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Macroeconomic determinants of European stock and government bond correlations: A tale of two regions.

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Abstract

This paper studies the dynamic correlation between stocks, between government bonds and between stocks and bonds within the Euro-zone in the last decade. In order to better understand the development of the financial market we argue that it is necessary to analyse all such relations simultaneously rather than focus at one. We firstly calculate the dynamic correlation for the previous asset classes. Results presented at the asset-region level, i.e. north-stock, north-bonds, south-stocks and south-bonds, visualise the divergence in integration in Europe and highlight the heterogeneity in these markets. Secondly, we study the macroeconomic factors that determine these correlations. We find that, when we allow for regional division, not only cross-asset correlations within regions behave differently from each other, but also cross-assets cross-regions dynamic correlations can be explained with macroeconomic factors such as the relative market uncertainty between countries and balance of payments dynamics.

JEL: C23, E44, G14, G15

Keywords: Currency union, financial markets, time-varying correlation.

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1 Introduction

In the first decade after the introduction of the Euro, Euro-zone financial markets showed an increasing degree of integration and of economic and financial convergence. This feature was present both in the equity and sovereign bond market. With respect to the latter, it seemed that differences in current accounts, balance of payments, debt ratios and growth rates were not strongly highlighted by the markets.[1] However, after the Greek financial mis-report and the beginning of the sovereign debt crisis , all the previous mentioned differences within the Euro-zone have apparently been revalued by the markets and mirrored in sovereign bond spreads as fears of southern countries' default mounted. One well-known evidence at this point was the flight-to-quality from southern countries' bonds towards the "risk-free" northern countries' counterparts. The equity markets instead did not suffer such a strong flight-to-quality between countries but rather an elevated degree of volatility.

Starting from those two observations, this work studies the dynamic correlations of the bond, stock and bond-stock markets in the Euro-zone in a new way. In order to understand the development of financial markets in Europe, it is insufficient to look only at bonds between countries or only at the correlation of bonds and stocks in countries individually. What is necessary is to analyse all relations simultaneously.

If we look at a change in the stock-bond correlation in one region without considering the other markets we might be tempted to explain it in terms of structural changes in that regional economy. But if by looking at a wider picture we observe that both assets have experienced a decrease in correlation with the other region's assets, we could think that the previous change in correlation was due to the location of the assets rather than to a change in characteristics between the two.

This general approach to financial markets enables us to highlight patterns between assets and countries that would otherwise remain hidden and neglected. Moreover this comprehensive perspective helps to disentangle causal relations from casual first impressions.

This approach is in contrast to studies that look at the relation of an asset class between countries, or at a relation of asset classes in some markets. Therefore, for the estimations we do not consider the EMU as one economic unit but, with the benefit of hindsight, we divide our sample of Euro-zone countries in 2 groups, north and south and proceed in two steps.[2]

First, for each country pair and asset combination we compute the time-varying dy-

[1] Besides economic indicators, there are institutional (government setup, health and elderly insurance) and sociological (participation rate, demography, etc.) differences that are highlighted now but were of no concern before.

[2] We follow the same regional division as the one of Jaumotte and Sodsriwiboon (2010) driven by current account imbalances considerations. See also Lane and Milesi-Ferretti (2007).

namic conditional correlations (DCC) using Engle (2002) methodology, which have shown to reflect well relations among markets. By grouping together the correlation pairs at the asset-region level we study six categories of correlations: north-bond north-stock, south-bond south-stock, north-bond south-bond, north-stock south-stock, north-bond south-stock and north-stock south-bond.

In the second step we conduct a panel study to find the macroeconomic determinants of the pairwise correlations of these six asset market categories. Theory predicts differentiated impacts of macroeconomic fundamentals based on cash flow determinants, risk determinants and the interaction of the two. We will analyse to what extent such determinants changed since the European debt crisis. This method allows us to look at all country-asset relations simultaneously and at how macroeconomic factors affected these relations differently.

Since our methodology implies to analyse the entire set of correlations, we can relate to the previous literature that looked at some of the individual relations only. In this way we extend the existing literature by combining the rising sovereign bond market literature with the well-documented stock-bond factor pricing and international stock market convergence literature.

We find that the division of North and South helps to visualise the divergence in the Euro-zone and subsequently to explain the underlying determinants of such divergence. The collapse of the bond market over time is clearly leading, and its effects on the other asset markets are apparent.

The regression results show that the correlations are mostly driven by two factors, the relative uncertainty between countries and balance of payments dynamics, represented by the current account and government debt. We find that the balance of payments dynamics is not only important for the pricing of bonds between countries, but even for the stock markets. However, debt dynamics appear unimportant once we control for other economic fundamentals and unobserved fixed effects. Moreover, we find no evidence that the results are driven by a change in investor's perceptions on the economic situation but that the variation in economic fundamentals can explain most of the development of markets comovements.

The remainder of the paper is set out as follows, section 2 reviews the literature, section 3 estimates the asset market correlation and documents the DCC results, section 4 presents the panel regressions and finally section 5 concludes.

2 Related Literature

We will work with dynamic conditional correlations as a measure of markets relations. Such correlations can be interpreted as a measure of interdependence and integration but a careful discussion on that is beyond the scope of this paper. Nevertheless, the general observation is that markets with very similar fundamentals both in terms of supply and demand dynamics will be positively correlated. While there is a wide literature assessing the international (as well as European) correlations of equity and bond markets as distinct entities, the literature on the cross-asset correlations has gained momentum only recently.[3,4] The literature in this field moved in two directions: one investigating comovement in the cross-asset market and attesting the asymmetric nature of stock and bond market conditional variances and a second strand trying to introduce economic variables in order to determine the factors driving the bond-stock market correlation.

Strictly belonging to the first category employing a DCC model we have the studies of Scruggs and Glabadanidis (2003) and de Goeij and Marquering (2004) on the stock-bond correlation in the US. Both studies find a time-varying relation in conditional covariances. Scruggs and Glabadanidis (2003) find that bonds respond symmetrically to bond shocks and are "unaffected" by stock returns' shocks while stock variance responds asymmetrically to both stock and bond returns' shocks. De Goeij and Marquering (2004) highlight the asymmetric leverage effect in the conditional covariances: stock-bond covariances tend to be relatively low after bad news in the stock market and good news in the bond market.

Cappiello et al. (2006) add to the previous papers both in terms of methodology, by introducing an asymmetric dynamic conditional correlation model, and by the sample selection as they include European, Australasian as well as North American markets using data from 1987 to 2002. Regarding the Euro-zone they found an almost perfect correlation among bond yields after the introduction of the monetary union as well as an increased correlation of the stock returns in the Euro-zone. Regarding the degree of correlation of the stock-bond market they attest a stable and positive long-term relation before and after the introduction of the single currency.[5] Nevertheless, they found evidence of a "flight-to-quality" effect, defined as a move of capital from equities to safer assets in times of financial turmoil.

With respect to the second direction of research, on the determinants of comovements, the work of Kim et al. (2006) is the closest to our approach, studying the integration across the bond and stock markets within the Euro-zone as well as Japan and the US. Their attention is pointed to the introduction of the EMU and its effect on the within-market financial integration as well as the interdependence between financial markets. They find that real economic integration and the absence of currency risk leads to financial integration, e.g. intra-bond and intra-stock markets integration. However, monetary policy convergence may have created uncertainty about the economic future of the European

[3] A good survey for works dealing with the European stock market integration but using different methodologies can be found in the literature review of Kim et al. (2005). For a review on the sovereign bond integration see Laopodis (2008, 2010).

[4] Throughout the paper we refer to sovereign bonds simply as bonds. In no part of this paper do we consider the corporate bond market.

[5] The correlation of the EMU bond returns and the American and Australasian stock returns moved from slightly positive to slightly negative with the breaking point in 1999.

monetary union thereby stimulating a segmentation, e.g. a small but negative correlation between stock and bond markets. Their time horizon spans from March 1994 to September 2003. We employ data on the Euro period (2000-2012) on a selection of euro-zone bond and stock markets. Our results confirm the segmentation of these markets until the fall of 2008. We show that by differentiating among European regions and by taking into account cross-asset relations, a different pattern of correlations in European markets appears since the start of the European debt crisis.

Kim et al. (2006) also try to find the determinants of stock-bond correlations within countries given macroeconomic variables that are linked to open economies such as exchange rate volatility. Nevertheless, they find only marginal effects for the monetary variables. We extend their analysis by taking into account more macroeconomic variables that are potentially capturing the different price factors. Secondly, we test the determinants in a panel of across countries-assets correlations as opposed to within-country correlations.

Andersson et al. (2008) conduct a similar estimation for the within country stock-bond correlations regressed on national economic variables such as inflation, GDP growth and stock market uncertainty. They find only marginal explanatory effects. Finally, Li (2002) develops a theoretical foundation to support his estimation of dynamic stock-bond correlations regressed on uncertainty and inflation factors. In one of his tests he uses a dynamic conditional correlation model on a panel of G7 countries taken as individual cross-section observations.

Concerning intra-bond market analysis one study we relate to is Barrios et al. (2009). This study tests the bond spread of each country relative to the German Bund with certain risk factors such as the market perceived risk of defaults and liquidity risk.

Concerning the international stock-market integration there have been many studies. Kim et al. (2005) apply the same strategy as for their later article between bonds and stocks. Using real economic and financial variables they try to explain dynamic correlations and find that the financial variables work best as within country determinants. Bracker et al. (1999), while using a different measure for countries influence on each other, use a similar cross-country setup as we do where all countries in the data set are compared to each other with relative and difference variables such as relative exports and imports and the difference of inflation and real interest rates.

These previous studies attempt to find the determinants of comovements of assets but often limit themselves to one of the three categories, bond-stock, bond-bond and stock-stock. The first of the three is mostly within country oriented, even when multiple international markets are taken into the analysis. The other two categories are by their nature international. Our study argues that it is essential to analyse all the three categories of correlations in the Euro-zone simultaneously.

3 Estimating Comovements

In this section we estimate European asset markets correlations. To study the properties of the Euro-zone equity and government bond returns we use a multivariate dynamic conditional correlation model of Engle (2002). These multivariate studies are computed in two steps: first an univariate estimation is computed for all series, secondly, while using the standardised residuals from the first stage, a multivariate estimation results in the dynamic conditional correlations. In order to justify the estimation model used for the univariate and multivariate stage we discuss shortly the properties of the data.

3.1 Descriptive statistics

Our empirical analysis is conducted on a sample of eight European countries belonging to the Euro-zone. We decided to employ an even number of countries for the sake of symmetry in the second part of our study when we divide the sample in northern countries–Germany, France, Austria and the Netherlands–and southern countries–Greece, Italy, Portugal and Spain.[6]

The data used for this study are indexes for stocks and bonds taken from Datastream. For equity we employed the MSCI price index while for bonds the 10 years benchmark DS government index. Daily data is collected on the sample period spanning from 31 December 1999 until 24 February 2012. We have then a total of 3173 observations.

Table 1 provides descriptive statistics on the returns of both assets' categories. The statistics are presented clustered by regions and asset typologies. Namely north stocks, south stocks, north bonds and south bonds. Stocks are more volatile than bonds, positively skewed and with a relative high degree of kurtosis. This asset category seems indeed to have behaved homogeneously in the two regions over the sample period. When we look at bonds instead we can immediately detect two groups: northern and southern countries. We register a much higher skewness and kurtosis in the south bonds' returns than in the north ones. Regarding volatility all the southern assets present a slightly higher standard deviation than their northern counterparts. Interestingly, northern countries' bonds present a negative skewness and a degree of kurtosis that resembles more the equity returns behaviour detaching widely from the south country bond behaviour.

[6] We do not provide a formal test for our allocation of countries to regions. Note that the southern countries were often bundled together in the popular media in the acronym PIGS. The descriptive statistics below provide a basis for the division of regions for the bond markets more than for the stock markets. When we plotted dynamic correlations of each of the 7 markets against the German bund we found a clear division of the set of countries along the regions. A recent IMF study uses the exact same division, although expanded with more countries (Jaumotte and Sodsriwiboon, 2010). The problem is not so much in bundling the north, but rather in bundling the south. The economic situations that exist in each of them are not the same and treating them as such may obscures this fact. Nevertheless, since we aim to find general patterns between regions and we'll control for each country's situation the problem is mitigated.

Table 1: Daily data descriptive statistics

Assets' returns	Mean	St Dev	Skewness	Kurtosis	$\mathrm{corr}(x_t, x_{t-1})$
Austria stocks	0.014	1.612	0.038	11.720	0.043
France stocks	−0.002	1.537	0.152	7.811	−0.027
Germany stocks	0.002	1.609	0.161	7.418	−0.019
Netherlands stocks	−0.005	1.498	0.056	8.075	−0.022
Greece stocks	−0.058	1.939	0.330	8.682	0.041
Italy stocks	−0.016	1.475	0.103	9.039	−0.006
Spain stocks	0.004	1.574	0.383	9.889	−0.006
Portugal stocks	−0.016	1.181	0.123	11.802	0.050
Austria bonds	0.009	0.334	−0.240	5.247	0.078
France bonds	0.008	0.350	−0.099	5.842	0.015
Germany bonds	0.011	0.344	0.016	4.877	0.077
Netherlands bonds	0.011	0.329	−0.055	4.421	0.056
Greece bonds	−0.041	1.048	9.154	382.514	0.137
Italy bonds	0.005	0.402	1.676	39.671	0.133
Spain bonds	0.006	0.398	1.954	35.158	0.187
Portugal bonds	−0.010	0.674	−0.416	83.295	0.199

This preliminary analysis shows the presence of heterogeneity in bonds' returns. The evidence of such a differentiated market for European bonds was absent from previous studies (Cappiello et al., 2006) and it is a signal of a strong change in performance behaviour since the spreading of the crisis.

3.2 Dynamic Conditional Correlation Estimation

We estimate a DCC Multivariate Garch model described by Engle (2002) which is able to show the evolution of correlation across the different series in the selected data sample.

The univariate estimation, discussed below, results in standardised residual$\epsilon_{i,t} = z_{i,t}/\sigma_{i,t}$, where $z_{i,t}$ represents the residuals for each country-asset $i = 1, \dots k$ series at each time period $t = 1, \dots T$, and $\sigma_{i,t}$ its time varying variance.

The standardised residuals, $\epsilon_{i,t} = z_{i,t}/\sigma_{i,t}$, of the univariate study are passed to the multivariate stage under the assumption that the returns from the initial assets, r_t, are conditionally multivariate normal with mean zero and covariance matrix H_t, equation (1). This assumption is important for the maximum likelihood estimation of the model.

The model reads:

$$r_t|\Psi_{t-1} \sim N\ (0,\ H_t), \tag{1}$$

$$
\begin{aligned}
H_t &= D_t R_t D_t, && (2)\\
D_t &= diag\left\{\sqrt{\sigma_{i,t}^2}\right\}, && (3)\\
\epsilon_t &= D_t^{-1} z_t, && (4)
\end{aligned}
$$

$$
\begin{aligned}
Q_t &= (1-\alpha-\beta)\,\bar{Q} + \alpha\epsilon_{t-1}\epsilon_{t-1}' + \beta Q_{t-1}, && (5)\\
\bar{Q} &= E_t(\epsilon_{t-1}\epsilon_{t-1}'), && (6)\\
R_t &= diag(Q_t)^{-1} Q_t diag(Q_t)^{-1}. && (7)
\end{aligned}
$$

If we have k assets D_t is the $k \times k$ diagonal matrix of the time varying standard deviations, $\sigma_{i,t}$, from the univariate estimation with $\sqrt{\sigma_{i,t}^2}$ on the i^{th} diagonal. The expression for $\sigma_{i,t}$ could be a simple Garch model as well as any other formulations. The choice of this process is discussed below. Given a sample of T observations, ϵ_t is the $k \times T$ series of standardised residuals. Finally R_t is the time varying correlation matrix and $\bar{Q}$ is the unconditional covariance of the standardised residuals from the first stage estimation.[7]

Equations (3) and (4) refer to the univariate stage of the estimation while (5) to (7) to the multivariate one. To decide the best process to employ in the univariate stage we look at the descriptive statistics of daily raw returns. The statistics in Table 1 suggests the necessity for a Garch model that is able to detect the asymmetric nature of the data.[8] As a consequence we fitted all the series first with a simple AR-Garch and then with an AR-NAGarch and AR-EGarch.[9] The optimal number of lags both in the autoregressive part and in the relevant Garch process is decided according to Bayesian Information Criteria (BIC) and Akaike Information Criteria (AIC).

We conduct this study by comparing AIC and BIC criteria not only at the level of the single series but also by selecting groups defined by asset class and "geographical" regions. Hence we obtain four sub-samples: north-stock, south-stock, north-bond and south-bond. Our best performing model for all the different series proves to be an AR(1)-EGarch(1,1) defined for a single series as follows :

[7] Aielli (2006) shows that the DCC as setout by Engle (2002) needs theoretical corrections in the formulation but for empirical work there is no relevant difference in using either method (Aielli, 2009).

[8] While there is a widespread evidence of the asymmetrical behaviour of the stock market returns, the so called leverage effect, bond markets are generally not expected to have such a behaviour. However, a recent empirical literature found asymmetric volatility in bond returns given by macroeconomic news announcements (de Goeij and Marquering, 2006).

[9] We refer to Engle and Ng (1993) and Nelson (1991) respectively. Both models are appropriate to capture asymmetric behaviour of financial time-series.

$$r_t = \mu + \alpha_1 r_{t-1} + z_t \quad (8)$$

$$z_t = \sigma_t \epsilon_t \quad (9)$$

$$\epsilon_t \sim N(0,1) \quad (10)$$

$$ln(\sigma_t^2) = \omega + \alpha \left[\frac{|z_{t-1}|}{\sqrt{\sigma_{t-1}^2}} - \frac{1}{\sqrt{\pi/2}} \right] + \gamma \frac{z_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \beta ln(\sigma_{t-1}^2), \quad (11)$$

where (11) is the exponential Garch formulation of Nelson (1991). $E_t(|\epsilon_t|) = \sqrt{(2/\pi)}$ for the Standard Gaussian random variable ϵ_t. The coefficient β determines the degree of memory of the process; α the impact of new information and γ the asymmetric effect between positive and negative returns. Equation (11) expresses the choice of the process for the univariate series and the elements of the matrix D_t, of equation (3), in the formulation of DCC.

Since the DCC is computed in two stages, it has to be estimated in two steps. Following Engle et al. (2008b), the parameters of the model, θ, can be divided into two subgroups $\theta = (\phi, \psi)$ where the elements of ϕ corresponds to the parameters of the univariate estimation and ψ to the multivariate stage. The multivariate DCC estimation is then conditioned on the parameters of the first stage:

$$QL_2(\psi|\hat{\phi},\ r_t) = -\frac{1}{2} \sum_{t=1}^{T} \left(log(|R_t|) + \hat{\epsilon}_t^{'} R_t^{-1} \hat{\epsilon}_t \right), \quad (12)$$

where $|R_t|$ is the determinant of the correlation matrix R_t.

Particular to the DCC model is that rather than maximising the k-dimensional log-likelihood we can maximise the sum of the bivariate likelihoods: that is much easier to compute by avoiding to invert numerically the correlation matrix k times. The bivariate likelihood reads:

$$QL_2(\psi|\hat{\phi},\ r_t) = -\frac{1}{2} \sum_{t=1}^{T} \sum_{i=1}^{k} \sum_{j>i} \left(ln\left(1 - \rho_{i,j,t}^2\right) + \frac{\left(\hat{\epsilon}_{i,t}^2 + \hat{\epsilon}_{j,t}^2 - 2\rho_{i,j,t}\hat{\epsilon}_{i,t}\hat{\epsilon}_{i,t}\right)}{\left(1 - \rho_{i,j,t}^2\right)} \right). \quad (13)$$

3.2.1 Univariate estimation results

Table 2 reports the parameters' estimates for all markets. As we can observe all series present a strong memory (β) and a more or less pronounced degree of asymmetric response to (mostly negative) news (γ).

Once the single univariate series are estimated, and before passing the standardised residuals to the multivariate stage we assure that there is no further autocorrelation

Table 2: EGarch parameters

Assets' returns	ω	α	β	γ	μ	α_1
Austria stocks	0.010***	0.158**	0.983***	−0.083***	0.062***	0.027
France stocks	0.007**	0.103***	0.983***	−0.136***	0.005	−0.022
Germany stocks	0.012***	0.122***	0.980***	−0.125***	0.013***	−0.007***
Netherlands stocks	0.007***	0.121***	0.983***	−0.118***	−0.002***	−0.002***
Greece stocks	0.018***	0.167***	0.988***	−0.058***	0.021	0.064**
Italy stocks	0.007***	0.120***	0.985***	−0.109***	−0.007***	−0.018***
Spain stocks	0.010***	0.118***	0.982***	−0.119***	0.018	0.003
Portugal stocks	0.002	0.167***	0.974***	−0.091***	0.021*	0.049***
Austria bonds	0.000	0.082***	0.998***	0.014*	0.012**	0.041**
France bonds	0.000	0.092***	0.998***	0.015***	0.011***	0.023***
Germany bonds	0.000	0.071***	0.999***	0.022***	0.012**	0.054***
Netherlands bonds	0.000	0.075***	0.999***	0.016**	0.012**	0.039**
Greece bonds	0.010	0.198***	0.999***	−0.048***	0.007	0.080***
Italy bonds	0.000	0.151***	0.997***	−0.045***	0.004	0.069***
Spain bonds	0.000	0.136***	0.997***	−0.040***	0.004***	0.081***
Portugal bonds	0.011*	0.125***	1.002***	−0.035***	0.011	0.056**

Parameters of the first stage univariate estimation set out in the text.
Standard errors are based on the Hessian matrix. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 3: Univariate residuals descriptive statistics

Assets' returns	Mean	St Dev	Skewness	Kurtosis	corr(x_t, x_{t-1})	ACF	ACF2
Austria stocks	−0.021	1.000	−0.185	3.943	0.011	0.604	0.688
France stocks	−0.010	1.002	−0.206	3.422	−0.004	0.187	0.326
Germany stocks	−0.007	1.001	−0.228	3.488	−0.001	0.401	0.132
Netherlands stocks	−0.001	1.001	−0.183	3.484	0.008	0.376	0.287
Greece stocks	−0.028	1.000	0.110	4.367	0.031	0.358	0.003
Italy stocks	−0.006	1.001	−0.371	3.754	0.005	0.244	0.042
Spain stocks	−0.012	1.000	−0.131	3.826	0.005	0.202	0.013
Portugal stocks	−0.020	1.002	0.016	4.753	0.008	0.067	0.807
Austria bonds	−0.009	0.995	−0.143	3.717	0.001	0.871	0.200
France bonds	−0.006	0.994	−0.057	3.769	−0.001	0.548	0.214
Germany bonds	−0.006	0.992	−0.078	3.690	0.005	0.793	0.507
Netherlands bonds	−0.003	0.992	−0.043	3.607	0.007	0.825	0.401
Greece bonds	−0.032	0.998	−0.104	7.073	0.053	0.034	0.404
Italy bonds	−0.002	0.990	−0.177	4.893	0.017	0.319	0.000
Spain bonds	0.000	0.994	0.190	5.872	0.013	0.847	0.001
Portugal bonds	−0.038	0.999	−0.425	7.883	0.030	0.809	0.043

ACF is the Ljung-Box Q-test for residual autocorrelation (up to 20 lags), p-values reported.
ACF2 is the test for squared residuals autocorrelation.

in the standardised residuals and squared standardised residuals. Table 3 presents the same descriptive statistics as Table 1 with respect to the standardised residuals' series. Additionally, it reports the Ljung-Box Q-test for residual autocorrelation (up to 20 lags), by which we cannot reject the null hypothesis of no autocorrelation.

3.3 Dynamic Conditional Correlation Results

We will present the results divided in different categories, considering the country-asset subgroups at the aggregate level. Data are grouped at the country-asset level as follows: North-stock (Ns), North-bond (Nb), South-stock (Ss), South-bond (Sb). The main six categories we study are the within region cross-asset markets (Ns-Nb and Ss-Sb), the cross-country markets (Ns-Ss and Nb-Sb) and the cross-region cross-asset correlations (Ns-Sb and Nb-Ss).[10] In order to aggregate the 16 resulting correlations for each category we use a weighted average, where the weights are given by the stock market capitalisation for stock returns and the annual government gross liabilities for the bond returns. For both assets we used the reference value of the year 2002 to avoid having the weighting measures correlating with the return series.[11] The complete set of 16 correlations for each category are presented in Appendix A.[12]

The dynamic correlations in Figure 1 show an interesting picture of market movements of stock and bond returns between the two regions. There is one obvious case, the inter-bond market. In panel (1) a process towards perfect correlation of the European government bond market is visible since the launch of the euro. This is in line with the findings of previous and longer-sample studies attesting a drastic increase in the correlation of the Euro-bond markets since the introduction of the common currency. It shows that around the first half of the decade government bonds all over the Euro-zone were considered to be equally risky and perfect substitutes. Previous studies are in support of the idea that the introduction of the common currency lead to increased correlation both in the bond and stock market.[13]

Since the fall of 2007 this pattern in the bond market reversed dramatically as it became apparent that southern countries had been hampered strongly from the financial crisis and were at risk of default. Southern bonds were downgraded and revalued in line with the underlying risk. The correlation between north and south bonds started to decrease becoming negative in the last two years. The drop in correlation from approximately one to zero or negative values, shows clearly the period in which the southern

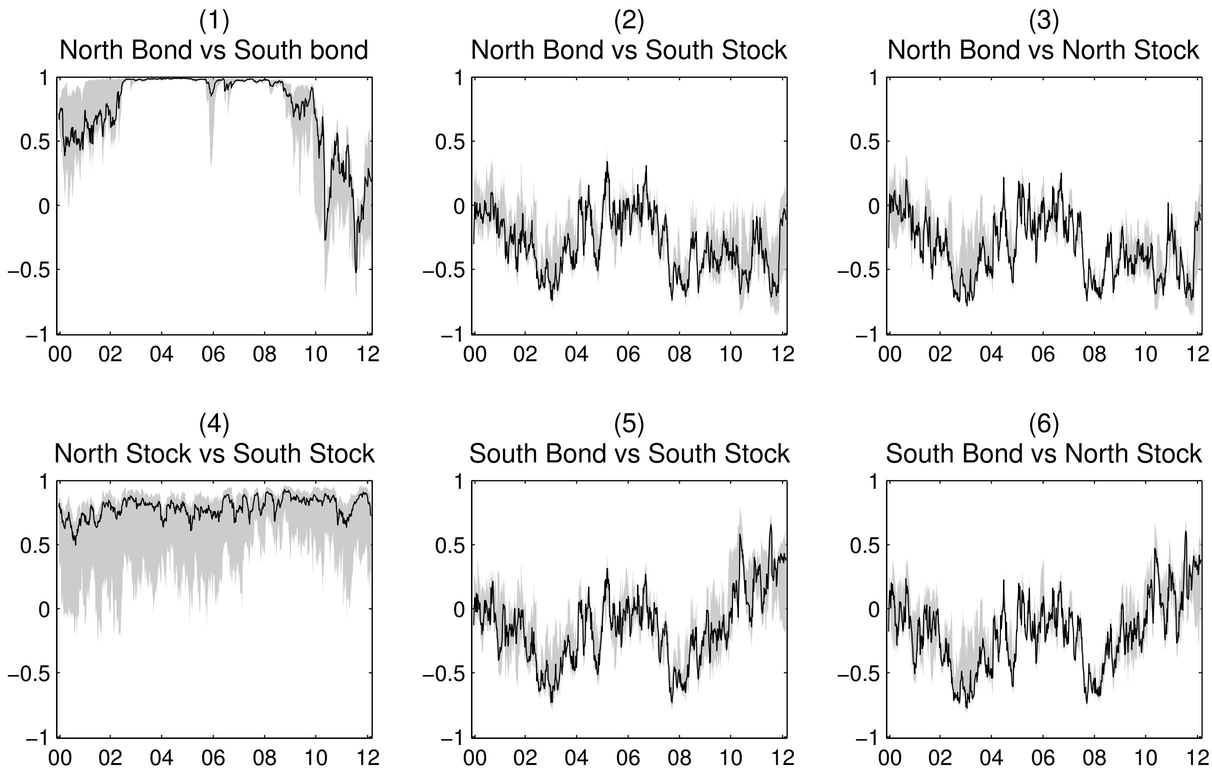
[10]We do not consider the within asset-within region categories Nb-Nb, Ns-Ns, Sb-Sb and Ss-Ss.

[11]Stock market capitalisation was obtained from Datastream, while the gross government liabilities figures come from the OECD.

[12]The correlations within every category are quite homogeneous and that is an additional reason, more than easiness of presentation, that lead us to use weighted averaged data.

[13]Among others Cappiello et al. (2006) considers the period between the 50's and 2003. Kim et al. (2006) show a similar striking increase in correlation in the European bond market studying the period 1994-2003.

Figure 1: Weighted Dynamic Conditional Correlations



Weighted average dynamic correlation series based on 16 country-asset pairs for each category (panel). The weights are constant over time and based on stock market capitalisation and gross government liabilities figures for 2002. The individual series are presented in Appendix A. Shaded areas denote the minimum and the maximum for every category at each point in time.

bond market behaviour detached from the northern one in line with the widening of the Euro-zone sovereign bond yield spreads (Deutsche Bank, 2009; ECB, 2008, 2009), and consistent with the view of de Grauwe and Ji (2012) on the mis-pricing of sovereign risk within the Euro-zone.

We interpret the correlations plots as evidence for a similar reaction across assets and across regions. For this reason we look at the correlations between stock and bond returns across the 2 regions. Looking at panels (3) and (5) of Figure 1 jointly we can observe the change in the within-region cross-asset correlations. Up to mid-2008 the pattern is similar in the two pictures showing a business cycle like behaviour remaining in the negative part of the correlation distribution. This is in line with Kim et al. (2006) and their findings of a negative correlation between bond and stock within the Euro-zone.

From mid-2008 onwards there is a divergence in the pattern of the southern and northern stock-bond markets. In contrast to previous studies we find evidence of an increase in correlation in the southern stock-bond market once we control for geographical blocks. It seems indeed that markets based on geography started to react differently to common information as if there were not two categories of assets but as if they became more. While in the north the correlation remains negative, in the southern countries' correlations increase ending up to be positive. The increase in correlation between south bonds and stocks can be explained by a joint selling of these assets against a third, safe, one.

The same pattern is visible in the comparison of panels (2) and (6) where the two bond markets are compared to the other region stock market. It is clear that the divergence between the patterns is due to the change in the performance of the southern bond market as shown in panel (1). This cross-area cross-asset comparison shows how after 2008 there was a change in the conditional correlation not only in the southern area stock-bond market but also at the cross regional level. What used to be considered a safe asset (south bond) started to co-move with the northern stock, a generally perceived more risky marker. In other words the safe asset in the "risky" area became more correlated with the risky asset in the "safe" area.

The inter-regional stock market in panel (4) does not show any of the dramatic changes that are observed in the other panels. The stock market was and remains highly correlated as given in the graph. There were some minor drops during the crisis but not too much lower values than in other periods.

The next step is to study the drivers or determinants of these correlation dynamics.

4 Estimating Determinants

4.1 Estimation Technique

We present regression results to understand the behaviour over time of the six correlation categories. There is one major difference in the way we set up our regressions compared to the literature discussed before. Studies on bond-stock correlations oftentimes have one regression per cross-section, using SURE, or separate OLS regressions. One of the implications of such strategy is that each estimated coefficient is allowed to differ across the cross-section which may be an appropriate assumption, and failing to recognise such heterogeneity when it is true would lead to potential biases (Baltagi, 2008).

Our choice of fixed coefficients for the cross-section is supported by the selection of countries. Arguably each country must be treated on its own merits but the same fundamentals should apply in the broader context of the European economy. Since we control for pair- and time-fixed effects we control for most of pair-wise and time varying unobserved effects that could be correlated with the regressors. Secondly, a separate estimation for each cross-section demands more from the time-dimension of the data. This would require us, like in other studies, to use much more data and in particular data from before the monetary union, a very different European context indeed. Using a higher frequency is not preferable, because many of the economic variables are available at no higher frequency than quarterly.

Studies on the determinants of correlations of the same asset between countries often use one benchmark country. We present cross-country panel regressions where each cross-section is a pair of two countries for a given set of assets. This setup allows us to have a fairly robust inference of what might be the fundamental economic determinants that drive the correlations over time as opposed to obtaining country specific elasticities.

The regression models may be summarised as follows,

$$\begin{aligned} \tilde{\rho}_{i,j,t,p} &= \gamma_p \tilde{\rho}_{i,j,t-1,p} + \boldsymbol{\beta}_p' \mathbf{x}_{i,j,t-1,p} + \boldsymbol{\alpha}_{ij,t,p}' + \varepsilon_{i,j,t,p}, \qquad (14) \\ &\text{for } i,j = 1,\ldots,16 \text{ and } i \neq j; \\ &p = \{\text{Nb v Sb, Nb v. Ss, Nb v. Ns, Ns v Ss, Sb v. Ss, Ns v. Sb}\}; \\ &\text{where } \tilde{\rho}_{i,j,t,p} = \frac{1}{2}\log\left(\frac{1+\rho_{i,j,t,p}}{1-\rho_{i,j,t,p}}\right). \end{aligned}$$

The dependent variable, $\tilde{\rho}_{i,j,t,p}$, is the Fischer transformed correlation for each country pair, i,j, for each quarter, t, and each category, p. The original correlation series are bounded between minus one and one, but the Fisher-transformed series are unbounded. The model includes a lag dependent variable to capture the dynamic transition of the independent variables, $\mathbf{x}_{i,j,t-1,p}$. The set of independent variables is discussed below. $\boldsymbol{\alpha}_{ij,t,p}'$ represents the fixed effects included for each regression. It is possible to use a different set of cross-section dummies, namely country specific fixed effect, resulting in two sets of country dummies. However, the pair-fixed effect captures more variation and principally controls for relative pair relations such as distance, historical, financial and trade links and financial integration between any two countries that a double set of country dummies does not necessarily control for.

All regressions include cross-section fixed effects, meaning a time constant dummy for each country pair. In the second specification we also include a cross-section fixed set of time-varying dummies for which we use the combination of quarterly and year dummies. Each equation p is separately estimated over a panel of 12 or 16 country pairs over about 48 quarters. Since we only look at cross-country effects we do not include in any of the results those observations that come from the same country.[14]

Theoretically it is possible to conduct a joint estimation over the 6 equations, but results showed that although this gives comparable results for the cross-asset relations, the combination with the within-asset correlations made the estimates inconsistent and imprecise. The correlation series are transformed using the fisher transformation to make them unbounded. We use a lag-dependent variable regression as in Li (2002) among others.[15]

A constant set of independent variables are used in each regression and obtained from Datastream at a quarterly frequency. For this reason the dependent variable, which was calculated at the daily frequency, is averaged over each quarter window.

$$\mathbf{x}_{ij,t-1,p} = \begin{bmatrix} dInfl_{i,j,t-1} & rVol_{i,j,t-1} & rDebt_{i,j,t-1} & dCa_{i,j,t-1} & dG_{i,j,t-1} & Rate_{t-1} \end{bmatrix}'.$$

The variables are meant to capture current market situation and general macroeconomic conditions. Inflation differential is measured by $dInfl$ and used often in the literature to capture the fact that bonds are more sensitive to inflation than stocks. Uncertainty is measured through the ratio of the respective stock market volatilities, $rVol$. We use the conditional variance series from the EGarch series of section 3.2 to measure this uncertainty. The government budgetary health is measured by its relative debt position, $rDebt$, the ratio of countries debt-to-GDP figures. In the same way, the current account measures a country net external asset position, dCa, capturing the sustainability of the public and private development. Differential in economic growth, dG, is another factor often indicated as important to explain the difference in stock and bond performance as

[14]For instance, for the North Stock v North Bond case we exclude the within country correlation. They could be easily included but all the independent variables that are represented as ratio or difference would be without variation and hence not explain anything.

[15]Lagged dependent variables are subject to Nickel-bias, since the lag-dependent variable is by construction correlated with the error term. However, the bias decreases with the time span, and in our case the average time span of 48 periods would imply a very limited bias. More critically, unbiased estimators that have been developed depend on cross-section asymptotics and small time-span and hence are not particularly fit for the dataset at hand where the time span is much larger than the cross-section (Baltagi, 2008).

well as correlations of bonds and stocks between countries. Since all countries in our sample are in the Euro-zone there is no nominal exchange rate risk and all countries face the same benchmark rate captured in *Rate*, which is the policy rate of the ECB. Other variables were tried before, such as the relative government budget deficit, unemployment forecasting variables (e.g. expected inflation) as well as different measures of the same variables (difference instead of ratios and *vice versa).* The ones we present give intuitive and consistent results.

Not all variables in each regression would be expected to have a significant explanatory power. Previous studies, such as those mentioned above, occasionally let their selection of regressors be guided by theory. For instance, for models concerning bonds versus stocks, there are clear predictions on the signs of cash-flow/growth variables, inflation indicators and monetary policy. Such channels, namely those related to real economics, monetary measures and risk, should appear with the set of variables above. A second reason to use a fixed set of variables is that in the results variables that are not always expected to play a role in fact do, and the other way around. For expected results it did not matter to include extra variables. For completeness, we keep the set of variables fixed for all the regressions.

The combination of the pair fixed effects and time dummies will make the (adj.-)R^2 of any regression high, but it is not immediately clear what fraction of the explained variance can be attributed to the other regressors. Therefore, a partial-R^2 is reported for each regression that includes both pair and time fixed effects. This partial-R^2 is defined as the share of the explained variance that is orthogonal to the unobserved fixed effects.[16]

Before estimating the model, the dependent variable can be tested for unit-root and cross-dependence features using methods developed in Pesaran (2004, 2007) which is essentially an extension of the Dickey-Fuller test for univariate series. The cross-dependence test serves to find out whether the panel-unit root test should take this into account. Appendix B gives the results of both tests. The cross-section dependence test shows a high degree of dependence. However, the panel unit root test finds no evidence for the unit root in any of the correlation series.

4.1.1 Is there a structural break?

Popular opinion and dynamic correlation plots suggest that a fundamental change in perception occurred since the start of the European debt crisis. Contrary, the panel setup of the estimation aims to explain the comovements of assets based on fundamental economic indicators. The question that remains is to what extent is there still a change in how countries' situations were perceived after controlling for the actual situation?

[16] The partial-R^2 is calculated in two steps. First regress the y on the unobserved fixed effects. Then regress the residuals of this regression on the unobserved fixed effects and the regressors. The R^2 of the last regression is the partial-R^2.

In order to test whether the fundamental variables explain the larger part of the story we can proceed in two ways. One is to include extra variables that may proxy for such expectations. Previous studies have been attentive to find such variables in implied volatilities, volatility indices and other variables that may be correlated with investors' perceptions. The limitations of such variables are firstly their sparse availability for the cross-section we study and secondly such variables may be very well correlated with fundamentals, in particular those we have not included.

A second method is to include a dummy for the crisis period, in analogy with studies that included a dummy for the period where the EMU started (Cappiello et al., 2006). We allow this dummy to be interacted with each of the explanatory variables so we can capture to what extent variables have changed playing a role in investors' behaviour. One could similarly split the sample in two sub-samples and estimate the regressions separately but this procedure suffers since all parameters have to be estimated with half the observations. With the dummy procedure this loss is mitigated. The estimation equation becomes,

$$\begin{aligned} \tilde{\rho}_{i,j,t,p} &= \gamma_p \tilde{\rho}_{i,j,t-1,p} + \boldsymbol{\beta}_p' \mathbf{x}_{i,j,t-1,p} + \boldsymbol{\delta}_p' d_t \times \mathbf{x}_{i,j,t-1,p} + \boldsymbol{\alpha}_{ij,t,p}' + \varepsilon_{i,j,t,p}, \qquad (15) \\ & d_t = \begin{cases} 1 & t \geq 2008q1 \\ 0 & \text{otherwise} \end{cases}. \end{aligned}$$

where $\boldsymbol{\delta}_p'$ are the coefficients on the independent variables interacted with the dummy variable, d_t, and everything else defined as before.

The date of the structural break is based on the dynamic correlations series, such as those plotted in Figure 1. The break coincides with the start of financial crisis. It can be argued that the financial crisis was followed by a European debt crisis which may be dated to start around 2010q1. Although this may be true it is interesting to see that the decrease in correlations in the European bond market started much earlier than 2010 although negative spike in early 2010 is certainly visible in the plot. Secondly, we performed a test, based on the lm-statistic, to obtain the optimal date for the cross-section dummies. This test suggests different dates for each category, where most dates are between 2008 and early 2010. A robustness check with a dummy equal to 1 for $t \geq 2010q1$ does not indicate substantial qualitative difference with our benchmark results[17].

If these coefficients are significant, then it indicates primarily that the role played by the respective variable has changed from one period to the next. Such a change can be explained in two ways: on the one hand it could represent a re-interpretation by investors of economic fundamentals; on the other hand, we could also observe a significant variable if there is a non-linear effect of the fundamental variable on the dynamic correlation as opposed to the linear form we model here.[18] More importantly, if there is no significant

[17] See Appendix C.

[18] For instance, debt can be at a stable and reasonable ratio for two countries. Small changes in this

coefficient on the interaction dummy, then neither is the case.

4.2 Panel Data Results

We present the results divided by asset market category. We first briefly review the literature in the field and then present the results. Estimations, in every table, follow the same sequence of model specifications, first only pair fixed effect, 2) pair and time fixed effects, 3) inclusion of crisis indicators and 4) with a dummy for Greece debt to account for the possibility that results might only be driven by (the signal of) the debt level of this country.[19] In Appendices D and E we present robustness checks based on different methods of the calculation of assets correlations. They are based on realised correlations and the Garch-Midas procedure. The former avoids using a two-step estimation procedure, while the latter accounts for the endogeneity of the economic fundamentals and the variance.

Standard errors are computed by bootstrap to account for the use of estimated dependent variables and they are robust to heteroskedasticity, serial correlation and cross-section correlation in the errors. Note that for the explanatory variables, when concerning north and south, the southern country is the numerator for ratios and the first variable in differences. In case of within region estimation, the stock country is first.[20]

4.2.1 Bond market

The literature on the European bond market correlations is very modest while there is a vast production on the assessment of government bond spreads determinants. Spreads and correlation are indeed closely related as an increase in spreads normally determines a decrease in correlation. Even if the two variables are not the same measure we refer to this literature as the benchmark for our estimation and comparison. Previous studies focused both on the effect of liquidity related factors on yields at high frequency data and the effect of credit risk based on macroeconomic fundamentals at lower frequency.

ratio over time correlate slightly with the correlation of the two markets of such countries. During the crisis, one of the countries has more fiscal problems than another, for example by having to bail out a larger bank, which adds to the deficit and enters the debt ratio. Subsequently, investors respond to these developments and correlation of the markets, between those two countries, stops or reverses. This means that during the crisis, a large effect on debt causes a large effect on the correlation, while there was no similar change in the ratio in the non-crisis period. The estimator will likely not allow to distinguish between what is due to the oversized change in the fundamental and what is due to the supposed change in perception of the relevance of the ratio to investors. In conclusion, only if we assume that the size of the change in the ratios does not affect the marginal effect on correlation we can assume that a significant coefficient on the interaction variable indicates that the underlying ratios has regained (or lost) some relevance.

[19]Note that the debt level of Greece is only included in those observations where Greece is part of. That is, the value of Greece debt is equal to zero for an observation of correlation that does not include Greece.

[20]For instance, for the case if between regions and a variable x for each country belonging to the S(outh) or the N(orth), $rx = x_S/x_N$, $dx = x_S - x_N$. In the case of within region but between two assets s(tock) and b(ond), $rx = x_s/x_b$, $dx = x_s - x_b$.

Codogno et al. (2003) study the determinants of EMU yield spreads on the period 1999-2002. At monthly data frequency they find that differences in debt-to-GDP ratios have no significant effect on relative asset swap spreads when considered separately, but become significant when interacted with international risk variables. They find that international risk factors dominate liquidity risk factors and suggest that interest rate risk factors rather than debt-to-GDP affected yield differentials.

Barrios et al. (2009) study the period between 2003-2009. Their empirical evidence highlights the importance of international factors like general risk perception but also to a smaller extent domestic factors, such as deteriorating financial outlook. More interesting, for the low-frequency case, is the significant coefficients on macroeconomic fundamentals on the spread. Among others, fiscal conditions and the current account have a strong impact on government bond yield spreads. In particular fiscal balance and current account surpluses decrease significantly the spread, while debt tend to increase it even if not in a linear way.[21]

More recently de Grauwe and Ji (2012) highlight the role of changes in perception of default risk in the Euro-zone. They focus their analysis on two macroeconomic variables: debt-to-GDP and current account. They find a significant and non-linear effect of debt on the spreads while they do not find any significant effect of the current account. Moreover they find evidence of a structural break around the year 2008 with respect to debt-to-GDP and its non-linear effect.

For the choice of our variables we mainly focus on credit risk in order to determine the impact of macroeconomic variables (as opposed to liquidity). Debt sustainability depends firstly on expected budget surpluses or deficits which is in turn determined by future economic activity and the interest rate. Secondly, the current account is a good indicator for measuring the overall asset position of the economy. The inflation differential could be expected to play a role when there are widely diverging regional prices.

Table 4 presents the results with respect to the bond market correlation. Starting with the first column the correlation between bond markets seems to be mostly determined by inflation, current account and GDP growth. A deterioration in the current account for a southern relative to a northern country decreases the correlation in line with Barrios et al. (2009) while an increase in southern inflation and GDP growth increases the correlation in the bond market.[22]

If European countries in the Euro-zone converge, the south must have, on average, a higher GDP growth rate than the north. Such favourable economic performance should

[21]As Barrios et al. (2009) explain, countries with historically high debt levels might benefit from liquid bond markets but suffer because of the reaction of financial markets if debt rises above a certain unsustainable threshold. A given the increase of the debt-to-GDP ratios has an higher impact on the spread when the ratio is already high.

[22]By construction, the variable on current account, dCA is the difference between the southern and northern current account and it is always negative. Hence a positive sign in front of the coefficient should be read as a worsening in the current account of the south with respect to the north.

Table 4: Bond market panel regressions

	Dependent variable: Dynamic Correlation			
	(1)	(2)	(3)	(4)
	1-way FE	2-way FE	Crisis	Gr Debt
Lag Dependent	0.9054***	0.5683***	0.5798***	0.568.***
	(0.0202)	(0.0541)	(0.0583)	(0.0544)
dInfl	0.0922***	0.0114	−0.0208	0.0116
	(0.0183)	(0.0216)	(0.0309)	(0.0217)
rVol	−0.0217	−0.0026	0.0023	−0.0052
	(0.0212)	(0.0196)	(0.0282)	(0.0170)
rDebt	−0.2641	−0.1938	−0.2422	−0.2041*
	(0.2328)	(0.1321)	(0.1492)	(0.1123)
dCa	1.9917***	1.0086***	0.8292*	1.027***
	(0.4229)	(0.2563)	(0.4710)	(0.2459)
dG	5.8937*	2.5687	9.3943***	2.718
	(3.4519)	(1.7870)	(3.0044)	(1.898)
Rate	0.1134***	−0.1588***	0.0666	−0.1577***
	(0.0231)	(0.0440)	(0.0721)	(0.0450)
d × dInfl			0.0599*	
			(0.0360)	
d × rVol			−0.0376	
			(0.0308)	
d × rDebt			0.0215	
			(0.0684)	
d × dCa			−0.3869	
			(0.5729)	
d × dG			−14.8389***	
			(4.7870)	
d × Rate			−0.4573***	
			(0.0797)	
d			−1.1961***	
			(0.2610)	
Debt Greece				0.0008
				(0.0020)
Observations	732	732	732	732
Number of pairs	16	16	16	16
Adjusted R^2	0.8645	0.9046	0.9068	0.9073
Partial R^2		0.3914	0.4104	0.3915
Time dummies		yes	yes	yes

Bootstrap based standard errors (100 reps.) in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Pair fixed effects always included

lead to a further integration of the respective sovereign bond markets. Hence the positive sign of the GDP coefficient can be interpreted as the catching-up of the southern countries with the north. Interestingly, the relative debt position between north and south is not significant.

The other specifications show that only the current account remains a significant explanatory variable for the bond market correlations. Time fixed effects wipe out the effects of inflation and GDP growth.

If non-linear effects are present, as suggested by de Grauwe and Ji (2012), then allowing for different coefficients between the two periods for each variable could uncover non-linear or non-constant marginal effects. Column (3) shows that for debt and current account there is no indication that there are such effects. Current account is still significant, while there appears no significant change in its elasticity for the crisis period. Similarly, relative debt level remains insignificant for both periods.

The interaction on ECB rate suggests that only since the crisis period this variable helps to explain a convergence of correlations, since as the policy rate was lowered the negative coefficient indicates a net positive effect for the correlation. The coefficient on GDP is significantly positive for the core equation while significantly negative for the crisis period. The crisis dummy itself indicates that the mean of the correlations decreased.

Finally, the inclusion of the Greek debt level as the driving factor for the Greek case, presented in column (4), does not improve any of the results.

In summary, we find only the current account to be a consistent explanatory variable for the comovement of the bond market prices. GDP growth appears to be related to comovement but has reversed effects in the two periods. Debt, inflation or market uncertainty appear unrelated to the comovements of bonds.

4.2.2 Stock market

The literature on the comovements of European stock markets focused primarily on the determinants of integration after the introduction of the EMU. The attention has been devoted to evaluate the impact of exchange rates as main driver of stock market comovements. On the side other variables had been studied, in particular those related to real convergence and monetary policy criteria. The idea is that asset returns reflect to a certain extent the business cycle. Having more synchronous business cycle means being more interdependent and prone to common shocks. From here studies address how shocks can be transmitted through economic variables like convergence in trade, dividend yields, GDP, interest rates and inflation rates and so on.

Fratzscher (2002) found that the reduction in exchange rate volatilities and the convergence in GDP growth and monetary policy (correlation of inflation) drew the integration of the Euro-area equity markets. Hardouvelis et al. (2006) consider the process of EMU integration over the period 1992-1998 with a focus on currency risk. They find that both

Table 5: Stock market panel regression

	Dependent variable: Dynamic Correlation			
	(1)	(2)	(3)	(4)
	1-way FE	2-way FE	Crisis	Gr Debt
Lag Dependent	0.5773***	0.3028***	0.2824***	0.3056***
	(0.0320)	(0.0335)	(0.0287)	(0.0319)
dInfl	−0.0593***	−0.0232*	−0.0215	−0.0239*
	(0.0091)	(0.0138)	(0.0190)	(0.0134)
rVol	−0.0293	−0.0716***	−0.0651**	−0.0611**
	(0.0194)	(0.0215)	(0.0279)	(0.0299)
rDebt	0.2005	0.0236	0.0645	0.0649
	(0.1252)	(0.0677)	(0.0859)	(0.0786)
dCa	−1.0216***	−0.5299**	−0.9331***	−0.6004**
	(0.1553)	(0.2127)	(0.3073)	(0.2359)
dG	1.9199	5.8282***	7.4645***	5.239***
	(1.2550)	(1.1135)	(0.9205)	(1.1334)
Rate	−0.0074	0.0403	−0.0267	0.0353
	(0.0101)	(0.0286)	(0.0495)	(0.0253)
d × dInfl			−0.0172	
			(0.0306)	
d × rVol			−0.0080	
			(0.0335)	
d × rDebt			−0.0435	
			(0.0704)	
d × dCa			0.6755**	
			(0.2735)	
d × dG			−5.7250***	
			(1.7180)	
d × Rate			0.1960**	
			(0.0843)	
d			0.0015	
			(0.2665)	
Debt Greece				−0.0035
				(0.0029)
Observations	732	732	732	732
Number of pairs	16	16	16	16
Adjusted R^2	0.4376	0.5596	0.5652	0.5737
Partial R^2		0.2301	0.2465	0.2328
Time dummies		yes	yes	yes

Bootstrap based standard errors (100 reps.) in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Pair fixed effects always included

forward interest rate differentials and inflation differentials are statistically significant determinants of the degree of stock market integration in the Euro zone. Interestingly they find that in 1994, a period they characterise as determined by pessimism in Europe and a sharp increase in the global bond yields, the degree of integration reduced. Concerns about the ability of highly indebted governments to control budget deficits led to a widening in the interest rate spreads among European countries and a reduction in integration.

Kim et al. (2005) considered the period 1989-2003 before and after the introduction of the common currency. They find that increasing stock market comovements can be explained with the overall macroeconomic convergence process associated with the introduction of the Euro rather than the specific effects of the elimination of foreign exchange rate risk due to the currency unification. Among others, GDP growth and stock market capitalisation to GDP ratio were the main drivers of stock market convergence.

Table 5 presents our results for the stock market. When only pair fixed effects are considered, the key determinants of the stock market correlation seem to be differentials in inflation, in line with Hardouvelis et al. (2006), and in the current account. When we introduce time fixed effect relative volatility in the stock market becomes a principal variable together with the current account and GDP. The higher is the relative degree of inflation and volatility in the stock market the lower the correlation between the two areas. The bigger the current account imbalance the more southern and northern stock markets are correlated. This seems a counter-intuitive result at first. A possible explanation could be that government expenditures in the south stimulated demand allowing for private sector convergence with the north. Hence, while this action causes a major repricing of bonds, it helps the development of the two areas increasing the correlation in the stock market. Also the GDP coefficient could be puzzling at first analysis, since increased differential in GDP growth increases correlations. This result can be interpreted in the same light as a catching-up effect of the southern countries with the northern ones.

Looking at the differentiated coefficients for the crisis period, it appears that the effect of current account and GDP growth falls majorly during the crisis, while the other variables are not affected. This finding does not correspond to the hypothesis that economic fundamentals such as the current account was revalued during the crisis period, since their effects diminish. Similarly, there seems to be no differentiated effect for the market uncertainty measure. However, the policy rate shows a significant positive coefficient for the second period, which stands in contrast with the negative coefficients in the bond-market case. Using the same reasoning as before implies that the decreasing rates in the crisis period decreased the comovements in the stock-market. Finally, controlling for the level of debt in Greece (column 4) does not alter any of the other findings and is by itself insignificant.

4.2.3 Bond-Stock correlation

Theoretical models, belonging to the bond-stock literature, point out that factors that affect the payments of stocks and bonds differ. While both stock and bond prices are the discounted sums of their future cash flows, bonds earn a fixed nominal cash flow while stock's cash flows are an infinite stream of uncertain dividends. Therefore these models predict that changes in factors that affect the discount rates are likely to increase the bond-stock correlation while asymmetric shocks in other dimensions tend to decrease it (Campbell and Ammer, 1993; Li, 2002; Ilmanen, 2003). Empirical studies which use these predictions tested them for within-country correlations only.

The first category includes real interest rate changes, monetary policy, and expected inflation. The second category includes unexpected inflation, economic growth and uncertainty measures such as stock market volatility. While expected inflation is already priced in the discount factors of both assets, unexpected inflation can hamper the asset that pays a predetermined amount. Similarly, expectations of strong GDP growth can help stocks and hurt bonds. On the contrary, in periods of high volatility in the equity market stocks perform badly while bonds are less affected and one can observe flight-to-quality dynamics from the equity market into the sovereign bond market. Hence the main drivers of periods of low correlation in bond-stock returns have been suggested to be unexpected inflation and stock market uncertainty.

Ilmanen (2003) suggests that stock-bond correlation is at the lowest when equities are weak and volatility is high (flight-to-quality behaviour) but also when inflation and growth are low. Li (2002) presents results based on an asset pricing model that includes inflation expectations next to the previously noted determinants. Kim et al. (2006), focusing specifically on the process of integration of European stocks and bonds between 1994 and 2003, find that real economic integration and the absence of currency risk lead to increased comovements. However, monetary policy convergence may have created uncertainty about the economic future of the European monetary union and consequently decreased comovements.

Andersson et al. (2008) study the US and Germany. For both markets they find evidence of a negative effect of stock market volatility on the stock-bond relation and a positive effect of expected inflation. GDP growth has a negative impact but is not always significant.

Table 6 and 7 presents, respectively, the stock-bond relation in the Northern and Southern regions. As we are considering the within region markets we should pay attention on the interpretation of the results. The relative variables are now referring to differences within one region variables. For this reason we use four pairs less, notably those that refer to correlations of stocks and bonds within the same country.

In the northern region the correlation between stock and bond markets seems to be

Table 6: Northern region Stock-Bond panel regression

	Dependent variable: Dynamic Correlation		
	(1)	(2)	(3)
	1-way FE	2-way FE	Crisis
Lag Dependent	0.7160***	0.2466***	0.2592***
	(0.0098)	(0.0100)	(0.0079)
dInfl	−0.0023	0.0001	0.0180
	(0.0221)	(0.0164)	(0.0222)
rVol	0.0170**	0.0529***	0.0565***
	(0.0074)	(0.0092)	(0.0067)
rDebt	−0.0322	0.0644	0.0049
	(0.1083)	(0.0977)	(0.1241)
dCa	−0.1180	−0.0416	0.1003
	(0.3963)	(0.2461)	(0.3378)
dG	0.6772	0.7279	0.8865
	(0.6892)	(0.7899)	(0.9567)
Rate	−0.0086**	−0.1161***	−0.2131***
	(0.0039)	(0.0132)	(0.0197)
d × dInfl			−0.0370
			(0.0388)
d × rVol			−0.0336*
			(0.0185)
d × rDebt			0.0303
			(0.0830)
d × dCa			−0.3530
			(0.3966)
d × dG			−0.9259
			(1.4858)
d × Rate			0.2200***
			(0.0200)
d			−0.9788***
			(0.1120)
Observations	564	564	564
Number of pairs	12	12	12
Adjusted R^2	0.5222	0.7066	0.7146
Partial R^2		0.1856	0.2059
Time dummies		yes	yes

Bootstrap based standard errors (100 reps.) in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Pair fixed effects always included

determined uniquely by the policy rate and volatility. While the policy rate is in line with the literature, the sign of relative volatility is counter-intuitive. Given the consistently bad performance of the other explanatory variables across the different specification we can conclude that the model does not work for the within northern region case.

The southern correlation, Table 7, delivers better results. The bond-stock correlation is decreased by the interest rate and GDP growth, as expected, and additionally by debt. Relative changes in the debt positions in the southern countries lead to a flight-to-quality within the same region. When we control for pair and time fixed effects and the level of the Greek debt we find the additional significance of current account. In the southern region heterogeneity in the level of debt-to-GDP leads to a decrease in the stock-bond correlation in the region. The current account has two cases: a positive and a negative balance. When the difference between the stock and the bond country current account is positive it leads to an increase in correlation, when it is negative to a decrease.

The addition of crisis indicators does not alter the main regression.

The fact that the model behaves better for the within region case of the south compared to the north may be explained by the relative degree of heterogeneity in the south relative to that among the northern countries. As noted before, pooling southern countries together seems to obscure a relative high degree of heterogeneity among them, while in pooling countries in the north this is much less the case.

Table 8 presents the case of North Bond-South Stock (Nb-Ss). The Nb-Ss estimation confirms the previous literature results with respect to expected inflation, volatility, GDP growth and the policy interest rate. Moreover it shows that current account is important in explaining this correlation. An increase in the relative debt or a deterioration of the current account is related to the reduction of correlation, confirming flight-to-quality dynamics. Once we control for time and pair fixed effects the coefficients on fiscal measure as well as on the current account lose significance. Controlling for the crisis and the Greek debt does not change further the results, but this is the only case where the Greek debt level appears to be an indicator for the correlation between bonds and stock comovements, but the sign is counter-intuitive. The marginal impacts of the growth differential and the policy rate on the correlation are decreased absolutely. Again the crisis-dummy indicates that there was a shift downward of the mean of the correlation.

In the North-stock and South-bond case (Ns-Sb), Table 9, an increase in the relative volatility makes southern bonds co-move more closely with northern stocks. The effect of expected inflation and the interest rate are in line with the prediction of theoretical models. GDP growth and an amelioration of the current account in the south instead is related to an increase in the correlation. However, when we control for time fixed effects we loose the significance on the coefficient for the current account measure .

Controlling for the crisis shows that the marginal effect of the current account seems to be completely driven by the crisis period with a negative sign. A worsening in the current

Table 7: Southern region Stock-Bond panel regression

	Dependent variable: Dynamic Correlation			
	(1)	(2)	(3)	(4)
	1-way FE	2-way FE	Crisis	Gr Debt
Lag Dependent	0.6429***	0.2936***	0.2922***	0.2941***
	(0.0240)	(0.0361)	(0.0317)	(0.0328)
dInfl	0.0027	−0.0001	0.0012	0.0001
	(0.0082)	(0.0067)	(0.0091)	(0.0084)
rVol	−0.0008	−0.0206	−0.0175	−0.0204
	(0.0224)	(0.0147)	(0.0150)	(0.0168)
rDebt	−0.0878*	−0.1053***	−0.0972***	−0.1049**
	(0.0483)	(0.0300)	(0.0281)	(0.0473)
dCa	0.3071	0.3149***	0.3192***	0.3143**
	(0.2270)	(0.1080)	(0.1043)	(0.1391)
dG	−1.5426**	−1.3615**	−1.8765*	−1.3583
	(0.7802)	(0.6761)	(1.0010)	(0.8521)
Rate	−0.0949***	−0.0964***	−0.1824***	−0.0969***
	(0.0056)	(0.0156)	(0.0262)	(0.0014)
d × dInfl			−0.0019	
			(0.0181)	
d × rVol			0.0033	
			(0.0196)	
d × rDebt			−0.0144	
			(0.0330)	
d × dCa			0.0078	
			(0.2003)	
d × dG			1.4538	
			(1.2565)	
d × Rate			0.1878***	
			(0.0420)	
d			−0.0287	
			(0.1325)	
Debt Greece				−0.0002
				(0.0014)
Observations	534	534	534	534
Number of pairs	12	12	12	12
Adjusted R^2	0.6480	0.7698	0.7725	0.7789
Partial R^2		0.1689	0.1882	0.1690
Time dummies		yes	yes	yes

Bootstrap based standard errors (100 reps.) in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Pair fixed effects always included

Table 8: North Bond-South Stock panel regression

	Dependent variable: Dynamic Correlation			
	(1)	(2)	(3)	(4)
	1-way FE	2-way FE	Crisis	Gr Debt
Lag Dependent	0.6908***	0.3069***	0.3094***	0.2952***
	(0.0247)	(0.0272)	(0.0266)	(0.0253)
dInfl	0.0402***	0.0119**	0.0011	0.0126***
	(0.0057)	(0.0054)	(0.0084)	(0.0053)
rVol	−0.0363***	−0.0219***	−0.0385**	−0.0359***
	(0.0091)	(0.0080)	(0.0196)	(0.0114)
rDebt	−0.1494***	0.0029	0.0093	−0.0534
	(0.0517)	(0.0505)	(0.0595)	(0.0467)
dCa	0.3830***	0.1331	0.0830	0.2320
	(0.0801)	(0.1661)	(0.2674)	(0.1684)
dG	−1.4734**	−3.0282***	−3.7623***	−2.213**
	(0.7097)	(0.6689)	(0.9460)	(0.8901)
Rate	−0.0181***	−0.1268***	−0.1798***	−0.1222***
	(0.0042)	(0.0135)	(0.0261)	(0.0144)
d × dInfl			0.0252	
			(0.0169)	
d × rVol			0.0383	
			(0.0238)	
d × rDebt			0.0147	
			(0.0427)	
d × dCa			0.3494	
			(0.2618)	
d × dG			2.1925**	
			(1.1030)	
d × Rate			0.1287***	
			(0.0276)	
d			−0.7297***	
			(0.1368)	
Debt Greece				0.0048***
				(0.0011)
Observations	732	732	732	732
Number of pairs	16	16	16	16
Adjusted R^2	0.5089	0.6777	0.6830	0.6921
Partial R^2		0.1856	0.2059	0.1992
Time dummies		yes	yes	yes

Bootstrap based standard errors (100 reps.) in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Pair fixed effects always included

Table 9: North Stock-South Bond panel regression

	Dependent variable: Dynamic Correlation			
	(1)	(2)	(3)	(4)
	1-way FE	2-way FE	Crisis	Gr Debt
Lag Dependent	0.6474***	0.3038***	0.2634***	0.3037***
	(0.0208)	(0.0216)	(0.0197)	(0.0198)
dInfl	0.0123**	−0.0042	−0.0028	−0.0041
	(0.0053)	(0.0101)	(0.0118)	(0.0098)
rVol	0.0368***	0.0378***	0.0447**	0.0368**
	(0.0109)	(0.0139)	(0.0189)	(0.0149)
rDebt	0.0772	0.0118	0.0382	0.0078
	(0.0556)	(0.0517)	(0.0619)	(0.0544)
dCa	−0.5081***	−0.0245	−0.0867	−0.0174
	(0.1520)	(0.1634)	(0.1612)	(0.1823)
dG	2.5149***	2.6466***	−1.1923	2.703***
	(0.9560)	(0.5266)	(0.9712)	(0.5522)
Rate	−0.0804***	−0.0689***	−0.2367***	−0.0685***
	(0.0042)	(0.0179)	(0.0284)	(0.0154)
d × dInfl			−0.0003	
			(0.0108)	
d × rVol			0.0083	
			(0.0210)	
d × rDebt			0.0482	
			(0.0337)	
d × dCa			0.5794***	
			(0.1843)	
d × dG			7.7352***	
			(1.5543)	
d × Rate			0.3552***	
			(0.0357)	
d			−0.4378***	
			(0.1154)	
Debt Greece				0.0003
				(0.0009)
Observations	732	732	732	732
Number of pairs	16	16	16	16
Adjusted R^2	0.6334	0.7504	0.7760	0.7576
Partial R^2		0.1770	0.2677	0.1771
Time dummies		yes	yes	yes

Bootstrap based standard errors (100 reps.) in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Pair fixed effects always included

account of the south relative to the north determines an increase in the correlation of Ns-Sb since 2008. If any, this result is the clearest indication thus far that a fundamental variable is related differently between the periods. The coefficients on GDP growth indicate that it is rather the second period that helps to explain the comovement rather than the first. The crisis dummy is significantly negative also for this category.

We can conclude that, looking at all the categories considered, the results suggest quite clearly the relevance of macroeconomic variables in explaining a significant portion of the international financial market correlations in the Euro-zone. For instance, the outcome of the previous tables indicates that current account and debt dynamics impact both on the private and public sector, with an opposite sign, as well as on the different geographical markets. The results indicate that worsening of the southern current account makes its bonds move more like its own stocks (Table 7), but also like northern stocks (Table 9), and less like northern bonds (Table 4). This is a consistent story but may be lost when one looks only at a single region as represented in the southern bond-stock market (Table 7). Not taking all these dimensions into account can deliver a partial view of the Euro-zone asset markets and in particular of the impact that macroeconomic variables have on them.

Moreover, the hypothesis that something else caused the disintegration of markets between northern and southern Euro-zone apart from macroeconomic fundamentals is not supported by any of the markets. However, there is a general downward shift in the correlations as given by the coefficient on the crisis period dummy. Nevertheless, there is no model where the dummy variable indicates a significant and consistent change in the role played by the macroeconomic variables. However, we find that the coefficient of GDP growth is often significantly different between the two periods. Most of the coefficients on the other interaction variables are insignificant and the occasional significant sign does not give enough reason to attribute this to the change in the role played by the underlying variable.

5 Conclusion

Since the spreading of the financial turmoil and the sovereign debt crisis in the Euro-zone it has been clear that European countries ceased to behave uniformly posing serious problems to the existence of the single currency. In order to understand what occurred in the financial markets we propose to analyse these markets in a multi-dimensional fashion. We do this by looking simultaneously at all correlations for two regions and two asset markets. The division of regions in North and South works well to visualise the divergence in the Euro-zone and subsequently explain the underlying determinants of such divergence.

The comparison of the conditional correlations of the between regions and assets shows how, after 2008, there was a change in the dynamics not only in the southern area stock-bond market but also at the cross regional level. What used to be considered a safe asset (south bond) started to co-move with the deemed Northern risky one. The safe asset in the "risky" area became more correlated with the risky asset in the "safe" area as well as with stocks in the south. In contrast, the dynamics on the stock market do not show any fall in correlation apart from a short-term and minor drop between 2010 and 2011.

We present cross-country panel regressions to find the determinants of the international dynamic correlations. By using all possible pairs of countries for each correlation category we obtain a fairly robust inference of what might be the fundamental economic determinants that drive the correlations over time for our sample. The panel estimations of assets' correlations between countries also allows to introduce variables that highlight differences between those countries.

We find as main determinants for the overall set of equations relative stock market volatility, debt and current account, growth, inflation differentials and monetary policy. Not all of these factors are important for each regression however. The results are consistent with the theory when available. Additionally, debt and current account have not been considered in the literature for all of the correlations we study, such as for the international stock market correlations. The inflation, volatility, policy rate and economic growth variables have been tried in the literature with mixed results.

We find that the correlation between bond markets seems to be mostly determined by inflation, current account and GDP growth and relatively unaffected by differences in debt levels or stock market volatility. The correlations of stocks and bonds between regions behave as expected by theory of cash flow determinants on the one hand, and additionally by macroeconomic fundamentals that indicate relative economic performance between countries on the other hand. So, while inflation, stock market volatility, economic growth and policy rate have expected signs we find an additional significant impact for the current account in some of the specifications and for debt only when considering the southern region. Finally, the correlation of the stock markets between north and south are mostly affected by current account and economic growth on top of stock market volatility.

Although many studies have doubted the robustness of the union, the general perspective was that over time, the EU was seen as an ever integrating set of markets. We find that, when we allow for regional division, not only cross-asset correlations within regions behave differently but also the variation of cross-assets cross-regions dynamics can be explained with macroeconomic factors such as the relative uncertainty between countries and balance of payments dynamics. We do not find such effects when we look at each region separately, which shows that Europe indeed is a tale of two regions.

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A Individual DCC Results

Figure A-1: Nb v. Ns

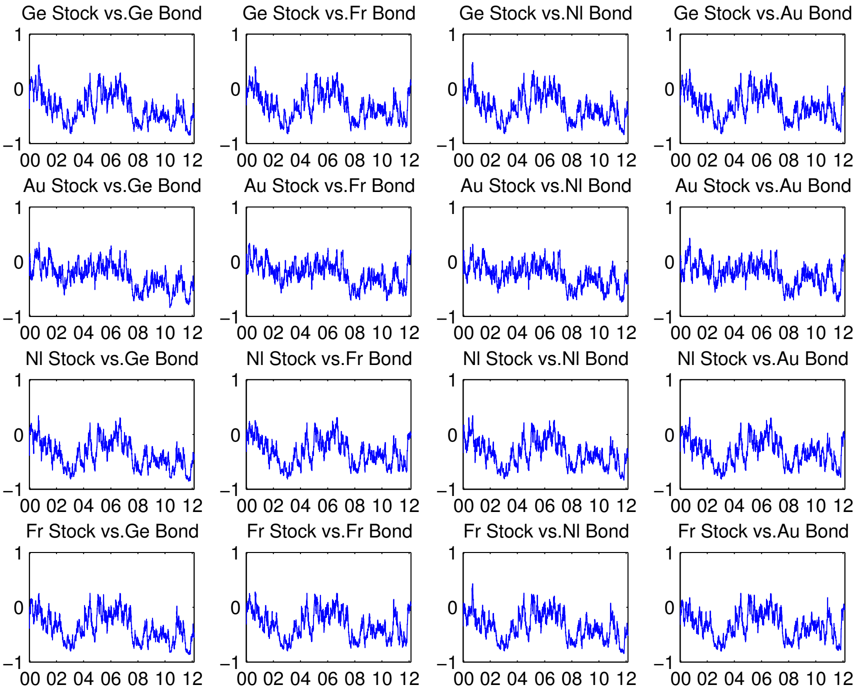


Figure A-2: Nb v. Sb

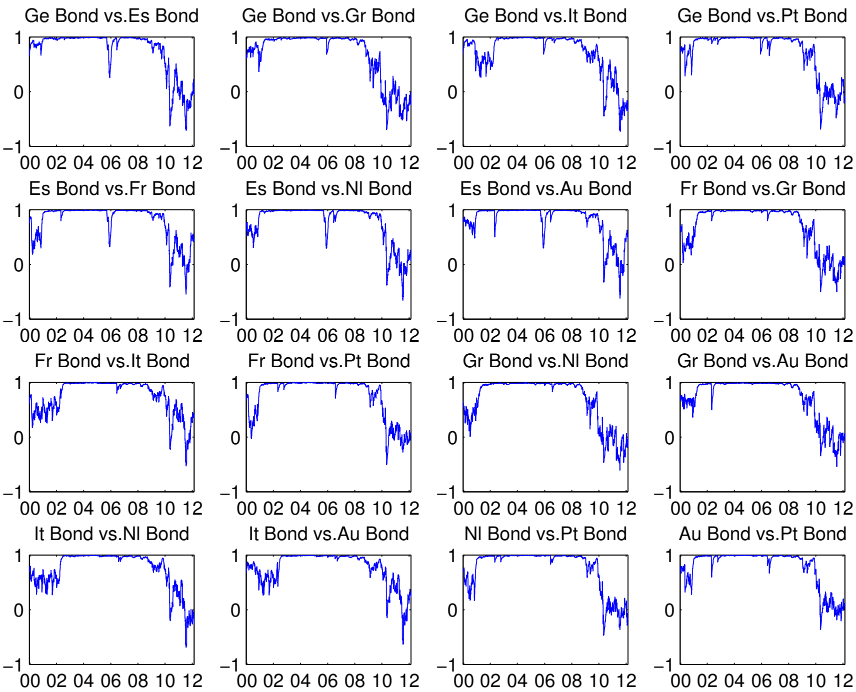


Figure A-3: Nb v. Ss

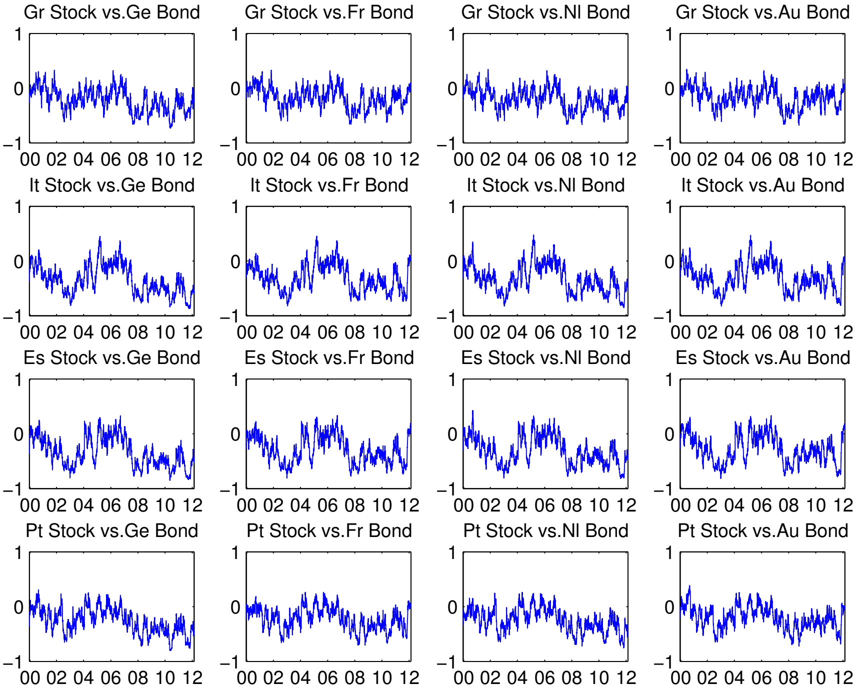


Figure A-4: Sb v. Ss

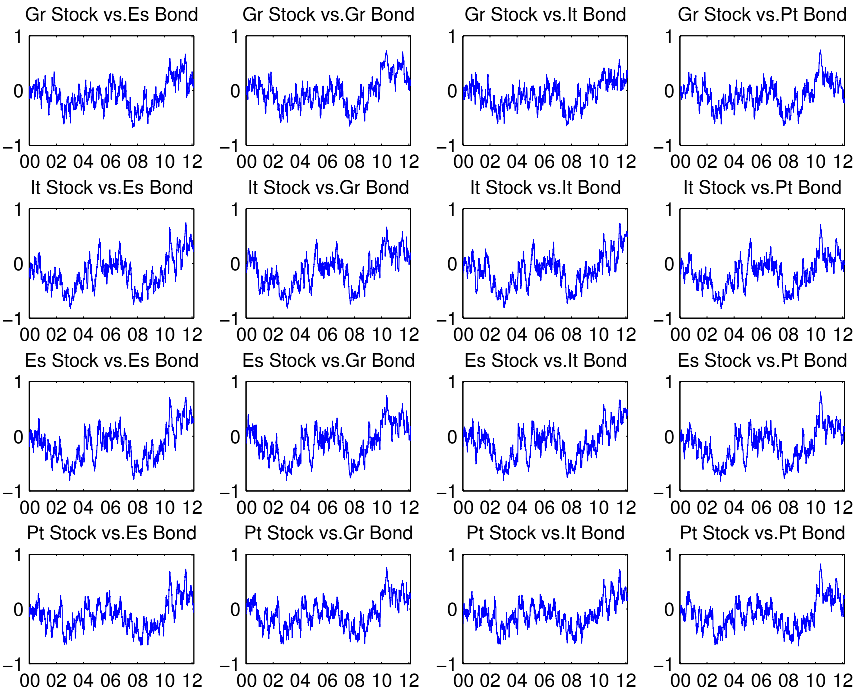


Figure A-5: Ns v. Sb

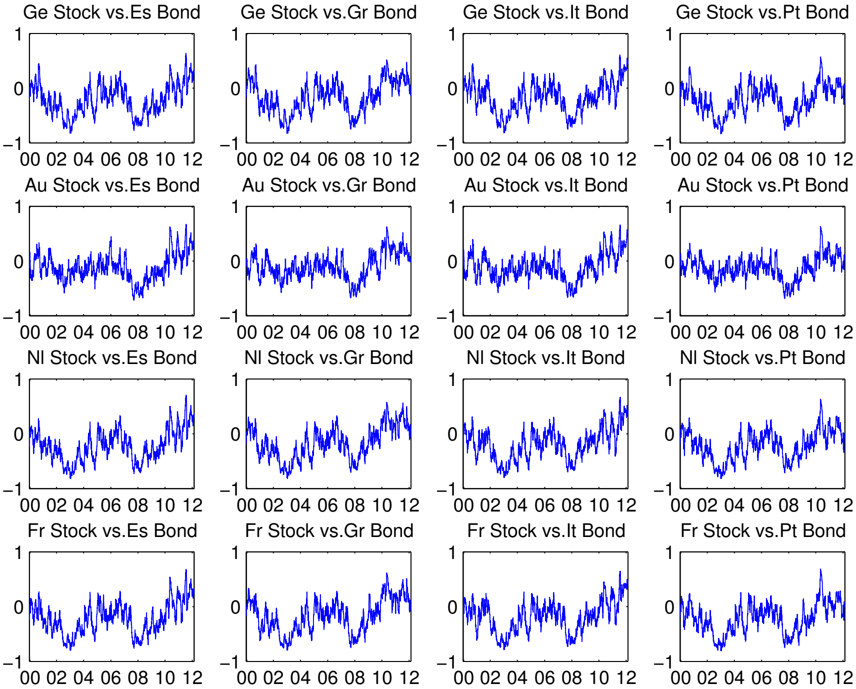
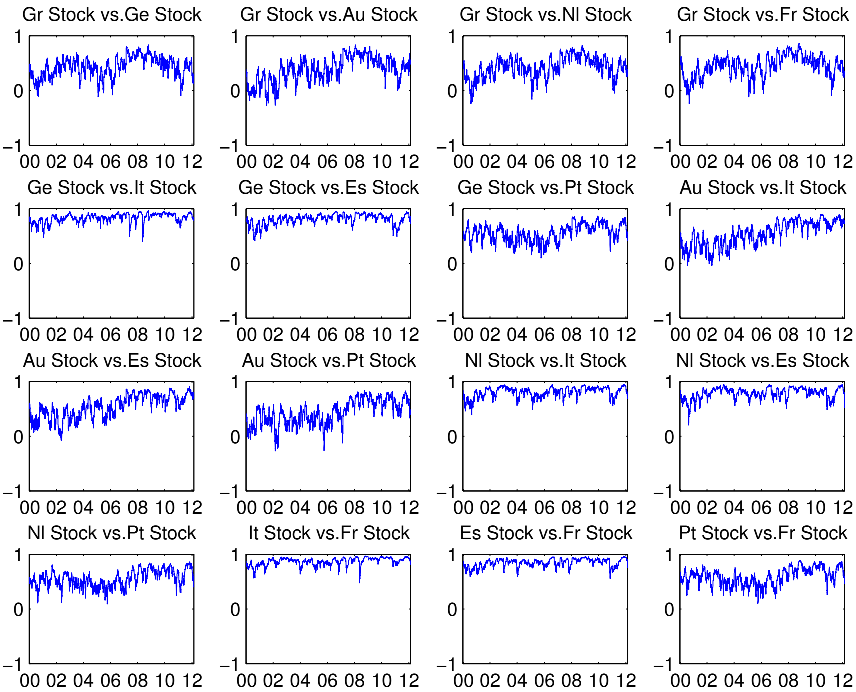


Figure A-6: Ns v. Ss



B Panel Unit Root Test

This appendix gives the result of the cross-dependence and panel unit root tests following Pesaran (2004, 2007) and described in Baltagi (2008). The cross-sectional dependence describes whether a panel unit root test should take into account cross-section dependence. The test results show that it should. The panel unit root test can be conducted in three fashions, normal, including cross-section fixed effects and including cross-section and time fixed effects. One should also include lags, where the lag-length can be defined by an information criteria. The AIC indicates a lag-length of one is sufficient. The H_0 is unit-root. Since the H_0 is always rejected, none of the tests indicate that the series follow a unit root.

Table B-1: Panel unit root test

	Panel unit root			cross-section
	1	2	3	dependence
critical values				
1%	−2.00	−2.60	−3.15	2.65
5%	−1.72	−2.34	−2.88	1.96
10%	−1.58	−2.21	−2.74	1.67
Nb v. Ns	−7.48	−5.91	−5.90	12.73
Nb v. Sb	−8.37	−8.54	−8.53	36.18
Nb v. Ss	−9.77	−7.10	−7.10	55.49
Sb v. Ss	−8.19	−8.26	−8.26	10.62
Ns v. Sb	−7.45	−7.31	−7.31	57.44
Ns v. Ss	−5.22	−4.48	−4.50	37.71

Cross-section augmented DF (CADF) tests and
Cross-sectional dependence (CD) following Pesaran (2004, 2007).
Critical values are given (CD) is normally distributed under H_0
For the Panel unit root, model 2 includes cross-section (cs) fixed effects,
model 3 time and cs fixed effect. All is based on EGarch-DCC results.

C Alternative Crisis Period Indicator

Following the discussion in the text in section 4.1.1 we present results with an alternative starting date of the crisis dummy indicator, namely starting at 2010q1. This date would approach closer to what is considered the start of the european debt crisis but foregoes the signalling effect of the broader financial crisis that was underway for some time at that point.

Table C-1: Alternative crisis-dummy, starting 2010q1

	Dependent variable: Dynamic Correlation					
	(1)	(2)	(3)	(4)	(5)	(6)
	Nb v. Sb	Nb v. Ss	Nb v. Ns	Ns v. Ss	Sb v. Ss	Ns v. Sb
Lag dependent	0.5677***	0.2938***	0.2483***	0.2579***	0.2734***	0.2653***
	(0.0604)	(0.0291)	(0.0173)	(0.0351)	(0.0302)	(0.0234)
dInfl	0.0206	0.0190***	0.0087	−0.0295	0.0025	−0.0054
	(0.0333)	(0.0060)	(0.0214)	(0.0203)	(0.0063)	(0.0097)
rVol	−0.0191	−0.0292*	0.0506***	−0.0687**	−0.0171	0.0540***
	(0.0280)	(0.0157)	(0.0113)	(0.0294)	(0.0195)	(0.0146)
rDebt	−0.2253*	0.0214	0.0551	−0.0261	−0.0863**	0.0417
	(0.1276)	(0.0544)	(0.0944)	(0.0891)	(0.0395)	(0.0527)
dCa	0.9900***	0.0850	0.0391	−0.6490**	0.2552*	−0.1178
	(0.3078)	(0.1775)	(0.2983)	(0.2641)	(0.1325)	(0.1482)
dG	6.8837***	−1.6273*	1.1709	5.0124***	−1.5121*	0.1110
	(2.5196)	(0.8442)	(1.0119)	(0.9849)	(0.9068)	(0.8324)
Rate	−0.1700***	−0.1222***	−0.1180***	−0.0143	−0.1186***	−0.1114***
	(0.0438)	(0.0150)	(0.0120)	(0.0311)	(0.0134)	(0.0216)
d × dInfl	−0.0691**	−0.0451**	−0.0373	0.0069	−0.0162	−0.0064
	(0.0298)	(0.0181)	(0.1078)	(0.0314)	(0.0147)	(0.0135)
d × rVol	0.0197	0.0245	0.0241	−0.0139	0.0075	0.0073
	(0.0252)	(0.0239)	(0.0323)	(0.0302)	(0.0284)	(0.0143)
d × rDebt	0.1664***	0.0069	−0.0522	0.0759	−0.0222	−0.0000
	(0.0577)	(0.0693)	(0.1494)	(0.1602)	(0.0532)	(0.0370)
d × dCa	1.7128***	0.9910***	−0.3491	−0.3404	0.4956	0.0343
	(0.5054)	(0.3691)	(0.3642)	(0.6455)	(0.3496)	(0.1791)
d × dG	−21.2773***	−5.5549***	−2.6442	−2.7602	−0.4251	9.0784***
	(4.1315)	(1.6948)	(4.4954)	(3.3688)	(2.0632)	(2.7593)
d × Rate	0.0729	−0.2971**	0.0473	1.6438***	0.5657***	0.8963***
	(0.1142)	(0.1470)	(0.1558)	(0.2826)	(0.1803)	(0.1303)
d	−1.0296***	0.1998	−0.2605	−2.0213***	−0.2634	−0.7420***
	(0.2021)	(0.2171)	(0.2377)	(0.4161)	(0.2087)	(0.1680)
Observations	732	732	564	732	534	732
Number of pairs	16	16	12	16	12	16
Adjusted R-squared	0.91	0.69	0.70	0.60	0.77	0.77

Bootstrap Standard errors (100 reps) in parentheses. *** p<0.01, ** p<0.05, * p<0.1
year and quarter dummies included. d equals 1 for periods 2010q1 and after.

D Realised Correlations

One disadvantage of the use of dynamic correlations such as the DCC is that the series are estimated as opposed to observed data. This feature is taken into account in the panel estimation by the use of bootstrapped standard errors what will take into account the additional estimation variance that results from the first stage estimation in the first stage of the main text. Alternatively one can avoid the first stage estimation by using the realised correlations. We compute quarterly realised correlation based on the returns series and use the resulting correlations as the dependent variables in the panel estimations. The results are presented in Tables D-1 and D-2.

Table D-1: Realised Correlations with one-way fixed effects

	Depdendent variable: Dynamic Correlation					
	(1)	(2)	(3)	(4)	(5)	(6)
	Nb v. Sb	Nb v. Ss	Nb v. Ns	Ns v. Ss	Sb v. Ss	Ns v. Sb
lag dependent	0.8198***	0.2885***	0.3369***	0.4365***	0.3955***	0.4701***
	(0.0213)	(0.0407)	(0.0289)	(0.0251)	(0.0250)	(0.0165)
dInfl	0.0774*	−0.0656***	−0.0621***	0.0269**	0.0205	−0.0293
	(0.0396)	(0.0154)	(0.0167)	(0.0131)	(0.0290)	(0.0479)
rVol	−0.0372	−0.0615**	0.0800***	−0.0707***	−0.0075	0.0338***
	(0.0443)	(0.0289)	(0.0201)	(0.0143)	(0.0320)	(0.0100)
L.rdebt	−0.5835*	0.3837*	0.1434*	−0.2680***	−0.1488*	0.0010
	(0.3235)	(0.2032)	(0.0854)	(0.0666)	(0.0775)	(0.1428)
dCa	3.3959***	−2.1055***	−0.4729**	0.9252***	0.6391**	0.0325
	(0.4300)	(0.2642)	(0.2082)	(0.1552)	(0.2929)	(0.6580)
dG	20.2848***	2.7450	−0.2076	−5.7343***	−1.8780	−0.4228
	(4.4459)	(2.4668)	(1.9717)	(1.2929)	(1.4753)	(1.8535)
Rate	0.1345***	−0.0302**	−0.1204***	−0.0033	−0.1440***	0.0062
	(0.0279)	(0.0132)	(0.0082)	(0.0065)	(0.0092)	(0.0052)
Observations	732	732	732	732	534	564
Number of pid	16	16	16	16	12	12
Adjusted R-squared	0.75	0.23	0.39	0.25	0.42	0.24

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table D-2: Realised Correlations with two-way fixed effects

	Depdendent variable: Dynamic Correlation					
	(1)	(2)	(3)	(4)	(5)	(6)
	Nb v. Sb	Nb v. Ss	Nb v. Ns	Ns v. Ss	Sb v. Ss	Ns v. Sb
lad dependent	0.3105***	−0.0113	−0.1114***	−0.0483	−0.0909***	−0.0751***
	(0.0520)	(0.0319)	(0.0212)	(0.0301)	(0.0233)	(0.0217)
dInfl	−0.0307	−0.0359*	−0.0054	0.0132	0.0062	−0.0115
	(0.0576)	(0.0185)	(0.0195)	(0.0151)	(0.0183)	(0.0310)
rVol	0.0085	−0.1144***	0.0745***	−0.0518***	−0.0505***	0.0800***
	(0.0340)	(0.0292)	(0.0160)	(0.0111)	(0.0195)	(0.0123)
L.rdebt	−0.5046***	0.1347	0.0381	−0.0109	−0.1532***	0.0957
	(0.1885)	(0.1311)	(0.0848)	(0.0809)	(0.0498)	(0.2218)
dCa	2.0008***	−0.9589***	0.0051	0.3534	0.5732***	0.0844
	(0.5979)	(0.2693)	(0.2778)	(0.2469)	(0.1850)	(0.4543)
dG	13.1235***	7.6013***	2.5453**	−5.6175***	−1.7372*	−0.0415
	(3.1713)	(1.4814)	(1.1461)	(1.2989)	(0.9695)	(1.2212)
Rate	−0.1085	0.0532	−0.0971***	−0.1034***	−0.1346***	−0.0862***
	(0.0779)	(0.0383)	(0.0246)	(0.0174)	(0.0233)	(0.0226)
Observations	732	732	732	732	534	564
Number of pid	16	16	16	16	12	12
Adjusted R-squared	0.84	0.41	0.64	0.53	0.67	0.55

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

E Midas-Garch Estimation and Results

It has been suggested that volatility in the returns is itself driven by market economic variables. In our results this would mean that the relation between the correlation measure and the independent variable is in fact partly endogenous (even when we use the lag of all independent variables). Secondly, a higher volatility would lead to a higher correlation. A solution is offered by the use of a newly developed Garch estimation that can account for long-term fundamental determinants of volatility (Engle et al., 2008a). This estimation approach can use variables measured at different frequencies, such as monthly, quarterly or yearly, to account for long term component of the conditional variance. Subsequently, the resulting standardised returns will be normalised in a more efficient way.

This model uses a mean reverting unit daily Garch process and a Midas polynomial which we apply to quarterly macroeconomic data. Our sample covers now Q1.2000-Q4.2011. We impute economic fundamentals directly into the volatility model in order to account for the impact of macroeconomic variables on the short horizon volatility. [23]

E.1 Model

The model used is a Garch-Midas with one-sided filters involving past macroeconomic variables. We follow the methodology introduced by Engle et al. (2008a).

The return process is an AR(2):

$$r_{i,t} = \mu + \alpha_1 r_{i-1,t} + \alpha_2 r_{i-2,t} + \sqrt{\tau_t g_{i,t}}\epsilon_{i,t}$$

where $\epsilon_{i,t}|\Phi_{i-1,t} \sim N(0,1)$ with $\Phi_{i-1,t}$ the information set up to day (i-1) of period t.

τ_t is the long-term component of the volatility (t stands for quarters) and $g_{i,t}$ the short-term one (i stands for days). We are considering the return for day i of a quarter t.

Respectively the short run volatility is given by a daily GARCH(1,1):

$$g_{i,t} = (1-\alpha-\beta) + \alpha\frac{(r_{i-1,t}-\mu)^2}{\tau_t} + \beta g_{i-1,t}$$

And the long run volatility is:

$$log(\tau_t) = m + \theta\sum_{k=1}^{K}\varphi_k(\omega)X_{t-k}$$

where X could be any macroeconomic variable expressed either in level or by the volatility. In this specification of the model X is debt (to GDP) and it is introduced in level. K is the number of lags of the X variable used in the estimation. In this formulation of the model we consider $K = 3$.

[23]Proceeding this way we can clean the single market volatility by picking up the effects of macroeconomic changes in provision of moving to the DCC estimation first and then to the panel one.

φ_k is the weighting function that in our specification is an "Exponential weighting":

$$\varphi_k(\omega) = \omega^k / (\sum_{j=1}^{K} \omega^j)$$

The parameter space is $\Theta = \{\mu, \alpha_1, \alpha_1, \upsilon, \alpha, \beta, m, \theta, \omega\}$ where υ is the constant (instead of $1 - \alpha - \beta$) in the GARCH estimation.

To estimate this model we use maximum likelihood where the log-likelihood function is written as:

$$LLF = -\frac{1}{2} \sum_{t=1}^{T} \left[log\left(g_t(\Phi) \tau_t(\Phi) \right) + \frac{(r_{i-1,t} - \mu)^2}{g_t(\Phi) \tau_t(\Phi)} \right].$$

E.2 Results

Tables E-1-E-4 present the results. E-1 shows primarily that debt is not a driving factor of the long-run volatility process. Hence, the results of the panel estimations is qualitatively the same as we found using the Egarch model in the main text.

Table E-1: Garch-Midas parameters

	const	α	β	m	debt	ω	μ	α_1	α_2
Austria stock	0.017*	0.112	0.878***	0.064***	0.004	−43.990	0.088	0.019***	−0.013
France stocks	0.004**	0.101	0.893***	−0.010***	0.022	0.839***	0.060	−0.012***	−0.035
Germany stocks	0.004***	0.100	0.893***	−0.008***	0.026	3.512***	0.067	−0.029***	−0.006
Netherlands stocks	0.006**	0.102	0.889***	−0.010***	0.023	−0.983***	0.046	−0.011***	−0.006
Greece stocks	0.002***	0.110	0.889	−0.007***	0.024	3.257	0.056	0.064**	−0.001***
Italy stocks	0.012**	0.099	0.891***	−9.729***	0.093	13060.718***	0.039	−0.033**	−0.001
Spain stocks	0.006**	0.103	0.892***	0.008***	0.024	−14.146**	0.072	−0.026	−0.035
Portugal stocks	0.001	0.073	0.927	0.004	0.016	0.484	0.013	0.000	0.016
Austria bonds	0.000	0.039	0.954***	−0.010***	0.007	1.609	0.008	0.036	−0.007**
France bonds	0.000	0.039	0.954***	0.013***	0.015	3.508*	0.009	0.019	−0.021
Germany bonds	0.001**	0.037	0.956***	0.006***	0.008	−2.298	0.008	0.056	−0.021***
Netherlands bonds	0.000**	0.036	0.957***	0.004***	0.010	−0.193	0.009	0.043	−0.020**
Greece bonds	0.001	0.118	0.882	−0.001	0.001	1.774	0.008	0.058	−0.011
Italy bonds	0.001**	0.081	0.907***	0.003***	0.002	45.298	0.008	0.071	−0.043***
Spain bonds	0.001*	0.071	0.923***	0.006***	0.006	−0.114	0.008	0.082	−0.033***
Portugal bonds	0.000	0.070	0.930	−0.001	0.011	0.602	0.013	0.045	0.013

Estimation following the model in the text. Standard errors are based on the Hession matrix.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table E-2: Midas-Garch with one-way fixed effects

	Depdendent variable: Dynamic Correlation					
	(1)	(2)	(3)	(4)	(5)	(6)
	Nb v. Sb	Nb v. Ss	Nb v. Ns	Ns v. Ss	Sb v. Ss	Ns v. Sb
Lag dependent	0.9044***	0.6790***	0.7060***	0.5691***	0.6336***	0.6286***
	(0.0172)	(0.0238)	(0.0109)	(0.0337)	(0.0252)	(0.0192)
dInfl	0.0822***	0.0414***	−0.0002	−0.0580***	0.0039	0.0110**
	(0.0185)	(0.0063)	(0.0238)	(0.0107)	(0.0083)	(0.0050)
rVol	−0.0180	−0.0383***	0.0176*	−0.0290	−0.0027	0.0416***
	(0.0274)	(0.0088)	(0.0106)	(0.0188)	(0.0263)	(0.0105)
rDebt	−0.2581	−0.1479***	−0.0497	0.2009	−0.0883*	0.0832*
	(0.1916)	(0.0572)	(0.1341)	(0.1239)	(0.0519)	(0.0501)
dCa	2.1805***	0.3966***	−0.1298	−1.1043***	0.3082	−0.5697***
	(0.3872)	(0.0953)	(0.4647)	(0.1331)	(0.2236)	(0.1507)
dG	7.1943**	−1.5241**	0.8475	2.4168*	−1.7028*	2.8060***
	(3.0177)	(0.7243)	(0.6644)	(1.4305)	(0.8834)	(0.9664)
Rate	0.1193***	−0.0165***	−0.0072*	−0.0104	−0.0971***	−0.0817***
	(0.0224)	(0.0044)	(0.0038)	(0.0100)	(0.0072)	(0.0048)
Observations	732	732	564	732	534	732
Number of pairs	16	16	12	16	12	16
Adj.-R^2	0.86	0.48	0.49	0.42	0.623	0.61

Bootstrap Standard errors (100 reps.) in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table E-3: Midas-Garch with two-way fixed effects

	Depdendent variable: Dynamic Correlation					
	(1)	(2)	(3)	(4)	(5)	(6)
	Nb v. Sb	Nb v. Ss	Nb v. Ns	Ns v. Ss	Sb v. Ss	Ns v. Sb
Lag dependent	0.5676***	0.3018***	0.2436***	0.2883***	0.2773***	0.2779***
	(0.0583)	(0.0247)	(0.0097)	(0.0323)	(0.0254)	(0.0196)
dInfl	0.0086	0.0125**	0.0019	−0.0195	−0.0006	−0.0031
	(0.0299)	(0.0054)	(0.0209)	(0.0149)	(0.0078)	(0.0108)
rVol	−0.0017	−0.0243***	0.0554***	−0.0739***	−0.0234	0.0431***
	(0.0164)	(0.0084)	(0.0065)	(0.0210)	(0.0147)	(0.0137)
rDebt	−0.2008*	0.0053	0.0519	0.0236	−0.1063***	0.0175
	(0.1211)	(0.0540)	(0.1031)	(0.0731)	(0.0281)	(0.0471)
dCa	1.1691***	0.1395	−0.0292	−0.5814**	0.2992***	−0.0503
	(0.2507)	(0.1613)	(0.2851)	(0.2339)	(0.1052)	(0.1804)
dG	3.8229**	−3.1674***	0.8599	6.1717***	−1.4968**	2.7138***
	(1.8667)	(0.8614)	(0.8812)	(1.0059)	(0.7330)	(0.7155)
Rate	−0.1343**	−0.1266***	−0.1184***	0.0465	−0.1021***	−0.0785***
	(0.0567)	(0.0145)	(0.0137)	(0.0286)	(0.0143)	(0.0175)
Observations	732	732	564	732	534	732
Number of pairs	16	16	12	16	12	16
Adj.-R^2	0.90	0.66	0.69	0.55	0.76	0.74

Bootstrap Standard errors (100 rep.) in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table E-4: Midas-Garch with two-way fixed effects and crisis dummy

	Depdendent variable: Dynamic Correlation					
	(1)	(2)	(3)	(4)	(5)	(6)
	Nb v. Sb	Nb v. Ss	Nb v. Ns	Ns v. Ss	Sb v. Ss	Ns v. Sb
Lag dependent	0.5827***	0.3069***	0.2590***	0.2705***	0.2761***	0.2471***
	(0.0528)	(0.0245)	(0.0097)	(0.0328)	(0.0299)	(0.0211)
dInfl	−0.0373	0.0025	0.0209	−0.0231	0.0020	−0.0031
	(0.0355)	(0.0079)	(0.0252)	(0.0222)	(0.0109)	(0.0116)
rVol	−0.0046	−0.0412**	0.0588***	−0.0655**	−0.0197	0.0488**
	(0.0275)	(0.0202)	(0.0097)	(0.0288)	(0.0213)	(0.0227)
rDebt	−0.2445*	0.0195	−0.0114	0.0625	−0.0908**	0.0411
	(0.1350)	(0.0627)	(0.1125)	(0.0826)	(0.0415)	(0.0620)
dCa	0.9108*	0.0705	0.1279	−1.0183**	0.2678**	−0.0917
	(0.4800)	(0.2319)	(0.4493)	(0.4323)	(0.1243)	(0.1855)
dG	11.4707***	−4.0180***	0.9983	7.9350***	−2.1194*	−1.1524
	(3.2419)	(1.0499)	(1.2977)	(0.9080)	(1.2869)	(1.1208)
Rate	0.1429*	−0.1840***	−0.2174***	−0.0129	−0.1849***	−0.2403***
	(0.0744)	(0.0268)	(0.0200)	(0.0533)	(0.0269)	(0.0331)
d × dInfl	0.0902**	0.0236	−0.0395	−0.0064	−0.0052	0.0034
	(0.0382)	(0.0146)	(0.0434)	(0.0322)	(0.0175)	(0.0121)
d × rVol	−0.0233	0.0412*	−0.0349*	−0.0129	0.0027	0.0086
	(0.0269)	(0.0247)	(0.0205)	(0.0322)	(0.0235)	(0.0230)
d × rDebt	0.0119	0.0026	0.0314	−0.0339	−0.0236	0.0491*
	(0.0656)	(0.0393)	(0.0829)	(0.0797)	(0.0314)	(0.0276)
d × dCa	−0.3010	0.3986	−0.3883	0.7162**	0.0597	0.5347***
	(0.5080)	(0.2519)	(0.4521)	(0.3405)	(0.2198)	(0.1728)
d × dG	−15.8384***	2.4550*	−0.9309	−6.0523***	1.5689	7.8458***
	(4.3048)	(1.3106)	(1.4995)	(1.9142)	(1.3805)	(1.8236)
d × Rate	−0.5615***	0.1395***	0.2244***	0.1782*	0.1808***	0.3426***
	(0.0849)	(0.0285)	(0.0230)	(0.0925)	(0.0404)	(0.0388)
d	−0.9500***	−0.7286***	−0.9824***	0.0567	−0.0080	−0.4497***
	(0.2897)	(0.1311)	(0.1093)	(0.2976)	(0.1362)	(0.1201)
Observations	732	732	564	732	534	732
Number of pairs	16	16	12	16	12	16
Adj.-R^2	0.90	0.67	0.70	0.55	0.76	0.77

Bootstrap Standard errors (100 rep.) in parentheses *** p<0.01, ** p<0.05, * p<0.1

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