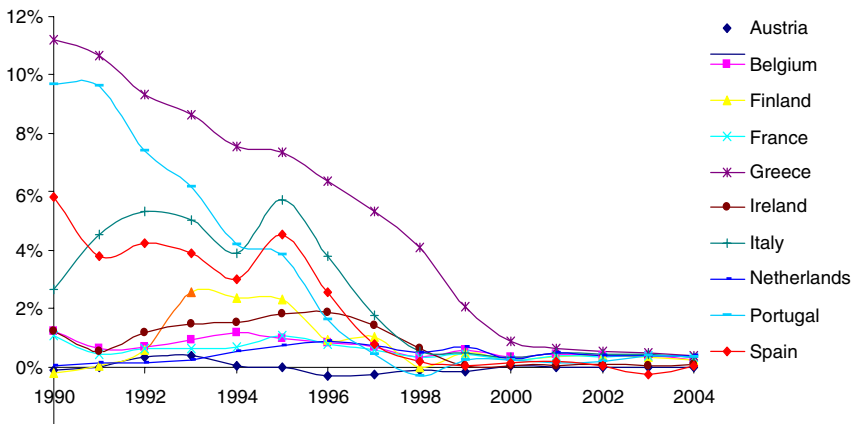
**a**



Source: DataStream\Thomson Inc.

Note: Yield differentials are computed as the difference of each Euro market benchmark bond yield over Germany benchmark bonds with daily basis

**b**



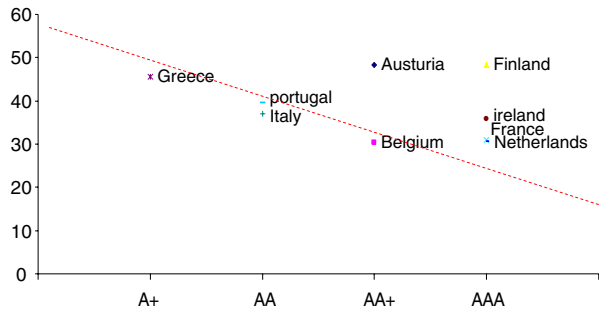
Source: DataStream/Thomson Inc. and International Financial Statistics, Author's own calculations.

Yield differentials are computed as taking the difference from each Euro benchmark bond yield from Germany bond yield in annual basis

**Fig. 2** **a** 10 year benchmark Government Bond Yield Differentials of Euro Members for January 1999–December 2004. **b** 10 year benchmark Government Bond Yield Differentials of Euro Members for years between 1990 and 2004

members in terms of bond returns. Figure 2a and b present government bond yield differentials among euro members for a time interval including the pre and post-euro era. As illustrated in the figures, there has been a considerable decline in government bond yield spreads since the second half of the last decade. It might be concluded that in the wake of monetary union, bond yield convergence has been exhibited for the countries experiencing higher

**Fig. 3** 10-years average bond yield differentials and credit risk for years 1999–2004



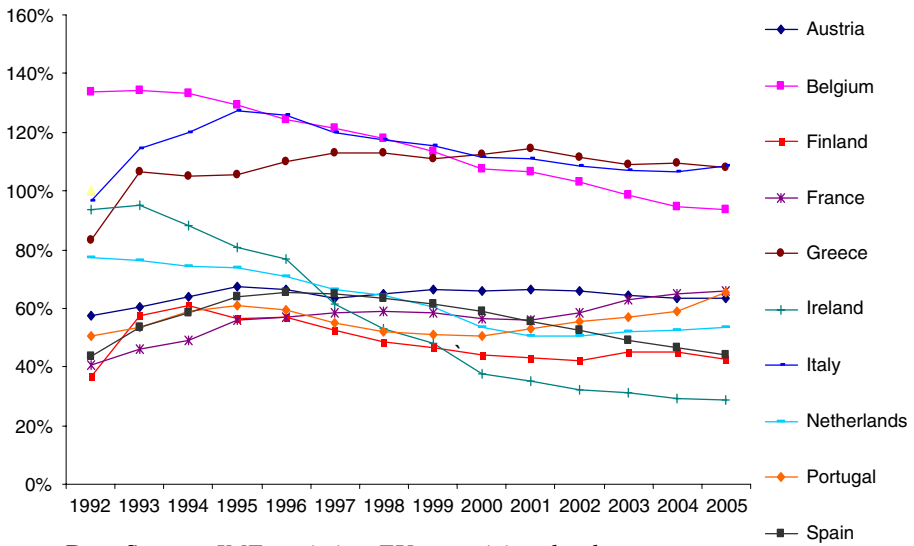
Source for yield differentials: DataStream \Thomson Inc.  
Average yield differentials are calculated in yearly basis for each bond relative to benchmark German Government Bond.

credit(default) risk premia for their sovereign debts compared to the “low risk” euro members.<sup>2</sup>

Although there has been such a convergence among euro area government bond yields, yield differentials across euro bond markets have not been wiped out completely. One possibly expect that residual spreads would definitely reflect the differences in credit standings of euro markets, since the markets are not perfectly homogenous even after the inception of monetary union. The Stability and Growth Pact and European fiscal frameworks appear insufficient to guarantee that all member states have the same creditworthiness from the market point of view, even though the Maastricht Treaty has forced the members to be in similar fiscal positions.<sup>3</sup> In that case, euro sovereign bond yields would be counted as an important indicator of market sensitivity to domestic fiscal exposure, since higher bond yields generally result from higher government debt costs or higher current account deficits that require tighter market discipline on national governments’ fiscal policies. From the portfolio holders’ point of view, it is usually expected that those bonds tend to have higher credit risk premium. In Fig. 4, it is shown that Belgium, Greece, and Italy have experienced higher debt service costs compared to other euro

<sup>2</sup>It is observed from historical data that Portugal, Spain, Italy, and Greece government bonds have higher default risk premia to attract cross border portfolio holders.

<sup>3</sup>However, an important argument used by the Stability and Growth Pact opponents is that governments were not sufficiently forced to dispose of extreme government service debt and deficits. Since the beginning of monetary union, government bond yields have not effectively shown the various degrees of default (credit) risk associated with the sovereign debt issued by euro-zone central governments. It is observed that since the beginning of the common currency, there is – surprisingly – only a modest difference in the risk premia for euro-denominated central government bond yields, despite the fact that the total debt of each country differs enormously, ranging from around 30% for Ireland to over 100% for Italy, Belgium and Greece. Remaining euro countries are gathered around the Maastricht “ceiling,” especially after 1999. Figure 3 illustrates the relationship between the average bond yield differentials for each market benchmark bond relative to the German benchmark government bond. Although we can see clear relationship between the ratings and yields, there are significant exceptions.



Data Source: IMF statistics, EU commission database

**Fig. 4** Debt to GDP ratios of EMU members

members. Similarly, Portugal, Italy and Greece have been experiencing higher current account deficits compared to the rest of the EMU members. Even though the current account deficit/surpluses and government service debt costs are very important indicators for measuring market sensitivity to the credit risk of government bond returns, and these measurement are in higher levels for those markets, the sovereign bond yields do not reflect such risk premia particularly after 1999.<sup>4</sup>

Particularly with start of the monetary union, the default risk indicators have very little power to explain the yield spreads in the region. Theoretically, higher debt service holders' borrowing tends to have higher risk premia compared to those holding lower debt service, but euro government bond yields do not have such patterns robustly. A sufficient explanation for why the default risk premium cannot be rationally observed in the euro denominated government bond yields could be that there is a widely shared belief that even if the government of any EMU member country threatened to not pay its debt, it would be bailed out by the collective EMU governments. This unspoken belief makes foreign portfolio holders consider the debt instruments of all EMU member governments as bearing the same default risk. Under this

<sup>4</sup>Similar results could be extracted from the credit ratings announced by the Standard and Poor's and MTS groups in the last five years. Fiscally vulnerable countries are expected to bear lower credit ratings, and they would have higher yield outlays, but the results are not as expected.

implicit bail-out commitment, the market will treat all instruments as being of equivalent default risk.<sup>5</sup>

### 1.1 The effect of global shocks

Concentrating on financial asset pricing models, the recent literature finds strong evidence that idiosyncratic properties of each market or disparate fiscal positions could straightforwardly explain the yield spreads of government bonds between those markets. Nevertheless, after the start of monetary union, the picture is not the same for euro bond markets. Fiscal and other sets of indicators could barely help us explain the differentials in euro bond markets. In other words, local factors are not as effective in explaining the yield spreads as in the periods before the start of euro. At this time, these findings might indicate a full financial market integration among members, since one can claim that financial asset prices no longer depend on local risk factors. The main contribution of the paper comes out at this point. While we control the specific market risk factors such as default risk, liquidity risk or maturity risk, global shocks influence the government bond yield differentials among euro markets differently and cause distortions among bond yield differentials. These findings document that for euro bond markets, global factors play more important role in explaining the bond yield differentials than the specific market risk does. The disappearance of default (credit) risk premium on euro region government bond returns is associated with increasing importance of the global risk and international risk factors on those bonds. In this case, we can barely talk about full market integration given that the global shocks in the bond yields creates the deviation in the yield differentials. We modeled the financial integration by considering both the local and global factors and concluded that financial integration is not perfectly realized in euro bond markets.

Secondly, for the first time in the literature – up to now, the volatility of the yield spreads were not modeled, according to our investigation of the literature – we model the volatility of euro originated government bond yield differentials by using the Multivariate GARCH model to control the effect of global shocks. We find that not only the yield differentials but also the volatility of the yield differentials are affected by the global shocks, proving that full financial integration of euro bond markets does not exist yet.

The paper is arranged as follows. In Section 2, we perform a detailed literature survey, concentrating on both the government bond markets' integration and the effect of global shocks through macroeconomic announcements on the markets. We discuss data issues and variable definitions in Section 3. The next section contains the empirical study explaining the yield differentials

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<sup>5</sup>Not only do the government debt obligations have credible differences, but also the current account risks are implicitly “bailed out” in the markets, though the head of central bank argued that it is not convincing to think European Central Bank (ECB) will guarantee each government's debt service obligations.

by employing global risk factors such as macroeconomic announcements and other international risk factors. Section 5 presents the empirical results of the Multivariate GARCH model. The next section contains the robustness checks for the empirical models. The final section offers concluding remarks.

## 2 Literature

There are a limited number of studies that have focused on measuring the integration in government bond markets. Besides, the literature generally used asset prices as the measurement of the market integration. In one of the studies, Barr and Priestley (2004) tried to explain the bond prices as being mostly related to world risk factors rather than domestic risk factors. They argue that under full integration, exposure to purely local factors can be wiped out and local factors will cease to have any systematic impact on expected returns. In a similar investigation, using monthly data, Codogno et al. (2003) proxy the country-specific risk factor by national debt to GDP ratios and international risk factors by U.S. markets. They find that the domestic risk factor is irrelevant in explaining yield differentials, except for the cases of Austria, Italy, and Spain. Interestingly, for the latter two countries the ratio of debt to GDP is statistically insignificant as a single variable for their studies.

Favero et al. (2005) attempted to explain the reasons behind the bond yield differentials in euro bond markets using various financial factors, particularly for the period after start of monetary union. Recently, Pagano and Von-Thadden (2004) have provided extensive research on the impact of the different financial and macroeconomics factors on bond yield spreads. They focused on the importance of the international risk factors on the bond yield differentials. Geyer et al. (2004) estimate a state-space version model of the time varying bond yield spreads for four EMU members. Similar to Codogno et al. (2003), they find that global factors explain an important part of the changes in yield spreads, whereas the local shocks have no explanatory power.

Up to this point, we have focused on literature about the steady financial integration or limited changes with annual or monthly bases. However, financial market integration is related to international finance, and it does make economic sense that financial market integration changes with economic conditions. The generally accepted economic explanation is that the level of risk aversion changes and investors require time varying compensation for accepting a risky payoff from financial assets. Thus, more recent studies allowed integration to vary over time and to be mostly affected by economic conditions. In this sense, financial economists needed to study the time varying integration with more frequent databases. For example, Aggarwal et al. (2004) and Barr and Priestley (2004) provide studies related to time-varying expected bond returns using an asset pricing model by employing daily asset prices. These very well-known studies for the first time illustrate a time varying financial integration in bond markets. Recently, Christiansen (2007) has used the GARCH model of Beckaert et al. (2005) to assess return spillovers in European bond markets. She provides empirical evidence that regional effects

have become dominant over both own country and global effects in EMU markets with introduction of euro but not in non-EMU countries. Although at first glance it seems that our study is similar, we examine the full integration differently, by considering the effect of the global shocks on asset price distortions and then employing the GARCH model. In a parallel study, Driessen et al. (2003) find that factors relating to the term structure of the interest rates explain most of the variations in excess bond returns, hence it is conceivable that economic convergence required as part of EU membership has inevitably led to high levels of bond market convergence. In a well-known study related to the integration of European equity markets, Fratzscher (2002) has studied the volatility and return spillovers on the European stock markets by employing a multivariate GARCH model. In addition, he tested for cointegration—long-term relationship—in European stock markets, finding that national stock markets mostly are integrated with each other by the beginning of the monetary union. Also, Kim et al. (2006) examine the time varying level of integration of European government bond markets by applying cointegration tests and the GARCH model, and they find higher levels of integration among existing European union countries than among new members.

From a short-term perspective, some other studies have addressed market reaction to fundamental news released on announcement days in terms of financial asset pricing and volatility. Such research has focused on the conditional volatility implied by ARCH/GARCH models introduced by Engle (1982) and Bollerslev (1986). For example, Engle and Li (1998) examine the degree of persistence heterogeneity associated with scheduled macroeconomic announcement dates and non-announcement dates in the treasury futures market. They present a filtered GARCH model that takes care of cyclical patterns of time-of-the-week effects and announcement effects by decomposing returns volatility into transitory and non-transitory parts. Regarding stock market returns, Flannery and Protopapadakis (2002) use a GARCH model to detect the effect of macroeconomic announcements on different stock market indices. They consider as a potential risk factor any macro announcement that either affects asset returns or increases conditional volatility. Their results show that inflation measures, Consumer Price Index and Producer Price Index, affect only the level of stock returns. Besides, three real factor candidates, Balance of Trade, Unemployment, and Housing Starts, affect only the return's conditional volatility. Similarly, Bomfim (2003) examines the effect of monetary policy announcements on the volatility of stock returns. His findings suggest that unexpected monetary policy decisions tend to boost significantly the stock market volatility in the short run. As expected, positive sign surprises tend to have a larger effect on volatility of the returns than negative sign surprises.

### 3 Data description

The dataset for this paper includes variables, explain the government bond returns, as well as the macroeconomic announcements published in the euro area and U.S.. To capture the effect of the single currency on bond markets



integration more effectively, we employed the daily dataset from the starting date of monetary union, namely January 1 1999, to December 31 2004. The dependent variable, the 10-year euro denominated benchmark government bond yield for each market, is acquired with daily frequency from DataStream/Thompson Inc. DataStream uses Merrill Lynch database as a data source for the bond returns. We chose for the start date of the dataset the beginning of the monetary union since daily prices are regularly available through DataStream from that date. For eliminating short run fluctuations in yield differentials, we utilize benchmark long-term government bonds matured in ten years. The effect of liquidity premia on each bond market are captured accurately when we use bid-asking spreads. Usually in the financial markets, the bid-ask spread reflects the costs to the dealers in providing immediacy. Besides, the spreads may be affected by the level of competition among dealers. We identify the variable as;

$$Liq_t^i = \frac{Bid_t^i - Ask_t^i}{Ask_t^i} .$$

The  $Bid_t^i$  stands for the bid daily price for the given sovereign bond yield  $i$  at timet.  $Ask_t^i$  stands for the daily asking price for the same bond in the financial markets. The spread measures how liquid is the sovereign bond market. Apparently, the higher the spread, the less liquid the market is. The bid-asking spread of the bonds is employed from MTS S.P.A.,<sup>6</sup> the first wholesale electronic market for government bonds. MTS is a quote-driven market in which market-makers quote continuously two-way prices during the entire trading session for agreed securities with a maximum bid-ask spread that depends on the characteristics of the security.<sup>7</sup> Another financial factor that might influence the domestic sovereign bond yields is the maturity variable. The maturity variable is calculated by modifying the duration of the 10 year government bond  $i$ . The data is taken from DataStream/Thompson Inc. To capture the effect of international risk factors on benchmark bond yield differentials in the euro zone, we have employed various variables. Some studies on emerging markets government bonds, including Folkerts-Landau et al. (1997) and Erb et al. (2004) documented the possible effect of the yield on U.S. government bonds or the slope of U.S. yield curve on the emerging market bond returns. For the euro zone government markets, Blanco (2001) employed U.S. corporate bond yields<sup>8</sup> as a proxy for the international risk factor to explain the yield differentials among euro government bonds. Dungey et al. (2000) conducted an empirical study to demonstrate that for euro bond markets there is also strong evidence that yield differentials are affected by the

<sup>6</sup>Even though the dataset starts from 1999, for some of the markets, MTS does not contain bid and asking price data before 2001, the rest of the missing data is obtained from the Bloomberg Cooperation.

<sup>7</sup>For more info about the dataset check <http://www.mtsgroup.org/newcontent/data/>.

<sup>8</sup>Corporate bond spreads are calculated by subtracting the corporate bond index from the benchmark government bond yield.

presence of the common international factors. In this paper, considering this recent literature, we employ two different international risk factor variables to explain the volatility of the yield differentials. These variables are the differences between fixed interest rates on U.S. swaps and U.S. government bond yields, and the spread between the yields on U.S. 10 year AAA rated corporate bonds and government bonds. These datasets are also gathered from DataStream/Thomson Inc.

So far, we have defined domestic market risk factors that are previously effective to explain the government bond yields. To assess the financial integration among the government bond markets, we definitely need the common shock factors. In particular, we use macroeconomic and monetary policy announcements to proxy common shocks on benchmark bond yields. The announcements were released monthly in U.S., Germany, and the euro area during the period of January 1999 to December 2004. We consider various macroeconomic announcements<sup>9</sup> that are reported to be the most influential announcements both in the academic literature and in the press. To explain the source of the announcements briefly, in the Bureau of Statistics PPI and CPI, retail sales and industrial production indexes are published monthly, while the Federal Reserves Federal Open Market Committee meetings are scheduled eight times a year, and ECB announces economic indicators with monthly frequency. By considering the time differences between U.S. and euro markets, we modify the date of the announcements according to market openings in euro markets.<sup>10</sup>

The response of bond prices to macroeconomic announcements is evaluated by utilizing the following identity;

$$K_t^i = \frac{S_t^i - \mu_t^i}{\sigma_t^i},$$

where  $S_t^i$  is the percentage change in the economic indicator,  $\sigma_t^i$  is the standard deviation of the indicator distribution and the  $\mu_t^i$  is the mean of the distribution. Dividing differences relative to announcements to the standard deviation allows one to interpret in a consistent manner the estimated coefficients.

## 4 Model

### 4.1 Basic yield differentials model

The econometric evidence of the baseline model will explore the importance and magnitude of common shocks on government bond yield differentials among euro members. These factors will not only consider the macroeconomic

<sup>9</sup>The economic indicators used in this paper are listed in [Appendix](#).

<sup>10</sup>When the announcements are released in U.S., the Euro markets are generally closed. Therefore, we utilize the effect of announcements in euro markets one business day after they were released.

statements observed in U.S., Germany, and the euro area markets, but also compare the interactions between the risk factors in global markets with the euro area risk-free bond yield spreads.

Using the daily data for the period 1999–2004, we model benchmark government bond yield differentials in the euro zone as;<sup>11</sup>

$$\begin{aligned} \Delta S_t^{ig} = & \alpha + \rho_1 * (Liq_t^i - Liq_t^g) + \tau_1 * (Mat_t^i - Mat_t^g) + \sum_{h=1}^v \varpi_i^{eu} |K_{h,t}^{eu}| \\ & + \sum_{j=1}^y \varpi_i^G |K_{j,t}^g| + \sum_{m=1}^z \varpi_i^{us} |K_{m,t}^{us}| + \varepsilon_{1t} . \end{aligned} \tag{1}$$

The dependent variable is the change in government bond yield differential for benchmark bond *i* over the Germany benchmark bond. Unlike the recent literature, we use the daily change in bond yield differentials as a dependent variable instead of employing yield differentials itself as a left hand side variable and the lag of yield spreads as an independent variable, since yield differential variables are not all stationary.<sup>12</sup> Control variables for the local risk factors are measured by the liquidity variable  $Liq_t^i$ , the bid-asking price spread for benchmark government bond issued in country *i*, and maturity variable  $Mat_t^i$ , the residual maturity of the particular bond. The variables  $K^g$ ,  $K^{eu}$  and  $K^u$  are the German, the euro area, and U.S. announcements respectively.<sup>13</sup>

Table 1 encloses the coefficients of macroeconomic announcements published in U.S. & Germany presented in Eq. 1. The coefficients of U.S. macroeconomic announcements are statistically significant for all regressions. Besides, macroeconomic announcements released in Germany have positive and statistically significant effects for some bond markets in the euro area. Table 1 contains essential results evaluating the financial integration level in the euro region. The significant coefficients are showing that full financial integration among euro bond markets has not existed yet, despite what some literature has claimed.

However, the reliability of the macroeconomic announcements might be questioned since they are released in monthly frequency and might have limited effect on daily bond yield differentials. Therefore, we alternatively employed two international risk factor variables that obtain full set information instead of the announcements. International risk factor variables used in

<sup>11</sup>In the model, we employed some number of lag variables of the announcements to find the best model; however, by using the general to specific model—known as GS model—we ended up that the lag variables of the announcements are strongly insignificant, thus, we decided not to use the lag variables of the announcements. To neglect the asymmetric shock effect and make it simpler, we got the absolute values of the macroeconomic announcements.

<sup>12</sup>Table 9 provides the stationary test results of the dependent variables. ADF test results documented that not for all yield differential variables are stationary.

<sup>13</sup>Similar stationary test has been performed for the control variables as well. We performed that the control variables are stationary.

**Table 1** Effect of macroeconomic announcements on government bond yield differentials in European bond markets

Countries	K <sup>us</sup> <sub>j,t</sub>				K <sup>g</sup> <sub>j,t</sub>		
	U.S. CPI	U.S. PPI	U.S. retail sales	U.S. indust. production	Ger CPI	Ger PPI	Ger UN
Austria	0.03*** (2.9)	0.002** (1.99)	0.003** (2.12)	-0.002** (2.15)	0.0008 (1.16)	0.0004* (1.94)	0.01*** (2.51)
Belgium	-0.06** (-2.12)	-0.04* (-1.83)	-0.04* (-1.92)	0.05* (1.88)	-0.001 (-1.14)	-0.04 (-1.18)	-0.001* (-1.89)
Denmark	0.03* (1.88)	0.07** (2.12)	-0.005 (1.00)	0.004 (1.31)	-0.001* (-1.85)	0.007*** (2.85)	-0.002 (-1.51)
Finland	0.03** (2.34)	0.007** (2.45)	-0.001* (1.80)	-0.0001 (1.18)	0.001* (1.69)	-0.008* (-1.89)	0.2* (1.89)
France	-0.002* (-1.61)	-0.006** (-1.98)	0.001 (1.3)	0.0005 (1.32)	-0.005** (-2.04)	-0.008** (-2.16)	-0.007** (-1.98)
Greece	0.003* (1.86)	0.01*** (2.76)	-0.005 (1.93)	0.004** (2.01)	0.003* (1.81)	0.006** (2.11)	0.011*** (2.51)
Ireland	0.003* (1.93)	0.001** (1.99)	0.002 (1.18)	0.001** (2.12)	-0.004** (-2.12)	-0.002* (-1.82)	-0.003 (-1.49)
Italy	0.001** (2.12)	0.001** (2.08)	-0.0002 (1.55)	-0.001* (1.88)	0.0004 (1.31)	0.01* (1.88)	0.005** (2.11)
Netherlands	-0.04** (-2.45)	-0.002* (-1.83)	0.008 (1.07)	0.003* (1.87)	-0.01** (-2.1)	-0.002* (-1.85)	0.001** (2.15)
Norway	0.03* (1.85)	-0.001** (-1.99)	0.004 (1.22)	0.003 (1.55)	0.01 (1.1)	0.002** (2.42)	0.011* (1.77)
Portugal	0.004** (1.98)	0.002* (1.88)	0.004 (1.41)	0.003 (1.16)	0.01*** (2.85)	0.002* (1.85)	0.004* (1.71)
Spain	0.01 (0.44)	0.01 (1.12)	0.00 (1.33)	0.01** (2.12)	0.033* (1.84)	0.003** (2.12)	0.001** (2.06)
Sweden	0.005 (1.15)	0.004* (1.91)	0.001* (1.65)	-0.001** (-2.07)	0.001* (1.92)	0.003* (1.66)	-0.001* (-1.73)
U.K.	0.0068** (1.28)	0.001* (0.99)	0.08 (0.93)	0.01* (1.83)	0.0005 (0.1)	-0.0005 (-1.26)	0.01*** (2.96)

Estimation method: OLS. White Heteroscedastic errors are corrected. T-statistics are in parenthesis denoting \*\*\*1%, \*\*5%, and \*10% significance. The estimated model is

$$\Delta S_t^{ig} = \alpha_1 + \rho_1 (Liq_t^i - Liq_t^g) + \tau_1 (Mat_t^i - Mat_t^g) + \varpi_{eu} \sum_{j=1}^v |K_{j,t}^{eu}| + \varpi_G \sum_{j=1}^y |K_{j,t}^g| + \varpi_{us} \sum_{m=1}^z |K_{m,t}^{us}| + \varepsilon_{1t}$$

$\Delta S_t^{ig}$  is the change in yield differentials for 10 year government bonds for country *i* over Germany.  $Liq_t^i$  is bid-asking price spread for of 10 year government bonds country *i*.  $Mat_t^i$  is modified duration of Government bonds for country *i*. The coefficients  $K_{i,t}^{eu}$ ,  $K_{j,t}^g$ , and  $K_{m,t}^{us}$  are the macroeconomic announcements released in euro Area, Germany and United States respectively. Only a few of the announcement variables are illustrated. U.S. CPI, U.S. PPI U.S. Retail Sales, U.S. Industrial Production are the Consumer Price Index, Producer Price Index, Retail Sales, Industrial Production indicators released in U.S.. Similarly, Ger CPI Ger PPI, Ger UN, are the Consumer Price Index, Producer Price Index, Unemployment indicators released in Germany.

the empirical model are either the spread between U.S. swap rates and U.S. 10 year government bond yields or the difference between the U.S. S&P's AAA corporate bond yield index and U.S. 10-year government bond yield. The former one is issued to capture the effect of the exchange rate risk in U.S.

**Table 2** Effect of international risk factors on government bond yield differentials in European bond markets

Countries	$\rho_2$	$\tau_2$	$\theta_2$
Austria	0.006 (0.08)	0.05 (0.83)	0.06** (2.01)
Belgium	0.007 (0.07)	0.06 (0.51)	0.03*** (2.89)
Denmark	0.01 (1.16)	0.41 (0.16)	0.02*** (2.71)
Finland	0.006 (0.99)	0.7 (0.78)	0.015* (1.67)
France	0.007 (0.08)	0.08** (2.11)	-0.028* (-1.75)
Greece	0.006 (0.85)	0.08 (0.88)	0.02** (2.23)
Ireland	0.007 (1.02)	0.03 (0.75)	-0.08*** (4.21)
Italy	0.006 (0.81)	0.03 (0.39)	0.02*** (3.21)
Netherlands	0.002 (0.51)	0.03** (2.55)	-0.07** (2.31)
Norway	0.0011 (1.22)	0.5* (1.78)	0.021** (2.16)
Portugal	0.002 (1.01)	0.04** (2.11)	0.02*** (3.31)
Spain	0.003 (1.31)	0.04 (1.33)	0.02** (2.10)
Sweden	0.007 (1.16)	0.04 (1.33)	0.06*** (3.02)
U.K.	0.05 (1.41)	0.11 (1.66)	0.04*** (3.13)

Estimation method is OLS. T-statistics are in parenthesis. White Heteroscedastic standard errors are corrected. The estimated model is

$$\Delta S_t^{ig} = \alpha_2 + \rho_2 (Liq_t^i - Liq_t^g) + \tau_2 (Mat_t^i - Mat_t^g) + \theta (R^{cor} - R^{us}) + \varepsilon_{2t}.$$

$\Delta S_t^{ig}$  is the change in yield differentials for 10 year government bonds for country  $i$  over Germany.  $Liq_t^i$  is the bid-asking spread of government bonds.  $Mat_t^i$  is the residual maturity. International risk factor,  $(R^{cor} - R^{sus})$ , is the spread between 10-year U.S. AAA corporate bond yield index and the yield on 10-year U.S. government bonds.

dollar, and the latter one contained corporate market risk (non-diversified) in U.S. markets.<sup>14</sup> The estimations of the regressions<sup>15</sup> are presented in Table 2.

The estimated model is,

$$\Delta S_t^{ig} = \eta + \rho_2 (Liq_t^i - Liq_t^g) + \tau_2 (Mat_t^i - Mat_t^g) + \theta_2 (R^{cor} - R^{sus}) + \varepsilon_{2t}, \quad (2)$$

<sup>14</sup>Since the government bond yield is the risk free return rate and the AAA corporate bond yield index contains the market risk excluding the specific factors. The difference surrogates for the U.S. market risk factor.

<sup>15</sup>Codogno et al. (2003) have employed a similar dataset and found that for almost all euro countries, U.S. market risk has significant and positive coefficient.

where the  $(R^{cor} - R^{sus})$  refers to the difference between the AAA corporate bond index and the benchmark 10 year government bond yield.<sup>16</sup> The coefficients of the international risk factors are significant for almost all benchmark bond yield differentials, although sign of the coefficients are not always the same. Intuitively, having a significant coefficient indicates that international risk factors cause divergences in yield differentials. In Table 3, even when we control both announcements and international risk factors to explain the yield differentials, we document the significance of these factors in explaining the yield spreads.

Although the yield spreads among euro government bond markets compressed to very small percentages, they did not vanish completely. However, they cannot be explained precisely by the default risk factor. By employing international factors and macroeconomic announcements, we find that euro zone government bond markets have not achieved full financial integration. The coefficients of international risk factors and U.S. macroeconomic announcements are significant in the first and second regression, expressed in both Tables 1 and 2 even when we control for the macroeconomic announcements in Germany and other euro markets. These results are indicating that full financial integration among the euro markets has not taken place completely.

#### 4.2 Multivariate GARCH model

In Tables 1–3, we demonstrate that macroeconomic announcement effects and international risk factors have statistically significant effects on euro benchmark government bond yield differentials even after controlling for local market risk factors. In this part of the paper, we measure the integration among euro bond markets by using generalized autoregressive conditional heteroskedasticity, also known as the GARCH. This model allows us to observe the time varying integration by considering the simultaneous effect of U.S. bond markets on each euro bond market return. Financial integration theories explain that the effect of global shocks will not be statistically different from zero for different bond market returns when full financial integration among the markets exists. By employing a multivariate GARCH model, we observe the effect of the global shocks via U.S. bond markets on the bond yield differentials among euro markets simultaneously. Accordingly, we will be able to reveal the time-varying nature of euro bond market integration.

For investigating the various levels of euro market reactions to global shocks (U.S. bond yield curve), euro markets daily bond yield differentials are modeled by considering the effect of pair-wise yield differential equations. To obtain the spillover effect, we need to estimate a multivariate GARCH model for euro market  $i$ , Germany and U.S. government bond yields simultaneously.

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<sup>16</sup>We used the latter variable, the spread between U.S. swap rates and U.S. 10 year government bond yields, and found similar results.

**Table 3** Government bond yield differentials in European bond markets

	Germany CPI	Germany PPI	U.S. CPI	U.S. PPI	Risk factor
Austria	0.001** (2.05)	-0.001 (-0.575)	0.006* (1.84)	0.003 (1.03)	0.008*** (4.31)
Belgium	0.001** (1.88)	0.003 (0.96)	0.002** (-1.78)	-0.003 (0.23)	0.003*** (3.38)
Denmark	0.001 (1.12)	0.002* (1.93)	0.004** (2.06)	-0.002** (-2.11)	0.001** (2.17)
Finland	-0.0001 (-0.16)	0.004** (2.33)	-0.006** (-2.11)	-0.002** (-1.86)	0.005*** (4.2)
France	-0.0006 (-0.44)	-0.006** (-1.64)	0.001** (1.95)	-0.003 (-0.43)	0.007 (1.6)
Greece	0.002** (2.03)	0.001** (1.88)	0.0004** (1.98)	0.003 (1.36)	0.005** (1.99)
Ireland	0.002* (1.85)	-0.003 (-1.08)	-0.03*** (-3.11)	0.003** (1.88)	-0.002** (-2.48)
Italy	0.001 (1.77)	-0.008*** (-3.38)	0.002 (2.11)	0.003** (1.85)	0.002*** (2.94)
Netherlands	-0.002 (-1.02)	-0.006*** (-3.34)	-0.001* (-1.7)	-0.001 (-1.42)	-0.002** (-2.25)
Norway	0.0004 (1.33)	0.04** (2.11)	0.03* (1.68)	-0.005*** (-3.22)	0.011* (1.77)
Portugal	0.001* (1.88)	0.002** (2.16)	0.003* (1.77)	0.005** (2.22)	0.003*** (2.67)
Spain	0.003*** (3.11)	0.004** (2.12)	0.004* (1.67)	0.003** (3.11)	0.004*** (3.18)
Sweden	0.0001 (1.19)	-0.006** (-1.64)	0.001** (1.95)	-0.003 (-0.43)	0.007 (1.6)
U.K.	-0.002** (-2.12)	-0.003* (-1.77)	0.001* (1.88)	-0.003** (2.43)	0.013* (1.88)

Estimation method is OLS. White Heteroskedastic errors are corrected. T-statistics are in parenthesis denoting \*\*\*1%, \*\*5%, and \*10% significance. The estimated model:

$$\Delta S_t^{ig} = \alpha_3 + \rho_3 (Liq_t^i - Liq_t^g) + \tau_3 (Mat_t^i - Mat_t^g) + \phi_3 (R^{cor} - R^{us}) + \varpi_G \sum_{j=1}^y |K_{jt}^g| + \varpi_{us} \sum_{m=1}^z |K_{m,t}^{us}| + \varepsilon_{3t}$$

$\Delta S_t^{ig}$  is the change in yield differentials for 10 year government bonds for country  $i$  over Germany.  $Liq_t^i$  is the bid-asking spread of traded bonds.  $Mat_t^i$  is the residual maturity.  $(R^{cor} - R^{us})$ , international risk factor, is the spread between 10-year AAA corporate Bond yield index and the yield on 10-year US government bonds. U.S. CPI, U.S. PPI U.S. Retail Sales, U.S. Industrial Production are the Consumer Price Index, Producer Price Index, Retail Sales, Industrial Production indicators released in U.S.. Similarly, Ger CPI Ger PPI, are the Consumer Price Index, Producer Price Index, Unemployment indicators released in Germany.

The estimated model is;

$$\begin{pmatrix} \Delta S_t^{ig} \\ \Delta S_t^{iu} \\ \Delta S_t^{ug} \end{pmatrix} = \begin{pmatrix} a_t^{ig} \\ a_t^{iu} \\ a_t^{ug} \end{pmatrix} + \begin{pmatrix} T_1 Liq_t^{ig} \\ T_2 Liq_t^{iu} \\ T_3 Liq_t^{ug} \end{pmatrix} + \begin{pmatrix} \eta_1 Mat_t^{ig} \\ \eta_2 Mat_t^{iu} \\ \eta_3 Mat_t^{ug} \end{pmatrix} + \begin{pmatrix} \psi_t^{ig} \\ \psi_t^{iu} \\ \psi_t^{ug} \end{pmatrix} \begin{pmatrix} 3.a \\ 3.b \\ 3.c \end{pmatrix}, \quad (3)$$

where

$$\begin{pmatrix} \psi_t^{ig} \\ \psi_t^{iu} \\ \psi_t^{ug} \end{pmatrix} = \begin{pmatrix} \phi^{iu} & \phi^{ug} & 1 \\ 1 & \beta^{ug} & \beta^{ig} \\ \omega^{iu} & 1 & \omega^{ig} \end{pmatrix} \begin{pmatrix} \varepsilon_t^{iu} \\ \varepsilon_t^{ug} \\ \varepsilon_t^{ig} \end{pmatrix}$$

In the Eqs. 3.a–3.c, the predictable model has a  $\Delta S_t$ , the change in yield differentials, includes a constant, and liquidity and maturity variables.  $Liq_t^{mn}$  is the differential of the defined liquidity variable for market  $m$  relative to  $n$ . Similarly,  $Mat_t^{mn}$  is the differential of the defined maturity variable for market  $m$  relative to  $n$ . The unpredictable part in the model consists of innovations to change in yield differentials from the spillover effects. Say, in Eq. 3.a, the unpredictable part is in the form of;

$$\psi^{ig} = \varepsilon_t^{ig} + \phi^{iu} * \varepsilon_t^{iu} + \phi^{ug} * \varepsilon_t^{ug}, \tag{4}$$

$\varepsilon_t^{ig}$  is the unpredictable term of Eq. 3.a, where,  $\phi^{iu} * \varepsilon_t^{iu} + \phi^{ug} * \varepsilon_t^{ug}$  is the spillover term in the unpredictable part. The error term  $\varepsilon_t^{iu}$  and  $\varepsilon_t^{ug}$  are the error terms of Eqs. 3.b and 3.c respectively. Given that we solved the equations simultaneously with GARCH model, we will able to plug those error terms to the Eq. 3.a to get the spillover effects, namely  $\phi^{iu} * \varepsilon_t^{iu} + \phi^{ug} * \varepsilon_t^{ug}$ , from Eqs. 3.b and 3.c respectively.

Similarly, volatility of bond yield differentials is modeled as;

$$\begin{aligned} \sigma_t^2 &= \begin{pmatrix} \sigma_t^{ig^2} \\ \sigma_t^{iu^2} \\ \sigma_t^{ug^2} \end{pmatrix} = \begin{pmatrix} a_t^{ig} \\ a_t^{iu} \\ a_t^{ug} \end{pmatrix} + \begin{pmatrix} \lambda^{ig} \sigma_{t-1}^{ig^2} \\ \lambda^{iu} \sigma_{t-1}^{iu^2} \\ \lambda^{ug} \sigma_{t-1}^{ug^2} \end{pmatrix} + \begin{pmatrix} \omega^i \varepsilon_{t-1}^{ig} \\ \omega^g \varepsilon_{t-1}^{iu} \\ \omega^u \varepsilon_{t-1}^{ug} \end{pmatrix} \\ &+ \begin{pmatrix} \delta^{iu} & \delta^{ug} & 0 \\ 0 & \theta^{ug} & \theta^{ig} \\ \mu^{iu} & 0 & \mu^{ig} \end{pmatrix} \begin{pmatrix} \varepsilon_t^{iu^2} \\ \varepsilon_t^{ug^2} \\ \varepsilon_t^{ig^2} \end{pmatrix} \begin{pmatrix} 5.a \\ 5.b \\ 5.c \end{pmatrix}, \tag{5} \end{aligned}$$

where the  $\sigma_t^2$  is the variance matrix of the error terms in Eq. 3.<sup>17</sup> The innovations in Eq. 3,  $\varepsilon_t$ , are assumed to be normally distributed conditional on the past information set that is— $\varepsilon_t/\Omega_{t-1}$ — distributed as  $N(0, \sigma_t)$ .  $\sigma_t$  denotes the time varying variance, implies that variance of the change in yield differentials in euro bond markets is determined by its own past variance, own squared shock and by the contemporaneous squared external innovations, namely spillover effects. In these equations we model the volatility of yield differentials among

<sup>17</sup>The stationary conditions for the ARCH and GARCH model are tested. In the Appendix section at Tables 10 and 11, we document the stationary test results for ARCH and GARCH estimations.



euro government bonds by considering spillover effects of pair-wise yield differentials of each euro bond return over U.S. benchmark bond return. The spillover coefficients<sup>18</sup> for the volatility of yield differential regressions are  $\delta^{iu}$ ,  $\delta^{su}$ ,  $\theta^{ig}$ ,  $\theta^{ug}$ ,  $\mu^{iu}$  and  $\mu^{ig}$ . To make it clear, say for the Eq. 5.a, the spillover effect extracting from Eqs. 5.b and 5.c is in the amount of  $\delta^{iu} * \varepsilon_t^{iu^2} + \delta^{ig} * \varepsilon_t^{iu^2}$ .

The theoretical framework of GARCH model in this paper is based up on the maximization procedure of Berndt et al. (1974) (hereafter BHHH). The parameters are estimated by maximizing a multivariate log likelihood function. In the multivariate case, the part of log likelihood function becomes

$$L(\theta) = - \left( \frac{T}{2} \right) \ln(2\pi) - \frac{1}{2} \sum_{t=1}^T \left( \ln|\sigma_t| + \varepsilon_t' \sigma_t^{-1} \varepsilon_t \right) ,$$

where  $\theta$  is the parameter vector to be estimated or to be maximized, T is the number of observations and  $\sigma_t$  is the time varying conditional variance-covariance matrix. Simplex algorithm is used to get initial values for the maximization problem. To obtain the parameter estimates, numerical maximization is employed through the algorithm developed by Berndt et al. (1974).

### 5 Empirical results

The main contribution of this paper is to examine financial integration of euro region government bond markets through spillover effects. The multivariate GARCH model applied in this analysis allows us to investigate a time-varying correlation structure for the government bond yield differentials of each euro market bond yield relative to Germany benchmark bond yields. Maximum likelihood estimations of the multivariate GARCH model for both euro and non-euro bond markets are reported in Tables 4 and 5 respectively. The very first two columns of both tables contain the coefficients of the spillover effects belonging to Eqs. 3.a and 3.b. These columns show the spillover effect extracted from yield differentials of market  $i$  government bond yield over U.S. benchmark government bond, i.e  $\phi^{iu}$ , and yield differentials for Germany bond over US benchmark bond, i.e  $\phi^{su}$ . The results illustrate that yield differentials of each euro government bond relative to US benchmark bonds, i.e  $\phi^{iu}$ , have significant and positive coefficients, pointing out that they have statistically significant effect on determining the yield differentials in euro zone bond markets.

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<sup>18</sup>The motivation of this paper is to extract the effect of global shocks on euro markets, and modeling the yield differentials between U.S. and Germany, and not being affected by any other member country are really strong assumptions. Therefore in Eqs. 5.a and 5.c the spillover coefficients are not zero, but expectedly these coefficients are statistically insignificant.

**Table 4** Multivariate GARCH model for euro government bond returns

	Return spillovers		Volatility spillovers	
	$\phi^{iu}$	$\phi^{ug}$	$\delta^{iu}$	$\delta^{ug}$
Austria	0.66*** (5.21)	0.01 (1.44)	0.11** (2.11)	-0.00 (-0.11)
Belgium	0.42*** (6.11)	0.42 (1.21)	0.11*** (7.3)	0.01* (1.44)
Finland	0.32*** (12.2)	0.05 (1.21)	0.11*** (6.3)	0.00 (1.43)
France	0.61*** (9.3)	0.01 (11.23)***	0.16*** (4.18)	0.01*** (3.22)
Greece	0.33*** (5.24)	0.35*** (6.42)	0.14** (5.33)	0.22*** (5.14)
Ireland	0.13*** (11.4)	0.02* (1.67)	0.31*** (4.11)	0.01* (1.91)
Italy	0.54*** (2.12)	0.11 (0.99)	0.11*** (5.32)	0.00 (0.01)
Netherlands	0.04*** (4.44)	0.04 (0.11)	0.22*** (8.12)	0.01 (1.34)
Portugal	0.61*** (6.51)	0.032 (1.22)	0.33*** (4.44)	0.00 (1.14)
Spain	0.43*** (11.4)	0.00 (0.99)	0.22*** (4.32)	0.00 (1.32)

T-statistics are in parenthesis denoting \*\*\*1%, \*\*5%, and \*10% significance. The estimated model is

$$\Delta S_t^{ig} = \alpha^{ig} + T_1 (Liq_t^i - Liq_t^g) + \eta_1 (Mat_t^i - Mat_t^g) + \phi^{iu} \varepsilon_t^{iu} + \phi^{ug} \varepsilon_t^{ug} + \varepsilon_t^{ig} .$$

$$\sigma_t^{ig^2} = \alpha^{ig} + \lambda^{ig} \sigma_{t-1}^{ig^2} + \omega^{ig} \varepsilon_{t-1}^{ig^2} + \delta^{iu} \varepsilon_t^{iu^2} + \delta^{ug} \varepsilon_t^{ug^2} .$$

Yield differentials for euro member benchmark bonds over Germany bond would be explained through specific level of reactions of euro market  $i$  to the global shocks occurred in United states,  $\phi^{iu}$ , and the reactions of Germany bond markets to the same shocks,  $\phi^{ug}$ . In the second regression the volatility of the yield differentials is explained by the spillover effects, specific level of reactions of each euro market benchmark bond to U.S. based shocks and German benchmark bond to U.S. based shocks.

In terms of volatility, the effects of spillovers from the global factors on volatility of yield differentials is observed clearly. The last two columns of Tables 4 and 5 represent the spillover effect from Eq. 4. The coefficients  $\delta^{iu}$  and  $\delta^{ug}$  are measuring the spillover effects of yield spreads of euro government bond yield for market  $i$  over US benchmark bond and German benchmark bond over US benchmark bond respectively. In these tables while performing the GARCH model, the coefficient  $\delta^{iu}$  is significant and positive for almost all euro government bond markets, indicating that volatility of bond yield spreads among euro bonds is definitely affected by the yield differentials of the euro market benchmark bond over U.S. benchmark bond. The coefficient  $\delta^{ug}$ , is statistically insignificant and in terms of magnitude, infinitesimal proving that the yield differentials between Germany and U.S. have negligible effect on the volatility of yield differentials among euro members' benchmark bonds. Intuitively, for the volatility of the yield differentials, spillover parameters are

**Table 5** Multivariate GARCH model for non-euro government bond returns

	Return spillovers		Volatility spillovers	
	$\phi^{iu}$	$\phi^{ug}$	$\delta^{iu}$	$\delta^{ug}$
Denmark	0.77** (3.16)	0.12*** (4.12)	0.06 (1.13)	0.32*** (15.5)
Norway	0.42*** (15.5)	0.71*** (14.4)	0.74*** (6.77)	0.06 (1.44)
Sweden	0.61*** (4.12)	0.21** (1.99)	0.04 (1.41)	0.05** (12.3)
U.K.	0.51*** (11.3)	0.61*** (13.52)	0.06** (2.11)	0.04*** (15.4)

T-statistics are in parenthesis denoting \*\*\*1%, \*\*5%, and \*10% significance. The estimated model is

$$\Delta S_t^{ig} = \alpha^{ig} + T_1 (Liq_t^i - Liq_t^g) + \eta_1 (Mat_t^i - Mat_t^g) + \phi^{iu} \varepsilon_t^{iu} + \phi^{ug} \varepsilon_t^{ug} + \varepsilon_t^{ig}.$$

$$\sigma_t^{ig^2} = \alpha^{ig} + \lambda^{ig} \sigma_{t-1}^{ig^2} + \omega^{ig} \varepsilon_{t-1}^{ig^2} + \delta^{iu} \varepsilon_t^{iu^2} + \delta^{ug} \varepsilon_t^{ug^2}.$$

Yield differentials for non-Euro members benchmark bonds over German bonds  $S_t^{ig}$  is explained through particular level of reactions of country  $i$  market to the U.S. based market shocks,  $\phi^{iu}$  and the reactions of Germany markets to the US based market shocks,  $\phi^{iu}$ . These reactions are the spillover effects from Eqs. 3.b and 3.c. In the second regression, the volatility of the yield spreads is explained by the spillover effects which are particular level of reactions of each bond market to US based market shocks and German bond markets to U.S. based shocks. These are the spillover coefficients  $\delta^{iu}$  and  $\delta^{ug}$  respectively.

basically decomposition of yield differentials between any euro market and U.S., i.e.  $\delta^{iu}$ , and Germany and U.S., i.e  $\delta^{ug}$ , respectively.<sup>19</sup>

## 6 Robustness checks

### 6.1 Germany and US market integration

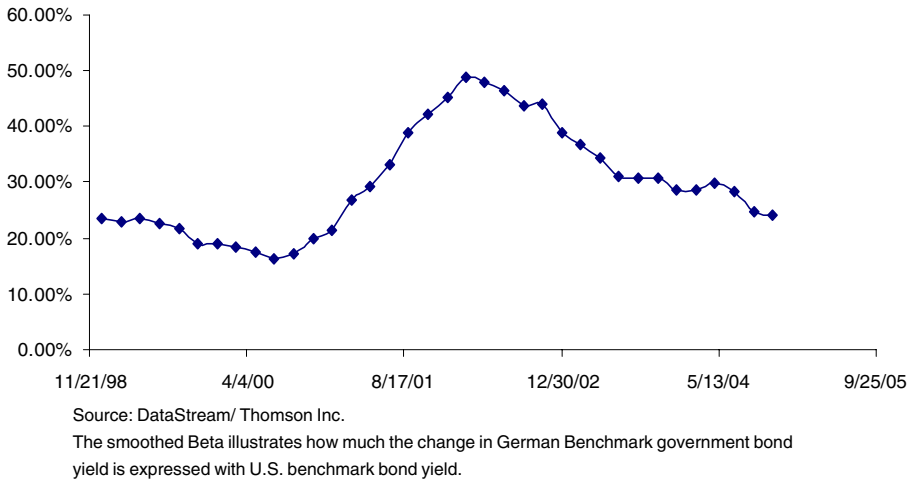
Economists may claim that since the Germany bond market is fully integrated with the rest of the OECD markets, it is expected that Germany benchmark bonds are absolutely hedged with world markets, and the effect of U.S.–Germany bond yield differentials on the GARCH model would be negligible—statistically not different from zero. However these expectations could not be fulfilled with the empirical studies. The model below measures the integration of the Germany bond market with the world bond markets.

The model is

$$\Delta R_t^g = \alpha_t + \beta_t \Delta R_t^{us} , \tag{6}$$

<sup>19</sup>The coefficients  $\mu^{iu}$  and  $\mu^{iu}$  are not presented in the tables. The coefficients are infinitesimal and statistically insignificant. These results indicate that the yield differentials between Germany and US benchmark government bonds are not affected by the pairwise yield spreads within any euro market.

<sup>20</sup>The swap interest rates are deducted from the bond yields for Germany and non-euro Bond market yields in order to eliminate the exchange rate fluctuations.

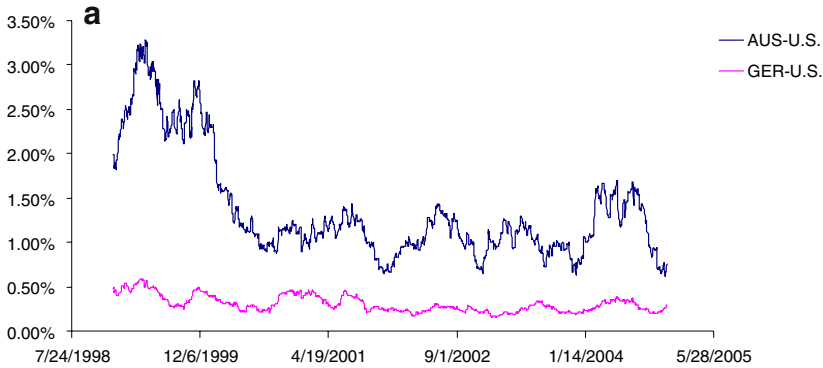


**Fig. 5** Average proportion of German benchmark bond yield changes explained by U.S. benchmark government bond yield changes

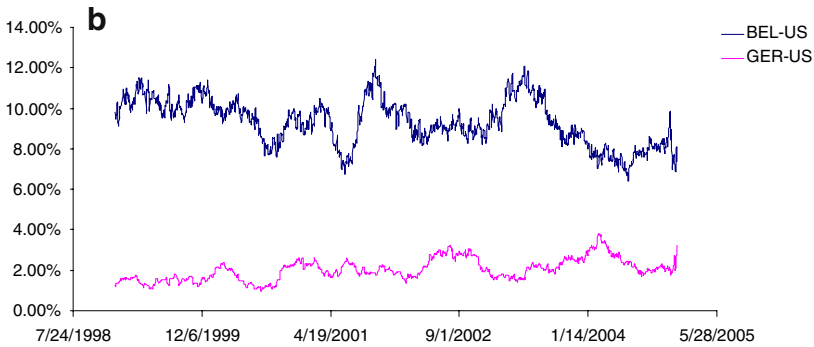
where  $\alpha$  is a time-varying intercept and the time-dependent  $\beta$  is the coefficient of integration of the Germany bond with U.S. benchmark bond. As we explained above, for fully hedged and integrated markets,  $\beta$  will converge with 1 and the intercept term will converge with zero. Figure 5 plots  $\beta$  for the equation above. For the daily dataset between the period of 1999 and 2004, we observe that the coefficient  $\beta$  is far behind the level of one. This result illustrates that U.S. and Germany benchmark bonds are not fully integrated, which is coinciding with our findings. Besides, for non-euro countries, the spillover effect of yield differentials of German benchmark government bonds over U.S. benchmark bonds can be observed evidently. Some factors, like high volumes of cross border financial asset trading with U.S. or currency exchange risk, made some non-euro markets more integrated with U.S. bond markets than Germany. Table 5 contains the coefficients of yield differentials from Eqs. 3.a and 5.a for non-euro countries. Spillover coefficients for Germany and U.S. yield differentials, i.e.  $\phi^{us}$  &  $\delta^{us}$ , are positive and significant while spillover effects from bond yield differential of  $i$  over U.S. are not significant.

## 6.2 Variance ratios

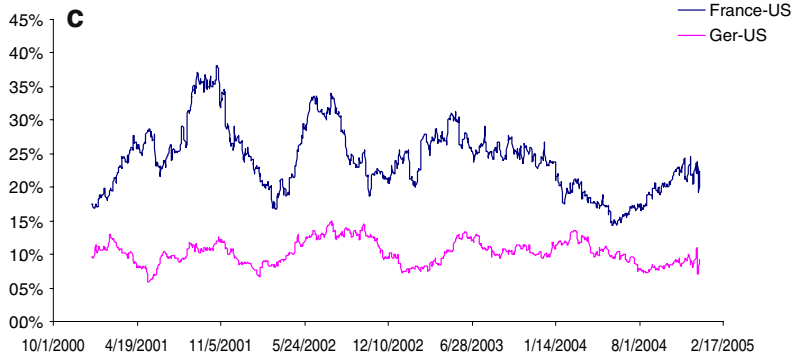
Another important method for comparing the effect of the spillover effects on each euro market is the measurement of the volatility ratios. We can roughly define volatility ratio as a test of measuring how much volatility of yield differentials among euro markets is explained by spillover effects from yield differentials of euro market  $i$  government bond over the U.S. government bond, or spillover effects of yield differentials of the Germany government bond relative to U.S. government bond.



Source: Datastream \Thomson Inc.  
AUS-U.S. stands for the variance ratio of yield spreads of Austria over U.S. on explaining the yield differentials among Euro markets  
GER-U.S. stands for the variance ratio of yield spreads of Germany over U.S. on explaining the yield differentials among Euro markets

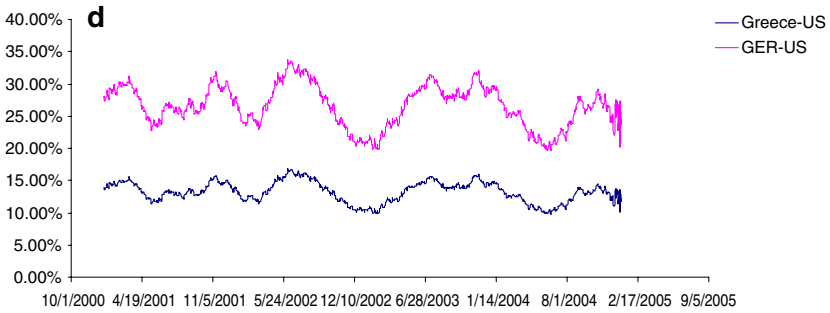


Source: Datastream \Thomson Inc.  
BEL-U.S. stands for the variance ratio of yield spreads of Belgium over U.S. on explaining the yield differentials among Euro markets  
GER-U.S. stands for the variance ratio of yield spreads of Germany over U.S. on explaining the yield differentials among Euro markets

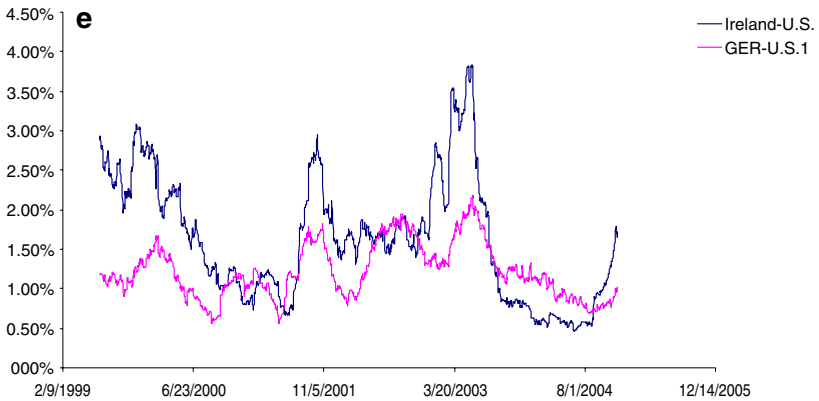


Source: Datastream \Thomson Inc.  
France-U.S. stands for the variance ratio of yield spreads of France over U.S. on explaining the yield differentials among Euro markets  
GER-U.S. stands for the variance ratio of yield spreads of Germany over U.S. on explaining the yield differentials among Euro markets

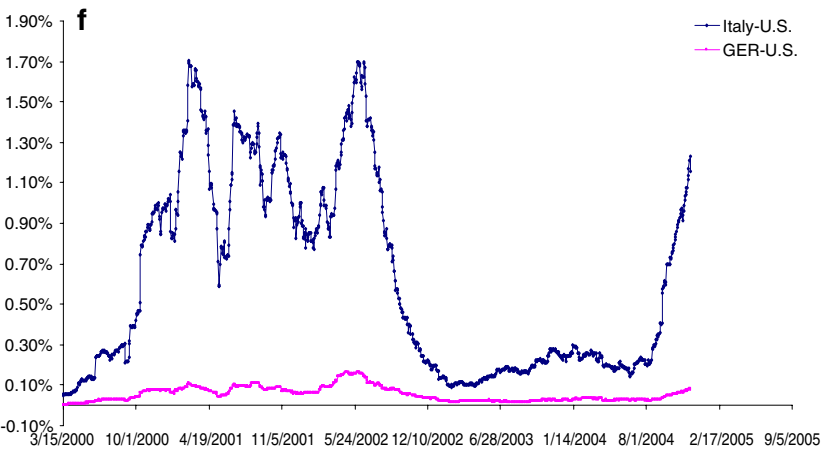
**Fig. 6** Spillover effects for euro zone government yield spreads for euro countries. (a) Austria (b) Belgium (c) France (d) Greece (e) Ireland (f) Italy (g) Netherlands (h) Portugal (i) Spain, and for non-euro countries: (j) Denmark (k) Norway. (l) Sweden (m) U.K. To eliminate the spikes and comprise a better intuition, we perform 30 day moving averages for the daily variance ratios



Source: Datastream \Thomson Inc.  
Greece-U.S. stands for the variance ratio of yield spreads of Greece over U.S. on explaining the yield differentials among Euro markets  
GER- U.S. stands for the variance ratio of yield spreads of Germany over U.S. on explaining the yield differentials among Euro markets

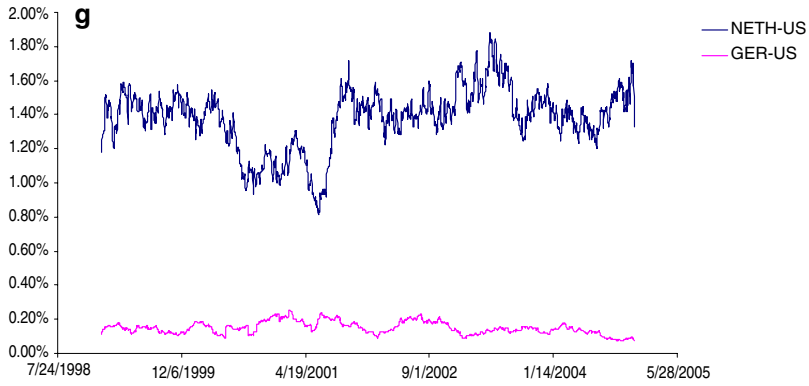


Source: Datastream \Thomson Inc.  
Ireland-U.S. stands for the variance ratio of yield spreads of Greece over U.S. on explaining the yield differentials among Euro markets  
GER- U.S. stands for the variance ratio of yield spreads of Germany over U.S. on explaining the yield differentials among Euro markets

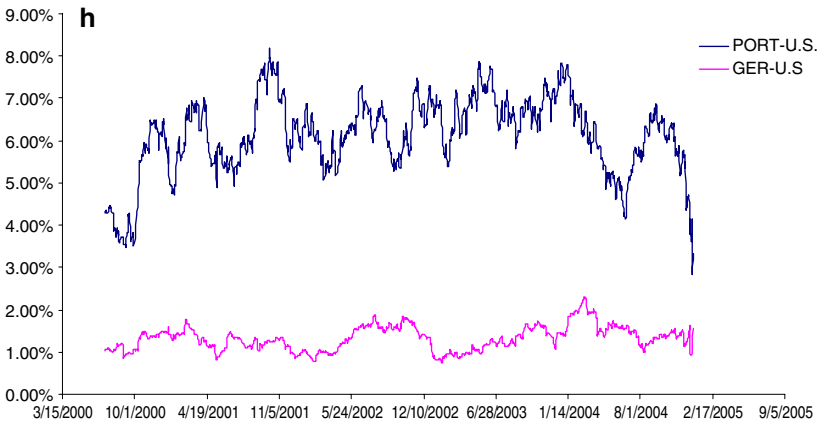


Source: Datastream \Thomson Inc.  
Italy-U.S. stands for the variance ratio of yield spreads of Italy over U.S. on explaining the yield differentials among Euro markets  
GER- U.S. stands for the variance ratio of yield spreads of Germany over U.S. on explaining the yield differentials among Euro markets

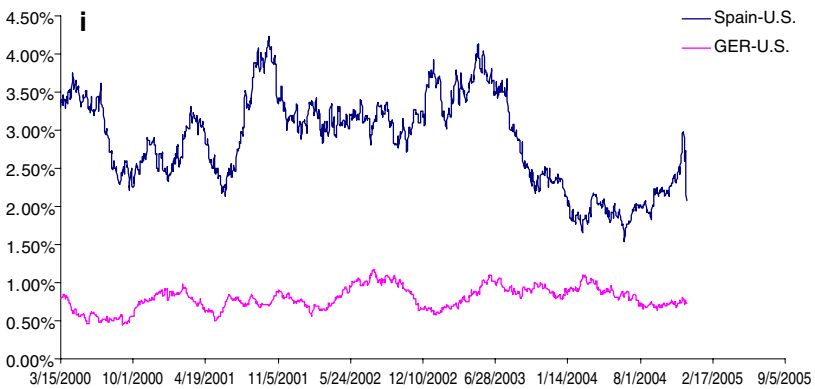
**Fig. 6** continued



Source: Datastream \Thomson Inc.  
NETH-U.S. stands for the variance ratio of yield spreads of Netherlands over U.S. on explaining the yield differentials among Euro markets  
GER-U.S. stands for the variance ratio of yield spreads of Germany over U.S. on explaining the yield differentials among Euro markets

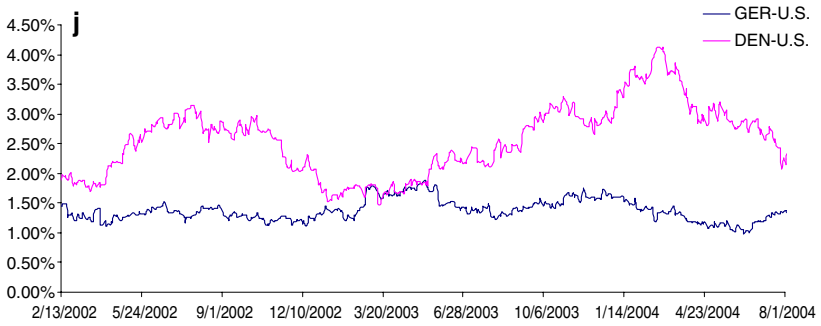


Source: Datastream \Thomson Inc.  
PORT-U.S. stands for the variance ratio of yield spreads of Portugal over U.S. on explaining the yield differentials among Euro markets  
GER-U.S. stands for the variance ratio of yield spreads of Germany over U.S. on explaining the yield differentials among Euro markets

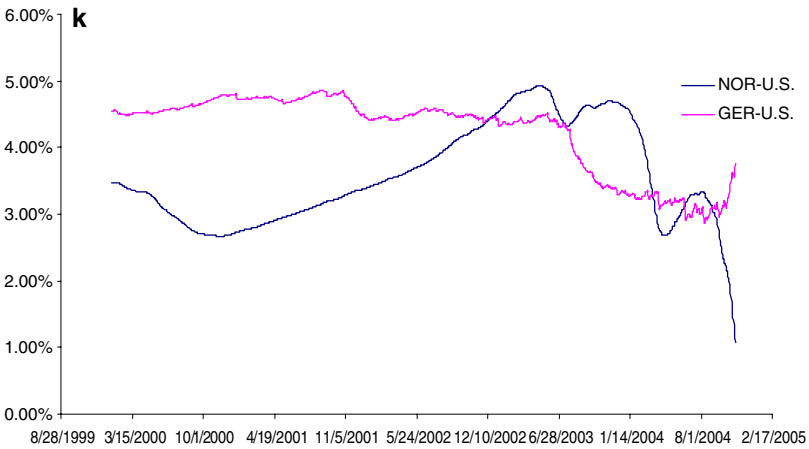


Source: Datastream \Thomson Inc.  
PORT-U.S. stands for the variance ratio of yield spreads of Spain over U.S. on explaining the yield differentials among Euro markets  
GER-U.S. stands for the variance ratio of yield spreads of Germany over U.S. on explaining the yield differentials among Euro markets

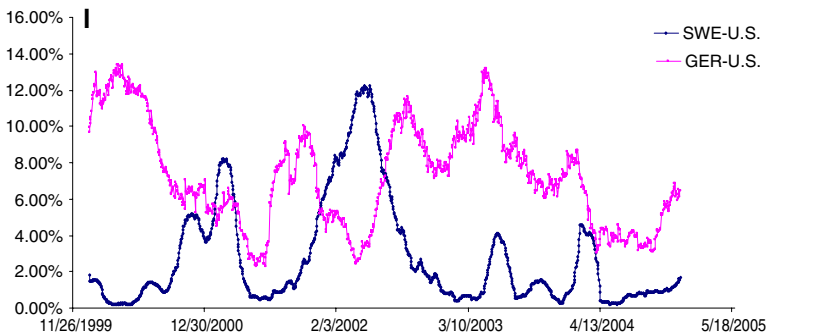
Fig. 6 continued



Source: Datastream \Thomson Inc.  
 DEN-U.S. stands for the variance ratio of yield spreads of Spain over U.S. on explaining the yield differentials among Euro markets  
 GER- U.S. stands for the variance ratio of yield spreads of Germany over U.S. on explaining the yield differentials among Euro markets



Source: Datastream \Thomson Inc.  
 NOR-US stands for the variance ratio of yield spreads of Norway over US on explaining the yield differentials among Euro markets  
 GER- US stands for the variance ratio of yield spreads of Germany over US on explaining the yield differentials among Euro markets



Source: Datastream \Thomson Inc.  
 Swe-U.S. stands for the variance ratio of yield spreads of Norway over US on explaining the yield differentials among Euro markets  
 GER- U.S. stands for the variance ratio of yield spreads of Germany over US on explaining the yield differentials among Euro markets

Fig. 6 continued





Fig. 6 continued

Variance ratios are defined as;

$$\frac{\phi^{iu^2} \varepsilon_t^{iu^2}}{\sigma_t^{ig^2}}, \tag{7}$$

$$\frac{\phi^{ug^2} \varepsilon_t^{ug^2}}{\sigma_t^{ig^2}}. \tag{8}$$

These ratios simply measure the goodness of the fit of the model. Basically, they give us an induction about how significant the spillover effects are for the yield differential regressions. In Fig. 6a–m, the ratios are illustrated for the entire period. It is observed that yield differentials of each euro benchmark bond over U.S. benchmark bond explain yield differentials among euro markets more accurately than a comparison of the yield differentials of the Germany benchmark bond over U.S. benchmark bond. These results denote that there are significant variations in the bond yields among euro bond markets. Added to these, they are explained more by the fluctuations of government bond yield differentials between market *i* and U.S., namely Eq. 7, typically not by the volatility of Germany and U.S. yield differentials, namely Eq. 8. The effect of the latter one is relatively smaller.

For non-euro European markets, Denmark, Sweden, and UK, the spillover effects of bond yield differentials of euro member *i* over U.S. bond are relatively small compared to yield differentials of euro member *i* over the Germany benchmark bond. However, the effect of the Germany benchmark bond yield differential relative to U.S. is not strong enough to explain the fluctuations of Norway government bond yields, compared to bond yield differentials of Norway benchmark bond relative to Germany government bonds. Since Norway government bond market is closely correlated with German bonds

**Table 6** Multivariate GARCH model for euro government bond returns with weekly data

	Return spillovers		Volatility spillovers	
	$\phi^{iu}$	$\phi^{ug}$	$\delta^{iu}$	$\delta^{ug}$
Austria	0.33*** (3.13)	0.07 (0.95)	0.02*** (3.21)	0.01 (0.44)
Belgium	0.55*** (3.21)	0.71 (1.54)	0.22*** (7.43)	0.01 (0.17)
Finland	0.27*** (18.7)	0.06 (0.77)	0.33*** (6.71)	0.01 (1.62)
France	0.87*** (13.2)	0.45** (3.12)	0.61*** (7.11)	0.02*** (3.83)
Greece	0.23*** (5.11)	0.41*** (3.66)	0.62** (5.04)	0.33*** (8.18)
Ireland	0.72*** (16.3)	0.15*** (6.23)	0.66** (5.35)	0.02*** (4.88)
Italy	0.35*** (6.32)	0.52 (0.23)	0.71*** (4.26)	0.01 (0.14)
Netherlands	0.81*** (14.12)	0.01 (0.86)	0.33*** (9.55)	0.01 (0.21)
Portugal	0.91*** (9.85)	0.32** (2.01)	0.44*** (9.56)	0.01 (1.62)
Spain	0.81*** (7.11)	0.76 (0.61)	0.35*** (4.11)	0.52 (1.77)

T-statistics are in parenthesis denoting \*\*\*1%, \*\*5%, and \*10% significance. The estimated model is

$$\Delta S_t^{ig} = \alpha^{ig} + T_1 (Liq_t^i - Liq_t^g) + \eta_1 (Mat_t^i - Mat_t^g) + \phi^{iu} \varepsilon_t^{iu} + \phi^{ug} \varepsilon_t^{ug} + \varepsilon_t^{ig}.$$

$$\sigma_t^{ig^2} = \alpha^{ig} + \lambda^{ig} \sigma_{t-1}^{ig^2} + \omega^{ig} \varepsilon_{t-1}^{ig^2} + \delta^{iu} \varepsilon_t^{iu^2} + \delta^{ug} \varepsilon_t^{ug^2}.$$

Yield differentials for euro members benchmark bonds over Germany benchmark bond  $S_t^{ig}$  would be explained through particular level of reactions of euro market  $i$  to the global shocks occurred in U.S.,  $\phi^{iu}$ , and the reactions of Germany bond markets to the to those shocks,  $\phi^{ug}$ . In the second regression the volatility of the yield differentials is explained by the spillover effects, particular level of reactions of each euro market benchmark bond to U.S. based shocks and German benchmark bond to U.S. based shocks.

recently, the Norway bond market might has similar pattern just like with other euro markets.

### 6.3 Weekly data estimations of spillover effects

For the framework of our analysis, we employed daily dataset. But there exist problems with the international daily bond price dataset. We note that euro area shocks generally affect U.S. returns on the same calendar day, whereas U.S. originated shocks affect European markets only on the following day due to the differences in asset trading times. Therefore, we need to re-perform same multivariate GARCH models by employing weekly dataset. The results presented in Table 6 contains GARCH model estimations with weekly basis data, not basically different from previous results. Government bond yield differentials among euro benchmark bonds are mostly affected from the

**Table 7** The effect of international risk factors on spillover coefficients

	$\nu$	$\xi$
Austria	0.002	0.021***
Belgium	-0.01	0.024**
Finland	-1.33	-0.0077
France	0.22***	0.0019***
Greece	1.23	-0.0044
Ireland	0.33**	0.005*
Italy	0.35**	0.023***
Netherlands	1.01	-0.044
Norway	-0.23*	-0.0042*
Portugal	-0.57	0.031***
Spain	0.34*	0.001**
Denmark	-0.33*	0.009**
Sweden	0.22	0.004*
U.K.	0.34***	0.001***

The estimated model is

$$\sigma_t^{ig^2} = a^{ig} + \lambda^{ig}\sigma_{t-1}^{ig^2} + \omega^{ig}\varepsilon_{t-1}^{ig^2} + \delta^{iu}\varepsilon_t^{iu^2} + \delta^{ug}\varepsilon_t^{ug^2}. \tag{4.a}$$

We relaxed the assumption of the parameters for spillover are fixed:

$$\delta_t^{iu} = \nu + \xi X_t.$$

\*\*\*1%, \*\*5%, and \*10% are denoting significance.  $X_t$  is the variable for measuring the international risk factors.  $X$  is the spreads between the yields on U.S. AAA rated corporate bonds and government bonds (for 10 years).

**Table 8** The effects of macroeconomic announcements on spillover coefficients

Countries	$\nu$	U.S. CPI	U.S. PPI	U.S. retail sales	U.S. industrial production
Austria	0.02	0.03**	0.07**	0.005**	0.007*
Belgium	-0.01**	0.01*	-0.004	0.03**	0.005**
Finland	0.02**	0.0011*	0.008***	0.001**	-0.001*
Denmark	0.04*	0.002**	0.008**	0.001***	-0.001**
France	0.03	0.001	-0.001	0.004*	0.01*
Greece	-0.01	0.001***	0.006	0.004*	0.002*
Ireland	0.02*	0.001***	0.0007*	0.004**	0.002*
Italy	0.04*	0.002***	0.0003	0.005***	0.002***
Netherlands	-0.03*	-0.004***	0.004	-0.004	0.002**
Norway	0.04**	-0.002**	-0.004*	-0.05	0.003*
Portugal	0.04*	0.005**	0.004	0.007**	0.003**
Spain	-0.07**	0.002***	-0.002	0.003	0.004**
Sweden	0.03*	0.002*	0.002*	0.003*	0.003*
U.K.	0.03**	0.01*	0.01***	0.001**	-0.001*

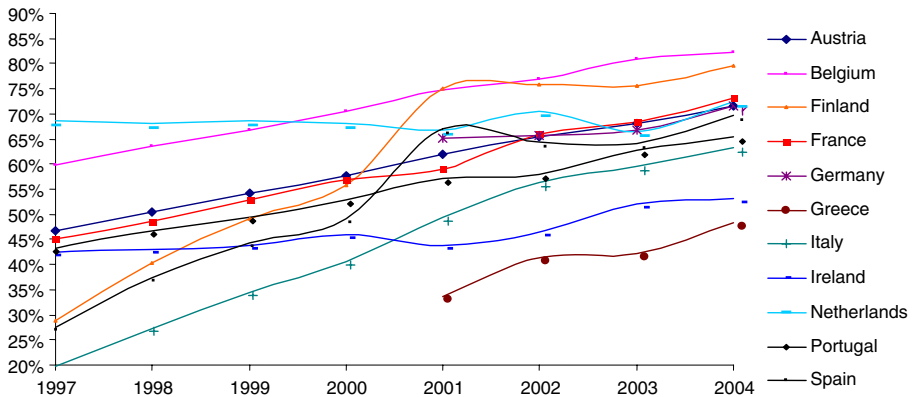
The estimated model is

$$\sigma_t^{ig^2} = a^{ig} + \lambda^{ig}\sigma_{t-1}^{ig^2} + \omega^{ig}\varepsilon_{t-1}^{ig^2} + \delta^{iu}\varepsilon_t^{iu^2} + \delta^{ug}\varepsilon_t^{ug^2}. \tag{4.a}$$

We relaxed the assumption of the parameters for measuring the spillovers is fixed:

$$\delta_t^{iu} = \nu + \xi X_t.$$

\*\*\*1%, \*\*5%, and \*10% are denoting significance.  $X$  is the macroeconomic announcements released in U.S.



Data is obtained from IMF, CPIS database for years 1997-, 2001-2004. The graph illustrates the Euro share in each country's foreign bond holdings. Euro share=value of foreign bond holdings held by Euro member in Euro area is divided by the total value of foreign portfolio held by that country in the world.

Fig. 7 Euro BOND BIAS of EMU members

pairwise yield differentials of each benchmark bond over U.S. benchmark bonds. The coefficients  $\phi_t^{iu}$  and  $\delta_t^{iu}$  are positive and statistically significant whereas  $\phi_t^{gu}$  and  $\delta_t^{gu}$  are not.

### 7 The effects of global risk factors on spillover effects

At this moment we relaxed the assumption that parameters of the spillover effects in Eq. 5.a are fixed and we modeled the parameters as;

$$\delta_t^{iu} = \nu + \xi * X_t . \tag{9}$$

$X$  contains the variables for measuring the international risk factors explained in the previous sections. Tables 7 and 8 represent the effects of common news and international risk factors on the spillover coefficients. The coefficient of  $\xi$  is positive and significant for explaining the parameter  $\delta_t^{iu}$ . Economically speaking, macroeconomic announcements, global shocks and the international risk factors have undeniably affected the spillover effects coefficients in Eq. 4. We can certainly conclude that the distortion of euro bond markets integration exists due to the macroeconomic announcements released in the global markets.

### 8 Foreign portfolio decisions of euro area domestic investors: an alternative explanation to spillover effects

Our empirical analysis indicates that even for each euro bond market, the effect of global shocks is different. In the variance ratio analysis, it is illustrated

that for pairwise yields among euro region bond markets the differentials of benchmark bonds over U.S. benchmark bonds have more explanatory power than euro market bond yield differentials over Germany benchmark bonds. Euro markets have generally performed as expected, except for Greece and Ireland. For those bond markets, the effect of yield differentials relative to Germany benchmark bonds is significant for both return and volatility regressions. Besides, by the variance ratio analysis, we demonstrate that the yield differentials for those benchmark bonds over Germany bonds explain more yield differentials across the euro region as compared to the yield differentials for those market bonds over U.S. benchmark bonds.

An alternative explanation for why Ireland and Greece lean towards the outside of the euro markets might be that these countries' "euro bond bias" levels<sup>21</sup> are relatively lower compared to other euro members. Figure 7 shows the volume of foreign bond holding portfolios of euro countries all over the world. Investors in Ireland and Greece hold more bond portfolios from other OECD markets instead of euro markets, whereas the rest of euro members' "euro bias" levels range from 60% to 80%, which are much higher than Greece or Ireland.

## 9 Concluding remarks

The fundamentally changed structure of the European bond markets has been triggered by the Maastricht treaty. The fiscal position of the euro members have strengthened, and previously fiscally vulnerable members such as Greece, Portugal and Italy have experienced incredible convergence to other euro members in terms of government bond yields. After the inception of the euro, this convergence performance has carried on, government bond yield differentials among these markets have decreased to very low levels. Macroeconomic indicators were not helpful to explain the differentials at this time.

We find that after controlling the market specific factors the common news through macroeconomic announcements and international risk factors are important factors to explain the yield differentials among euro benchmark government bonds. The integration of euro bond markets is enhanced when local factors diminish their importance on yield differentials among the members. We also find that the default risk no longer can explain the bond yield differentials in the euro area, since high default risk premium markets might outlay lower rates of bond yields. According to these findings, one can possibly expect that full financial integration has taken place in euro area. However, it

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<sup>21</sup>Euro bond bias refers to the euro share of international bond portfolios in the total volume of the international portfolio.

would not be totally true to conclude like that. Even though default risk factors are eliminated in those markets, there are other factors that might explain the bond yield spreads. The global risk factors-through common news-cause distortions in the asset pricing of the government bond markets across euro bonds.

After the start of monetary union, various responses of the markets to global shocks become the most important factor to explain the yield differentials in euro area bond markets. Ultimately, we conclude that full financial integration has not existed yet in the euro bond markets, since the global factors are still effective on the benchmark bonds in different levels. Besides, we model the volatility of yield differentials with a time varying integration process and find that changes in U.S. bond yield curve have a significant impact on the volatility of benchmark bond yield differentials in the euro area. The volatility of the euro area yield differentials is mostly explained by the various level responses of euro area markets to the changes in U.S. government bond yields. We find that almost all members have experienced fluctuations in the bond yields and these fluctuations are not homogenous across the members, creating a distortion in the yield differentials. When we observe the volatility of yield spreads in the euro area, it is again undeniably seen that full financial integration is not achieved for these markets.

## Appendix

Macroeconomic announcements<sup>22</sup> used in paper, are listed as,

**United States:** From the large range of U.S. economic announcements, we employ only seven, namely changes in non-farm payrolls (USNFP), NAPM (USNAPM), CPI (USCPI), PPI (USPPI), unemployment (USUNEMP), hourly earnings (USHRLYE), industrial production (USINDP), trade in goods and services (USTRDGS), final gross domestic product (USGDPF), housing starts (USHSES), and U.S. retail sales (USRSL). We have followed Fleming and Remolona (1999) and selected these indicators based on their paper. However, only four of them are statistically significant and illustrated in the tables (Tables 9, 10, and 11).

**Germany:** Unemployment Rate, Producer Price Index, Consumption Price Index

**Euro Area:** Trade Balance, Money Supply (M3), Consumer Price index (Harmonized), Producer Price Index, Unemployment Rate

<sup>22</sup>It is assumed that the effect of the announcements on the market will be simultaneously. The announcements are generally made before 11.00 am. The announcements realized in US will be effective on the following business day in euro markets.

**Table 9** Unit root test results for the variables

Country <i>i</i>	$S_t^{ig}$	$S_t^{iu}$	$\Delta S_t^{ig}$	$\Delta S_t^{iu}$
Austria	-1.74	-1.73	-21.21	-17.81
Belgium	-3.18	-3.96	-25.19	-28.68
Denmark	-4.26	-3.30	-23.26	-28.44
Finland	-1.71	-1.78	-23.81	-25.66
France	-4.16	-4.02	-40.18	-41.07
Greece	-4.33	-4.33	-9.74	-9.41
Ireland	-4.62	-4.97	-22.67	-24.88
Italy	-1.64	-3.06	-9.77	-29.42
Netherlands	-3.85	-3.57	-24.93	-25.23
Norway	-1.84	-2.21	-47.66	-34.27
Portugal	-3.88	-4.14	-14.14	-22.18
Spain	-3.78	-3.66	-13.86	-21.11
Sweden	-3.89	-2.83	-21.15	-22.01
U.K.	-2.26	-2.99	-19.79	-22.32

$S_t^{ig}$  is the change in yield differentials for 10 year government bonds for country *i* over Germany benchmark bond.  $S_t^{iu}$  is the change in yield differentials for 10 year government bonds for country *i* over U.S. benchmark bond. In order to test the stationarity of the series, Augmented Dickey-Fuller test has been performed. The MacKinnon critical values at 1, 5, and 10% are -3.96, -3.41, and -3.12, respectively.

**Table 10** Stationary tests for multivariate GARCH estimation

Country <i>i</i>	GARCH	ARCH
	$\lambda^{ig}$	$\omega^{ig}$
Austria	0.57***	0.33***
Belgium	0.53***	0.44**
Denmark	0.1**	0.69***
Finland	0.51***	0.13***
France	0.32***	0.73**
Greece	-0.1	0.47***
Ireland	0.31***	0.05**
Italy	0.19***	0.75***
Netherlands	0.69***	0.15***
Norway	0.03***	0.02***
Portugal	0.5***	0.31**
Spain	0.21***	0.32***
Sweden	0.25***	0.33***
U.K.	0.22**	0.17**

The estimated model is

$$S_t^{ig} = a^{ig} + B_1 S_{t-1}^{ig} + T_1 (Liq_t^i - Liq_t^g) + \eta_1 (Mat_t^i - Mat_t^g) + \phi^{iu} \varepsilon_t^{iu} + \phi^{ug} \varepsilon_t^{ug} + \varepsilon_t^{ig} .$$

$$\sigma_t^{ig^2} = \alpha^i + \lambda^{ig} \sigma_{t-1}^{ig^2} + \omega^{ig} \varepsilon_{t-1}^{ig^2} + \delta^{iu} \varepsilon_t^{iu^2} + \delta^{ug} \varepsilon_t^{ug^2} .$$

\*\*\*1%, \*\*5%, and \*10% are denoting significance.

$\Delta S_t^{ig}$  is the change in yield differentials for 10 year government bonds for country *i* over Germany.  $Liq_t^i$  is the bid-asking spread of traded bonds.  $Mat_t^i$  is the residual maturity. Yield differentials for euro members benchmark bonds over Germany benchmark bond  $S_t^{ig}$  would be explained through particular level of reactions of euro market *i* to the global shocks occurred in United States,  $\phi^{iu}$ , and the reactions of Germany bond markets to the to those shocks,  $\phi^{ug}$ . In the second regression the volatility of the yield differentials is explained by the spillover effects, particular level of reactions of each euro market benchmark bond to US based shocks and German benchmark bond to US based shocks ARCH and GARCH coefficients will be  $\omega^{ig}$  and  $\lambda^{ig}$  respectively. Conditions for stationary holds when  $\omega^{ig} > 0$ ,  $\lambda^{ig} > 0$ , and  $\omega^{ig} + \lambda^{ig} < 1$ .

**Table 11** Stationary tests for multivariate GARCH estimation

Country <i>i</i>	GARCH	ARCH
	$\lambda^{iu}$	$\omega^{iu}$
Austria	0.33***	0.17**
Belgium	0.44***	0.55**
Denmark	0.17*	0.39**
Finland	0.42***	0.48**
France	0.35***	0.38**
Greece	0.41**	0.5***
Ireland	0.41***	0.07**
Italy	0.61***	0.57***
Netherlands	0.44***	0.47***
Norway	0.07***	0.36***
Portugal	0.45***	0.38**
Spain	0.52***	0.62**
Sweden	0.51**	0.41***
U.K.	0.09*	0.29**
Switzerland	0.28**	0.54**

The estimated model is

$$\Delta S_t^{iu} = a^{iu} + T_1 (Liq_t^i - Liq_t^{iu}) + \eta_1 (Mat_t^i - Mat_t^{iu}) + \phi^{ig} \varepsilon_t^{iu} + \phi^{ug} \varepsilon_t^{ig} + \varepsilon_t^{iu}.$$

$$\sigma_t^{iu^2} = \alpha^i + \lambda^{iu} \sigma_{t-1}^{iu^2} + \omega^{iu} \varepsilon_{t-1}^{iu^2} + \delta^{ig} \varepsilon_t^{ig^2} + \delta^{ug} \varepsilon_t^{ug^2}.$$

\*\*\*1%, \*\*5%, and \*10% are denoting significance.

$\Delta S_t^{iu}$  is the change in yield differentials for 10 year government bonds for country *i* over U.S..  $Liq_t^i$  is the bid-asking spread of traded bonds.  $Mat_t^i$  is the residual maturity. Yield differentials for euro members benchmark bonds over Germany benchmark bond  $S_t^{iu}$  would be explained through particular level of reactions of euro market *i* to the global shocks occurred in Germany,  $\phi^{ig}$ , and the reactions of Germany bond markets to the to those shocks,  $\phi^{ug}$ . In the second regression the volatility of the yield differentials is explained by the spillover effects, particular level of reactions of each euro market benchmark bond to US based shocks and German benchmark bond to US based shocks ARCH and GARCH coefficients will be  $\omega^{iu}$  and  $\lambda^{iu}$  respectively. Conditions for stationary holds when  $\omega^{iu} > 0$ ,  $\lambda^{iu} > 0$ , and  $\omega^{iu} + \lambda^{iu} < 1$ .

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