Financial Contagion and the European Debt Crisis[1]

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Abstract

Since the beginning of 2010, the Euro Area faces a severe sovereign debt crisis, now generally known as the Euro Crisis. While the Euro Crisis has its origin in Greece, problems have now spread to several other European countries as well. Dynamic conditional correlation models (DCC) are estimated in order to assess if contagious effects are identifiable during the Euro Crisis, or if the countries' problems are instead due to fundamental problems in the affected economies. Our findings show that there is contagion within the Euro Area. Additionally, contagious effects generated by rating announcements are documented. These results are crucial when it comes to choosing the correct measure and timing of policy intervention.

JEL classification: E43, E44, E63

Keywords: Contagion, DCC, Euro Crisis

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1. Introduction

Since the beginning of 2010, the Euro Area faces a severe sovereign debt crisis, now generally known as the Euro Crisis. Rising government deficits and debt levels triggered rating agencies to downgrade several European countries' debt repayment probabilities, thereby creating a loss of confidence in financial markets. At the same time bond yield spreads widened considerably further worsening the repayment abilities of ailing countries. The creation of the European Financial Stability Facility on 9 May 2010 and the intervention of the International Monetary Fund did neither reverse the widening of the spreads nor contain the crisis to Greece. While the Euro Crisis finds its origin in Greece, the first country which had to be rescued with loans from other Euro area members and the IMF, figure 1 shows that problems have meanwhile spread to several other countries as well.

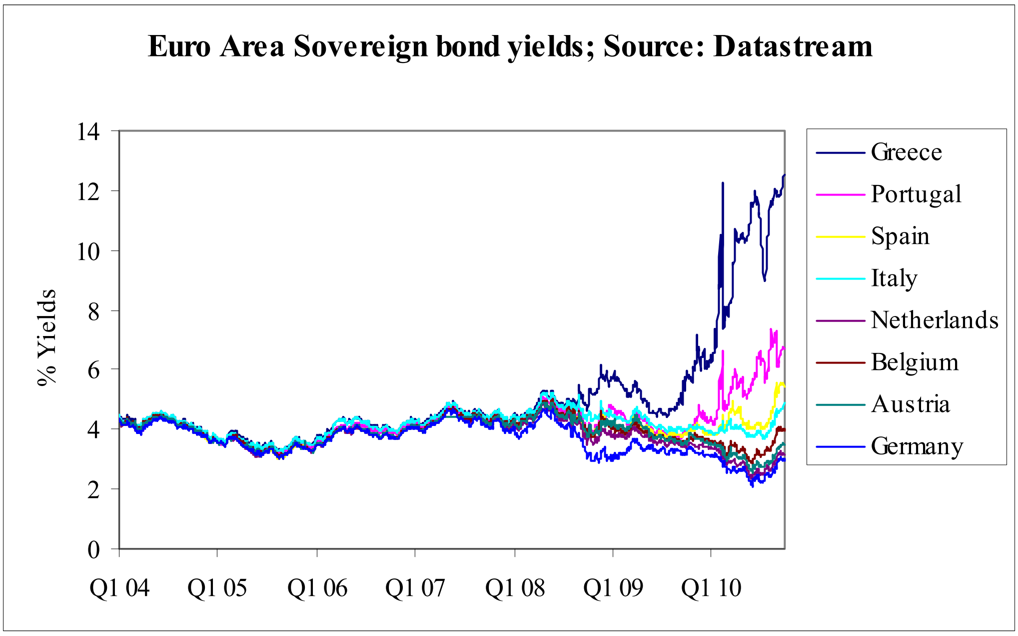


Figure 1: Bond yields of selected sovereigns of the Euro Area

This effect might result from financial markets recognizing that those countries are themselves fundamentally in severe trouble. However it might also be the case that Greece infected other countries by negatively influencing the markets' assessment of countries actually not being in too critical financial situations at all. The question if the current refinancing problems of some countries are disproportionate to their actual fundamental problems is therefore a question of contagion.

This paper aims at investigating if contagious effects are identifiable during the Euro Crisis. The main findings of the paper show the occurrence of contagion during the summer of 2010.

Results show that four countries (Portugal, Spain, Italy, Belgium) out of a sample of six (the Netherlands and Austria being the remaining two) were affected by contagion. Furthermore, it is examined if negative rating announcements generate contagious effects. The results are ambiguous, but there are at least strong tendencies that downgrades for Greece were translated to Portugal and Spain, while the other sample countries remained unaffected by contagious effects from rating cuts.

The remaining paper is organized as follows: We first give an overview of the literature on contagion and the potential econometric methods to detect contagion. Section 2 describes the so-called Dynamic Conditional Correlation model (DCC) which we use in our study to measure the time-varying nature of the correlation between different spreads. Section 3 presents the data and the estimation specification. Our results and some cautious possible politicy implications are provided in section 4. Section 5 extends the analysis to study if announcements of rating downgrades had any contagious effects. Section 6 concludes.

i. Literature on Contagion

Empirically examining contagion first requires defining what is meant by the term contagion. While several definitions have been used in the literature, Pericoli and Sbracia (2003) provide a summary of the five most commonly used ones. According to that summary contagion can be found if (i) the probability of a crisis in one country rises sharply as a response to a crisis in another country, (ii) the increase in asset price volatility is cross-national, (iii) comovements of asset prices are not fundamentally driven, (iv) the comovements of financial assets between countries increase significantly and (v) the transmission mechanism between countries changes conditional on a crisis in one of the countries, also leading to a change in the comovement of those countries' asset prices. Definitions (ii), (iii), (iv) and (v) all investigate contagion by looking at the volatilities or correlations of financial assets. Meanwhile stylized facts of contagion transmission mechanisms as summarized in Corsetti et al. (2010) support an analysis going in that direction. All four facts, (i) spreading stock price declines across countries, (ii) increasing return volatility in crisis periods, (iii) generally higher covariance and (iv) sometimes higher correlations in times of financial turmoil, are justifying a contagion analysis based on volatility and correlation measures. We next discuss in somewhat greater detail different empirical methods that have been used in the literature to study contagion.

The literature considering higher correlation of financial assets as evidence for contagion is extensive. An early contribution relying on this method is done by King and Wadhwani (1990). The paper examines the causes of the transnational stock market crash in October 1987, which could not be explained by fundamental data from the single countries being hit. The authors' analysis shows contagion, which is explained by the attempt of rational agents to extract information for one market by looking at price changes in other markets. A general problem with the kind of analysis used in that paper lies in the fact that the correlation of returns is crucially dependent on the volatility of the returns. As stylized facts demonstrate that volatility is higher in crisis times, this snaps through to the correlation measures. Therefore examining the correlation without controlling for the change in volatilities is problematic. Although King and Wadhwani mention the influence of volatility on correlation, they do however not correct for it in their empirical analysis.

Using correlation coefficients for different subsamples to determine contagion leads to biased results if heteroskedasticity is not accounted for. Therefore, more recent papers developed methods to account for changing volatilities. Forbes and Rigobon (2002) also analyse the stock market crash in 1987 in addition to the Asian crisis in 1997 and the Mexican crisis in 1994 with a heteroskedasticity adjusted measure of correlation. According to their results, the earlier found evidence for contagion is rejected. A high degree of comovements in different markets is defined to be normal interdependence which is caused by increased market volatility, but not by contagious effects themselves. Forbes and Rigobon were first to conduct such a useful distinction between contagion caused by changing investor sentiment, herding behaviour or panic and normal interdependence caused by economic relationships.

Corsetti et al. (2005), (2010) also identify contagion as a structural break in the transmission mechanism of shocks. Distinguishing between breaks caused by the dynamics of the variance and contagious shifts of cross-country linkages, the authors show other studies to be biased for the "no contagion, only interdependence"-hypothesis because only country-specific noise is assumed to cause dynamic volatility changes. In comparison to earlier studies restrictions on the origin of the variance measures are resolved by relying on a factor model in which a distinction between increases in volatility due to country specific noise on the one hand and to higher variance of some common factor on the other hand is implemented.

However there also remains a caveat for these newer models: The dynamic structure of the contagious effects plays an important role. One test might fail to deliver correct results, because contagious tendencies are present, however can only be recognized some lags later. Therefore when correcting for heteroskedasticity, the dynamic structure of the variance process should be accounted for. A test introduced by Hong (2001) controls for the phenomenon of volatility clustering. In order to investigate the causality of a volatility spill over between the U.S. dollar - Deutschemark and the U.S. dollar - Japanese yen exchange rates a test statistic built on the results from GARCH estimations is calculated. A test for contagion which accounts for the volatility dynamics in the time series can then be conducted.

The models discussed so far use differently suitable methods to correct for the presence of changing variances. However all of them still have one further inherent problem: By calculating static correlation coefficients or static test statistics for different subperiods, the test results crucially depend on the timing of those subperiods. The exact break of the transmission mechanism, i.e. the starting point of the contagion needs to be clearly identifiable, as different break points might generate different results. Consequently, by estimating models based on such exogenous assumptions, the dynamic structure of the contagious effects might get lost, as correct inference strongly depends on those assumptions regarding the data generating processes.

Recognizing the drawback of exogenously chosen break points, Caporale et al. (2005) develop a test in which the selection of the crucial timing is endogenized by implementing contagion dummies and sequentially testing their significance. In addition to that the test also offers increased power due to full-sample instead of subsample estimation, a problem demonstrated by Dungey and Zhumabekova (2001). This specification also accounts for the dynamic structure of heteroskedasticity. A potential drawback, however, is that only contemporaneous contagion is examined and lagged effects are therefore not captured.

Finally, Chiang et al. (2010) identify contagion and herding effects for the Asian crisis in 1997 by estimating a Dynamic Conditional Correlation (DCC) model. In the DCC model, dynamics of both the variances and the correlations are captured. Therefore the lag structure for each time series can be determined systematically according to the data. Additionally, the estimation method allows for a correction of heteroskedasticity and no exogenous subsample assumptions have to be made. Hence, the DCC model takes into account all the above mentioned drawbacks and problems and thus seems appropriate to empirically evaluate contagion. We therefore use the DCC estimation approach for our empirical analysis of contagion in the Euro Area.

ii. Literature on Multivariate GARCH models

The aim of this paper is to find the dynamic correlation structures of specific Euro Area government bond yields. Because we therefore study the dynamics of some assets' comovements and their correlation strcuture we need to rely on multivariate generalized autoregressive conditional heteroskedasticity (MGARCH) modelling. Specifying the correct MGARCH model is not easy however, as a compromise between parsimonious but still interpretable models needs to be found. Further, the models need to be constructed in a way that guarantees positive definiteness of the estimated covariance or correlation matrices. The literature of MGARCH models is vast and a good summary can be found in Silvennoinen and Teräsvirta (2008). Several MGARCH models apply specifications which successfully fulfill all technical requirements listed above. However, an interpretation in terms of a contagion analysis is not always easy. In the following, several models will be presented and judged regarding their suitability for contagion analysis.

A class of models in which the time varying covariances are modelled directly are BEKK-models and their generalizations, as initially introduced by Engle and Kroner (1995). Simultaneous equation systems can be analysed and sufficient constraints to allow for the positive definiteness of the conditional covariance matrices are provided. When it comes to technical correctness and the feasibility of estimation procedures, the model is suitable, however either general models with plenty of parameters or unreasonably restricted models need to be specified. In addition, the estimated parameters are difficult to interpret; consequently the use in contagion analysis is not meaningful.

Another class of models is the factor GARCH models, as first advocated by Engle et al. (1990). Factors, which follow a conditionally heteroskedastic process, are used to estimate covariance matrices. The estimation procedure is easy and parsimonious; however the difficulties emerge by selecting the correct factor generating the covariance matrices and by interpreting the estimated coefficients. Therefore, factor models are not used in our analysis.

Another model type does not directly estimate the covariance matrices, but models the conditional variances and conditional correlations instead. Those are of particular interest as correlation estimates are required when analysing contagion. An early model of this class is the constant conditional correlation model (CCC) proposed by Bollerslev (1990). Univariate GARCH estimations are calculated for each asset and the time varying covariances are assumed to be proportional to the square root of the product of the respective estimated variances. Thereby, a static, constant conditional correlation matrix can be estimated. However, constant conditional correlation is a strong assumption which needs to be tested. Additionally, initially assuming that there are no correlation dynamics at all leaves no room for an analysis if there is contagion (i.e. rising correlation) or only interdependence (i.e. constant correlation). Therefore, an extension of the model needs to be thought of.

Therefore, the preferred model for our analysis is the previously mentioned DCC model introduced and analysed in Engle (2002) and in Engle and Sheppard (2001). From an econometric point of view, the specification fulfils all requirements, i.e. the estimation is feasible for a high amount of assets being examined and nevertheless parsimonious. The estimated correlation matrices are guaranteed to be positive definite. As mentioned above, the results are suitably interpretable from a theoretical point of view as the volatility corrected correlation dynamics are of key interest in the contagion analysis.

2. Model

A DCC model is a straightforward extension of a CCC model. Univariate GARCH models are estimated for each single asset and the standardized residuals from the models for the conditional variances are used to calculate the conditional correlations. The particular procedure is presented in the following.

i. Model Setup

In a first step, mean zero returns r with covariance matrix H_t derived from some filtration (e.g. ARMA residuals) are used to estimate a GARCH specification of the conditional variances for all k assets in the analysis. Exemplarily, one representative asset follows a GARCH process according to (1), where the optimal ARCH and GARCH order needs to be identified for each single asset.

$$h_t = \omega + \Sigma_p\alpha_p r^2_{t-p} + \Sigma_q\beta_q h_{t-q} \quad (1)$$

Hereby h_t represents the variances, r_t the filtered returns and ω, the α's and β's the parameters to be estimated. The filtered return process can be written according to (2).

$$r_t = h_t\varepsilon_t \qquad \text{with} \quad \varepsilon_t \sim N(0,1) \quad \text{and} \quad r_t \sim N(0, H_t) \quad (2)$$

With the estimates of the univariate GARCH equations in (1), the conditional variances h_t can be used to derive the standardized GARCH residuals ε_t from (2). Those standardized residuals are required to model the dynamic correlation structure. Specifically, the correlation dynamics are estimated according to the DCC equation (3a) and the normalizition (3b).

$$Q_t = (1 - \Sigma_m\gamma_m - \Sigma_n\delta_n)\,\hat{O} + \Sigma_m\gamma_m(\varepsilon_{t-m}\varepsilon'_{t-m}) + \Sigma_n\delta_n Q_{t-n} \quad (3a)$$

$$R_t = Q^{*-1}_t Q_t Q^{*-1}_t \quad (3b)$$

Q_t represents the time varying covariance matrix of the standardized residuals; Ô the unconditional covariance matrix of the standardized residuals, the γ's and the δ's the estimated parameters of the DCC equation. As in a GARCH equation, the covariance dynamics depends on past shocks and past covarainces. The required lag length of the DCC equation (3a) again has to be identified. The γ's represent the reaction of the comovement to news, i.e. to past shocks, whereas the δ's represents the decay of past comovements. The unconditional covariance matrix Ô is positive definite and the lagged shocks $\varepsilon_{t-m}\varepsilon'_{t-m}$ are positive semidefinite, consequently also Q_t as weighted average of a positive definite and a positive semidefinite matrix will be positive definite. The exact conditions for this result can be found in Engle and Sheppard (2001).

The normalization (3b) is used to arrive at the dynamic correlation matrices R_t. Q^*_t is a diagonal matrix with the square roots of the diagonal of Q_t as diagonal elements. By multiplying with the inverse, the typical element of R_t is the correlation coefficient of two assets and the diagonal of R_t consists of ones (as the correlation of one asset with itself necessarily equals one).

Finally, the still unspecified time varying covariance matrix of the filtered returns r_t is derived according to (4).

$$H_t = D_t R_t D_t \qquad (4)$$

Here, D_t is a diagonal matrix with the square roots of the estimated conditional variances h_t as typical element.

ii. Model Estimation

The DCC model can be estimated using maximum likelihood. If the input variables r_t are not multivariate normal, quasi maximum likelihood is applied instead. A two stage estimation procedure can be use to solve for the parameters maximizing the likelihood function (5).

$$L = -1/2\ \Sigma_t\ [\ k\ \log(2\pi) + \log|H_t| + r_t'\ H_t^{-1} r_t\ ] =$$

$$= -1/2\ \Sigma_t\ [\ k\ \log(2\pi) + 2\ \log|D_t| + r_t'\ D_t^{-2}\ r_t - \varepsilon_t'\varepsilon_t + \log|R_t| + \varepsilon_t'\ R_t^{-1}\ \varepsilon_t\ ] \qquad (5)$$

In the first stage, the univariate GARCH equations for all k assets are estimated using the filtered return series r_t as input variables. By maximising the volatility part (6a) of the likelihood function jointly for all k assets, the GARCH parameters ω, α and β for each asset and each asset's lag order are estimated.

$$L_{GARCH} = -1/2\ \Sigma_t\ [\ k\ \log(2\pi) + 2\ \log|D_t| + r_t'\ D_t^{-2}\ r_t\ ] \qquad (6a)$$

Using these parameters, the conditional variances h_t can be derived, which are required to calculate the standardized residuals ε_t according to (2). With the standardized residuals, the second stage, i.e. the DCC estimation can be conducted. Therefore, the DCC part (6b) of the likelihood function is maximized conditional on the parameter estimates from the first stage. Here, the DCC parameters γ and δ for the required lag order are estimated.

$$L_{DCC} = -1/2\ \Sigma_t\ [- \varepsilon_t'\varepsilon_t + \log|R_t| + \varepsilon_t'\ R_t^{-1}\ \varepsilon_t\ ] \qquad (6b)$$

Under very general conditions, the two stage (quasi) maximum likelihood estimates are consistent and asymptotically normal as can be found in White (1994). Additionally, Bollerslev-Wooldridge consistent standard errors can be calculated according to Engle and

Sheppard (2001). Consequently, consistent t-tests on the parameters of both estimation stages can be conducted.

3. Dataset and Specification

For the investigation of contagious effects during the Euro Crisis we use a sample of seven countries vis-à-vis Germany: Greece, Portugal, Spain, Italy, Netherlands, Belgium and Austria. Thus, our sample of countries includes both countries which witnessed refinancing problems resulting from increased government bond yields as well as countries unaffected by the crisis. Additionally, we study those countries' yields vis-à-vis the German yield because the German yield serves as our riskfree benchmark and because of the sheer size of the German economy within the Euro Area. The exclusion of such a major country in a model of contagion would lead to errors due to misspecification as shown by Dungey et al. (2003).

i. Dataset

A dataset consisting of the 10-year benchmark government bid yields calculated by Thomson Reuters and provided on Datastream for a time period from 12/31/2008 until 12/31/2010 is applied in the analysis. Using daily returns for a five-day week, the sample covers a total of 522 data points. The benchmark yield thereby represents that yield, which countries need to offer for newly emitted 10-year government bonds in order to attract investors. German benchmark yields are used as a reference point in order to compare the risk premium of the affected countries. By subtracting the German benchmark yields, parallel developments of monetary policy and parallel inflation expectations of the countries examined are removed from the benchmark yields. Consequently, those yield spreads represent the country specific risk premium of Greece, Portugal, Spain, Italy, Netherlands, Belgium and Austria.

As mentioned above, the input variables for a DCC model need to have an expected return of zero according to (2), therefore the yield spreads from the original dataset need to be modified by some kind of filtration. As the focus of the analysis lies on the dynamic process of the second moments of the spread series, an ARMA-filtration for the original data is used in order to provide input variables not being autocorrelated with respect to the first moment.

ADF and KPSS tests for unit root identification are conducted for each time series. As every series is integrated of order one, the further analysis is continued using first differences. The government bond yield time series show clear signs for a structural break in 2008, however during the examined time span ranging from 12/31/2008 until 12/31/2010 no break needs to be modelled. The ARMA lag-length selection is identified via Hannan-Rissanen Model Selection and the Schwarz information criterion. Models are checked for no remaining autocorrelation using Portmanteau and LM tests. Applying the procedure to the seven spread series results in a filtration of the first differences according to ARMA(7,1) for Greece, MA(4) for Portugal, AR(3) for Spain, MA(2) for Italy, AR(2) for the Netherlands, ARMA(1,2) for Belgium and AR(1) for Austria. Remaining autocorrelation can clearly be rejected for all time series examined. Additionally, the filtered spreads nearly always exhibits signs for conditional heteroskedasticity as verified with ARCH-LM tests.[2] Consequently, a GARCH analysis is both reasonable from a theoretical point of view in order to investigate contagious effects and from an econometrically point of view.

ii. Specification

In order to estimate the dynamics of the second order moments and the correlation structure, the filtered spreads are applied in a DCC model. The specification of the DCC model requires the identification of the lag order for the single univariate GARCH equations provided in (1) and for the multivariate DCC equation provided in (3a).

For the specification of the GARCH order, nested versions of the models for each time series are sequentially evaluated with likelihood ratio tests. Alternatively, it would also be possible to choose the GARCH order according to the minimization of information criteria. Residuals are checked for remaining conditional heteroskedasticity using modified Portmanteau and LM tests for no remaining ARCH-effects. This methodology identifies a GARCH(1,1) process for Greece, GARCH(4,5) for Portugal, GARCH(1,3) for Spain, GARCH(1,1) for Italy, GARCH(1,3) for the Netherlands, GARCH(1,2) for Belgium and GARCH(2,3) for Austria. The resulting residuals are significantly tested for no remaining conditional heteroskedasticity.

[2] Portugal represents the only exception as conditional heteroskedasticity of the MA(4) residuals is clearly rejected by the ARCH-LM test.

The specification of the DCC equations requires more attention. As mentioned above, the DCC equation is used to estimate the correlation dynamics from the assets of interest. These correlation dynamics are required to analyse the potential presence of contagious effects. However, as a first step, it is important to investigate, if there are correlation dynamics at all, or if the correlation remains constant as assumed in Bollerslev (1990). If that was the case, contagion could be rejected right from the beginning of the analysis, only questions of interdependence could be answered. As argued in Forbes and Rigobon (2002), high comovements of markets are only a sign of strong economic linkages between those countries. If those comovements are similar high during crisis and non-crisis periods, one should only conclude for interdependence of those countries, as transmission mechanisms remain fairly stable. Only if the transmission and the cross-market linkages get propagated during crisis times, contagion might be at hand. Engle and Sheppard (2001) propose a test which evaluates the null of constant conditional correlation against dynamic conditional correlation. The OLS based test demonstrates good size and power properties against local alternatives. With a p-value of approximately zero, the null of constant conditional correlation can clearly be restricted at any level of significance. Estimation of a dynamic correlation structure is necessary.

Secondly, it needs to be analysed, if the dynamics of the comovements have a unit root and therefore an integrated dynamic conditional correlation model should be estimated instead of a regular DCC model. This can be accomplished by estimating a restricted model which imposes $1 - \delta = \gamma$ and comparing it via a likelihood ratio test to the unrestricted DCC(1,1) specification. An integrated DCC model can clearly be rejected.

Finally, in order to determine the lag length of the DCC equation sequential likelihood ratio test can again be conducted as in the univariate GARCH specification. However, those tests can only be used as an initial analysis, as the resulting test statistics are not necessarily Chi-squared distributed, as demonstrated in Foutz and Srivastave (1977). The identified specification should be verified with Wald tests, as those are consistent due to the modified standard errors. Using this test procedure, the DCC process is identified to be DCC(1,1).

4. Results

i. Correlation Dynamics

Using the DCC model as specified above six correlation series are calculated for each country of the sample. Greece was the first country witnessing the problems of the sovereign debt crisis and therefore represents the origin of the contagion analysis. By examining the pairwise dynamic correlations between Greece and Portugal, Spain, Italy, the Netherlands, Belgium and Austria, the question of contagion within the Eurozone can be studied. If the DCC results indicate that contagious effects between Greece and other countries were present, then financial market participants – at least to some degree – transferred the financial problems of Greece to other countries in the Euro Area that would otherwise be fundamentally sound. If no contagious effects can be shown, then the Greek situation is independent from the other countries' financial development.

The dynamic correlation structure between Greece and the other six countries of the sample is provided in figure 2. The figure shows the daily evolution of the bond spread correlation between 2009 and 2011. Both DCC and CCC models are estimated. The constant horizontal line depicts the bond spread correlation of the CCC model, i.e. under the assumption of constant correlation over the sample period. This assumption can however be rejected for the data, as is already discussed in the specification section. The time-varying line represents the dynamic correlation structure. Greek government bond spreads always exhibit positive correlations with the other countries' spreads. An overview of the descriptive statistics of the correlation structure for the three periods is provided in table 1.

The mean Greek and Portuguese spread correlation is highest with an average of 0.543, with an average of 0.315 the mean Greek and Dutch spread correlation the lowest. While significantly not being constant, all correlation dynamics are nevertheless not very erratic, with standard deviations ranging from 0.062 to (Greece – Netherlands) to 0.078 (Greece – Belgium).

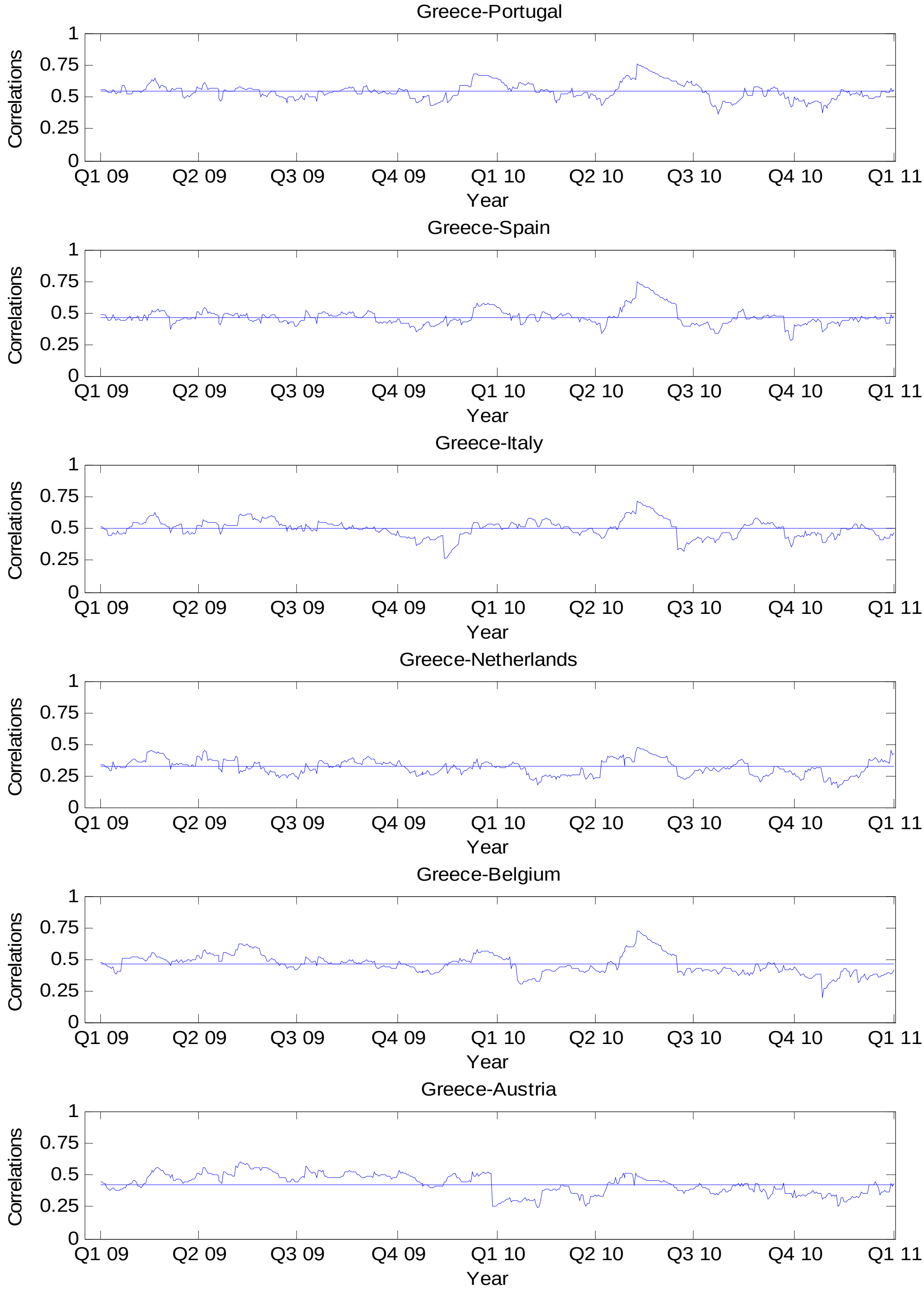


Figure 2: Greek correlation dynamics[3]

[3] The analysis aims at investigating if contagious effects are generated with Greece being the origin, therefore only the Greek correlations are displayed here. The results for the other countries can be found in the Appendix.

	Minimum	Maximum	Mean	SD
Greece – Portugal	0.369	0.757	0.543	0.064
Greece - Spain	0.277	0.740	0.463	0.065
Greece – Italy	0.260	0.713	0.498	0.068
Greece – Netherlands	0.158	0.476	0.315	0.062
Greece – Belgium	0.204	0.726	0.458	0.078
Greece - Austria	0.247	0.598	0.428	0.077

Table 1: Greek correlation dynamics: Descriptive statistics

ii. Determining contagious effects

The analysis aims at investigating if refinancing problems of some European countries are due to contagious effects. If that was the case, some countries would suffer unjustified financial problems which are solely driven from deteriorated investor sentiment stemming from independent and bad news of other countries. As the sovereign debt crisis initially hit Greece, we take Greece as the origin of the crisis and examine if other countries suffer directly from the fact that Greece was in financial distress, even though they might actually be unrelated to the Greek problems and are in fact financially sound.

If it can be shown that contagion infected for example Portugal, then bad news about the Greek economic performance, competitiveness and indebtedness is extrapolated to Portugal, even though a higher risk premium is not fundamentally justified. If no contagion can be shown, then the increase in the risk premium of Portugal is economically reasonable and is not only caused by bad investor sentiment and panic introduced by Greek.

According to major contagion literature, for the identification of contagion a strong increase in volatility adjusted cross-country correlation coefficients needs to be observed. As argued by Forbes and Rigobon (2002), a permanent increase in correlations which remain stable at the higher level once the increase is completed, is not contagious but driven by stronger economic interdependences. Such economic integration is a time consuming process and doesn’t revert back immediately. Consequently, contagious effects are identified if correlation measures increase significantly during the contagious period, but don’t remain permanently on the higher level.

The pairwise correlation dynamics show strong increases in the summer of 2010 for Portugal, Spain, Italy and Belgium. While the correlation coefficients fairly regularly bounce beyond and above the assumed constant correlation before Q2 2010 and after Q3 2010, the time period in between is characterised by a high increase of comovements. For all four countries, the maximum of the correlations fall within that period. Also this increase is not permanent, as it reverts to the assumed constant correlation clearly too fast as to argue for an economically driven increase. Consequently contagion can be identified with Greece infecting Portugal, Spain, Italy and Belgium. This does not mean that Greece alone caused the refinancing difficulties of the other four countries, but that potentially existing fundamental problems were further worsened to at least some extent. Quantifying that extent, however, is beyond the scope of our analysis.

All correlation series display some outliers, with the most prominent one being a huge spike in the summer of 2010 showing comparably high correlations as in the second period. Interestingly, for the Netherlands only a small effect can be observed. Austria does not show an effect at all. While bad news on Greece can influence the investor sentiment about the financial stance of economically problematic countries or politically unstable countries, contagious tendencies do not seem to hit economically and politically perfectly stable countries. If however countries are under close investors' watch for various reasons anyways, the sudden downturn in financing conditions of one observed country can cause spillover effects exaggerating the actual fundamental problems.

Summarizing, it can be concluded that the spreading refinancing problems of some European countries are to some extent caused by contagion and are not only based on suddenly deteriorating news about the competitiveness and fiscal stance of the affected countries. This conclusion is crucially important for the choice of political intervention. As argued by Forbes and Rigobon (2001), an identified contagion infecting countries with no economically justified financing problems would infact call for some form of bail-out mechanism. Thereby, investors could be calmed down and refinancing costs possibly decrease to normal or fundamental values. This would allow the normal economic development of the country to continue without any detrimental effects from the contagion. Consequently, the bail-out capital would not be sacrificed in such a scenario as the stance of the borrowing economy is robust enough to allow for repayment. If, however, no contagion is identified, then the financing problems are entirely due to fundamental economic and fiscal problems of the relevant country. In such a situation a bail-out might calm the investors down for a moment, but soon the economic grievance will reappear. The resulting renewed accentuation of financial distress would call for an additional bail-out, which however would again be useless when it comes to solving the fundamental problems of the country. Consequently, if there is no contagion a bail-out is unlikely to be successful and measures aiming at strengthening the competitiveness and structural reforms of the public debt and deficit levels of the country are preferable.

For the current European situation this means specifically that rescue strategies should be adjusted to these insights. The approval of a bail-out should – amongst other considerations – be related to the identification of contagious effects. In May 2010 the European Financial Stability Facility was implemented and a 110 billion Euro loan to Greece was provided by the countries of the Eurozone and the IMF. This was precisely at a time in which our DCC-model identifies contagious effects at work and thus this decision seems indeed very reasonable. Further bail-outs should be evaluated with respect to the same or similar quantitative analysis.

iii. Robustness

In order to check the robustness of the results observed so far, a similar analysis has been conducted using modified datasets. The DCC estimation of the correlation dynamics is also performed using the 10-year benchmark government bid yields instead of the bond yield spreads. Additionally, the 10 year CDS spreads between the seven analysed countries and Germany were implemented. All data is again used on a five-day week basis between 12/31/2008 and 12/31/2010 and is provided on Datastream.

The results of the robustness analysis are presented in figure 3. The solid line represents the correlation dynamics for the bond yield spreads, the dashed line for the bond yields and the dotted line for the CDS spreads. The model specification for the new datasets is performed according to the model specification of the original series.[4]

[4] Additionally, the models of the new datasets have been specified identically as for the original series, i.e. no specification adjustment to the new data has been applied. The conclusions for that alternative specification remain identical

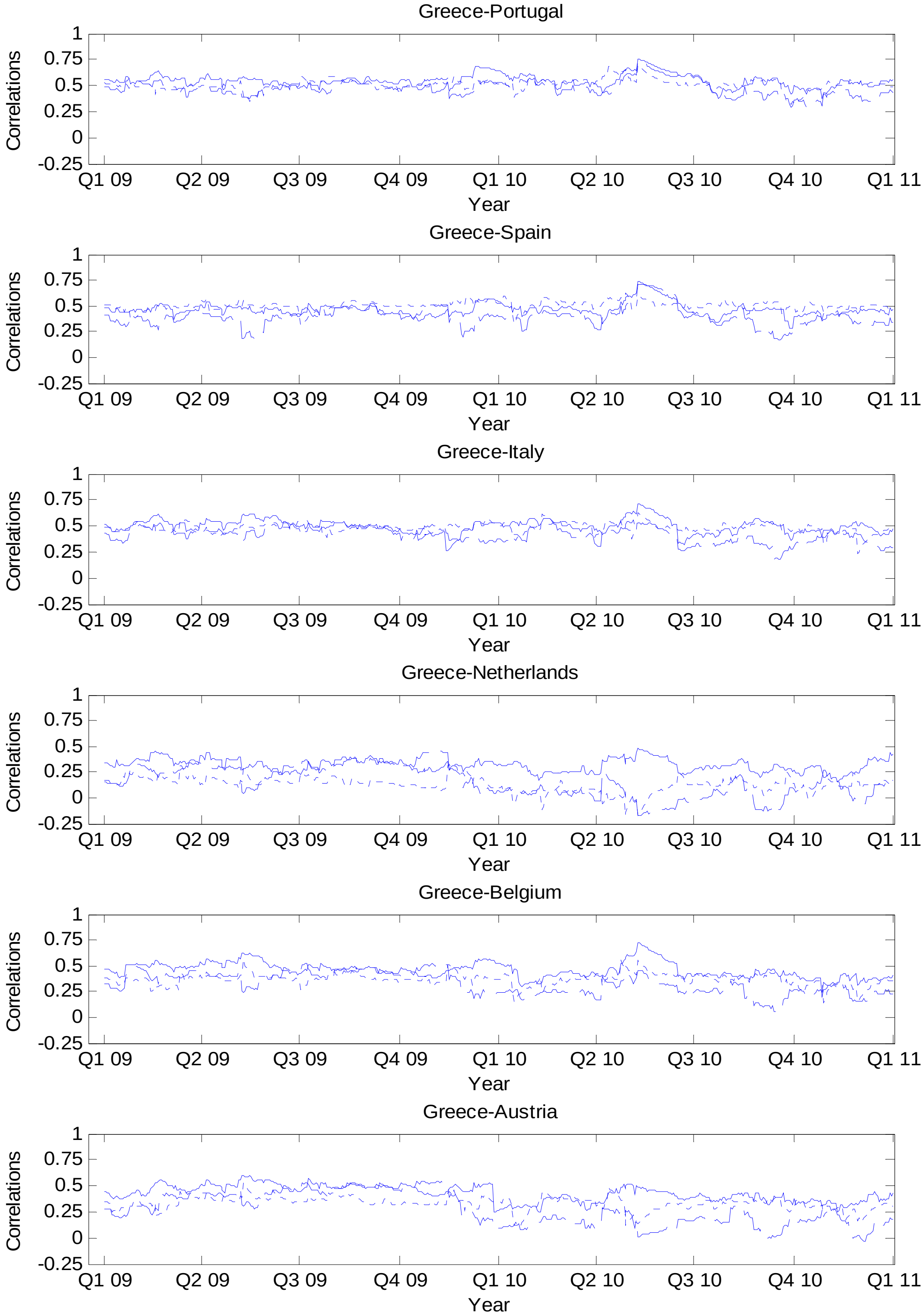


Figure 3: Greek correlation dynamics, robustness check. Solid line: Yield spread correlations. Dashed line: Return correlations. Dotted line: CDS spread correlations.

It can be observed that the pattern of correlation dynamics remains roughly identical for all three time series. While a similar development can be observed for Portugal, Spain, Italy and Belgium, the similarity of the dynamics is somewhat weaker for the Netherlands and Austria. Most importantly the significant increase in correlations between Q2 2010 and Q3 2010 can be confirmed by using different datasets with different specifications. Consequently the before mentioned results of the analysis are robust.

5. Announcement Effects

So far we have shown that there seem to be contagious effects at work during the Euro Crisis in general. We now study if single Rating Agency announcements can by themselves trigger contagious effects. If a negative rating announcement in one country significantly increases cross-country correlations, this rating cut also influences the investors' sentiment about other countries in which there was no rating downgrade at all. In the following we investigate if negative rating announcements for Greece significantly changed the correlation dynamics and consequently altered the financial situation of the other countries analysed.

i. Model Setup

In order to analyse the contagious effects of announcements, univariate time series models for the DCC correlations are estimated and enhanced by a rating announcement dummy. Taking Greece again as the origin of the crisis, the correlation series between Greece on the one side and Portugal, Spain, Italy and Belgium on the other side is implemented into an ARMA model. The country selection is due to the fact that those are identified to be affected by contagious effects in general and therefore it is interesting if announcements pronounce this phenomenon. Furthermore, a dummy variable indicating the negative rating announcements for Greece and a set of control variables according to (7) is introduced into the estimation equation.

$$\rho_t = \varphi + \Sigma_p\kappa_p\rho_{t-p} + \Sigma_q\theta_q u^2_{t-(q-1)} + \eta D_t + \Sigma_i\tau_i C_{i,t} \quad (7)$$

In (7), ρ represents the correlation estimated in the DCC-equation (3b), u_t the current and past shocks, D_t the rating announcement dummy for Greece, $C_{i,t}$ the set of the i = 1,…,I control variables and φ, the κ's, the θ's, τ's and η the parameters to be estimated.

ii. *Dataset*

A dummy variable constructed with rating announcements for Greek sovereign debt between the period of 12/31/2008 and 12/31/2010 is used in order to test the impact of rating news on correlations. During that time frame, only negative rating cuts were published. The dummy variable takes a value of one on each day, on which Fitch, Moody's or Standard and Poor's announced a downgrade and a value of zero otherwise. For the whole sample, there are 18 negative rating announcements, for the crisis sample there are 18.
The control variables are constructed with Fitch's sovereign debt ratings of the specific country being analysed. All publication dates can be directly obtained from the rating agencies' web sites.

iii. *Specification*

In order to estimate equation (7) for the four correlation series the suitable ARMA-specification again needs to be identified. All time series are stationary and model selection for the levels is again conducted with Hannan-Rissanen model selection and Schwarz information criterion, models are checked using Portmanteau and LM tests. According to this procedure all correlation series follow an AR(1) process. The filtered correlations exhibit no sign for remaining autocorrelation or conditional heteroskedasticity.

Equation (7) is estimated for three different specifications. In the baseline scenario, only the Greek ratings dummy is included into the AR(1) models in order to test if such a rating announcement significantly influences the correlation dynamics. If a rating cut for Greece significantly increases the yield spread correlation between Greece and another country, one might conclude for contagious effects. A country which is unrelated to Greece gets negatively affected by Greek rating deteriorations.
However, one might also argue that Greek ratings are not unrelated to another country's rating. If it is exemplarily more likely that Portugal will sustain a rating cut once Greece recently sustained one, then investors will anticipate a subsequent Portuguese downgrade from a recent Greek downgrade. Consequently, a correlation increase between Greece and Portugal is not due to the announcement itself and is not driven by irrational investor sentiment, but by the rational investors' anticipation of an increased likelihood of a

Portuguese rating cut. The worsened refinancing conditions of Portugal then don't result from announcement contagion, but from fundamental factors. Therefore, the second and third specifications control for the interdependence between Greek and other countries ratings.

For the second specification, a rating spread between the Greek and the four other countries' rating is used as control variable. Each rating is indexed to a number according to Afonso et al. (2011). Highest quality ratings (AAA ratings) receive a number of 17, very high credit risk and worse ratings (CCC+ and worse ratings) receive a number of 1, and all other ratings in between are linearly transformed to the number 2 – 16 accordingly. The rating spread is calculated by subtracting the Greek index from the different other countries' index. For the whole sample period, the Greek index is always smaller than other indices and therefore the control variable is positive. The smaller the spread turns out to be, the closer is the Greek rating to the compared rating. If it is more likely for similarly bad rated countries to sustain a rating cut once Greek was downgraded, then for such countries the control variable should have a positive impact on the correlation coefficients. Interdependences between the rating developments of two countries are consequently captured.

In the third specification, rating interdependences between two countries are captured by estimated dynamic correlations between those countries. Therefore, the rating development is again indexed and a DCC model is estimated for the ratings. In order to prepare the indexed ratings as suitable mean zero input variables for a DCC model, the rating time series are demeaned. Subsequently the simplest possible DCC specification with GARCH(1,1) and DCC(1,1) lag length selection is estimated. The resulting dynamic conditional correlations for the ratings are used as control variables accounting for the interdependence of rating developments. This third specification is however only feasible for Greece, Portugal and Spain, as those are the only countries for which rating changes occurred between 12/13/2008 and 12/31/2011. Consequently, only rating correlation time series Between Greece and Portugal and Greece and Spain can be calculated, as correlation coefficients are not defined if one of the two variables of interest is constant.

iv. *Results*

The conclusions of the contagion analysis of announcement effects are ambiguous. Equation (7) is calculated for all three specifications for the correlations of Greece with Portugal, Spain, Italy and Belgium. The results are presented in table 2.

Correlation Series	Parameter	1. Specification	2. Specification	3. Specification
Greece – Portugal	Rating Dummy	0.006 **	0.006	0.006 **
	Rating Spread	X	0.000	X
	Rating Correlation	X	X	0.000
Greece - Spain	Rating Dummy	0.007	0.006 ***	0.006 ***
	Rating Spread	X	0.001	X
	Rating Correlation	X	X	-0.003
Greece – Italy	Rating Dummy	0.001	0.001	X
	Rating Spread	X	0.000	X
	Rating Correlation	X	X	X
Greece – Belgium	Rating Dummy	0.001	0.001	X
	Rating Spread	X	0.000	X
	Rating Correlation	X	X	X

Table 2: Greek announcement effect estimation: Dummy parameter (η) and control variable (τ) estimates. *, ** and * denote statistical significance at the 10%, 5% and 1% confidence level.**

As long as one assumes that the Greek ratings are independent from the Portuguese ratings, the announcements of Greek rating cuts have a bad impact on Portugal. The announcement dummy in specification one has a significantly positive effect on the correlation between Greece and Portugal. As the correlation of Greek and Portuguese bond spreads increases on Greek announcement days, the bad information about Greece spreads over to Portugal and negative rating news on Greece seem to badly influence investors' perception of the financial stance of Portugal. Contagion can therefore be identified. If however one believes that the Greek and the Portuguese rating are related to each other, it would be rational to expect a rating downgrade for Portugal after Greece was downgraded. Therefore, contagion can only be identified if one controls for this increased downgrade probability. The hypothesis of contagion through rating downgrades is rejected for specification 2 and accepted for specification 3. In summary, the evidence for announcement contagion for Portugal is unclear, however slightly favouring the existence of such effects.

For Spain no contagion can be shown in the baseline regression, however the dummy coefficients are highly significant both in specification two and three. Consequently, contagious effects are identified if the Greek and Spanish ratings are dependent on each other, otherwise not. Finally, we do not find significant announcement effects for Italy and Belgium.

Summarizing the analysis of Greek announcements we conclude that bad rating news show at least some tendency towards a generation of contagious effects for some countries. This tendency for correlation increases on announcement days is shown graphically for the Spanish case in figure 4.

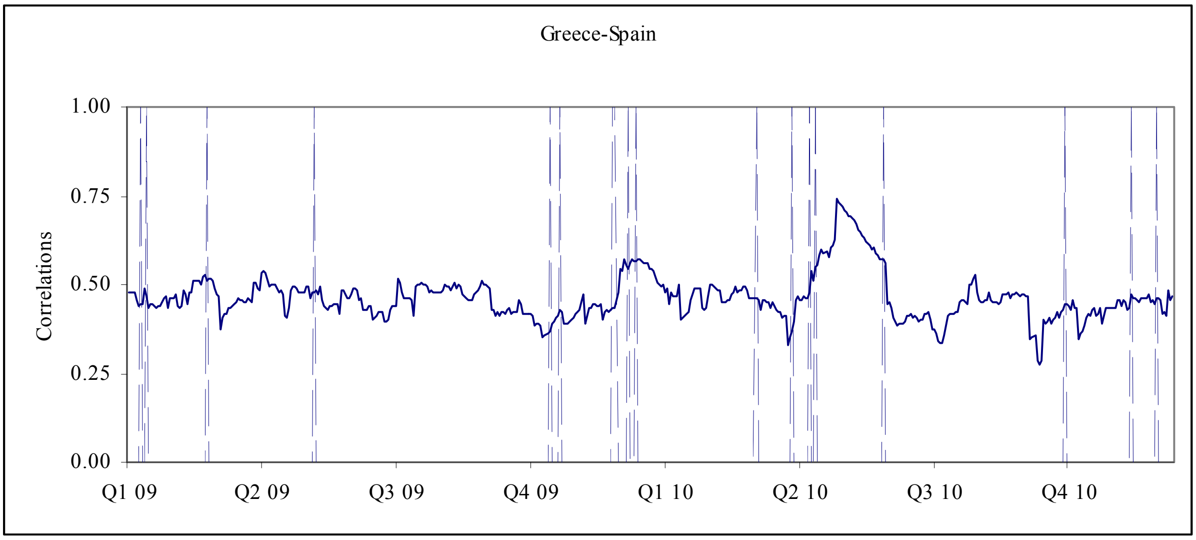


Figure 4: Announcement effect of Greek ratings. Solid line: Yield spread correlation between Greece and Spain. Dashed line: Rating announcements for Greece.

The figure shows the correlation dynamics between Greek and Portuguese yield spreads and indicates each day of rating announcements for Greece. For most of the announcement days it can be seen that the correlation tends to strongly increase with rating news.

The identification of contagious effects generated by rating announcements is important for different reasons. First, the rating development of different related countries needs to be kept in mind when it comes to interpreting bond yield movements or implementing measures aiming at influencing the bond markets. For instance countries which are badly affected by other countries' ratings should try to avoid the emission of new treasury bonds soon after downgrades of related countries as such news will put upward pressure on the required yield of their own new issue. Second, announcement effects are important from an investor's point of view (see e.g. Christiansen (2000)). The intraday behaviour of co-movements of different assets is important when it comes to risk management, asset allocation and asset pricing.

6. Conclusion

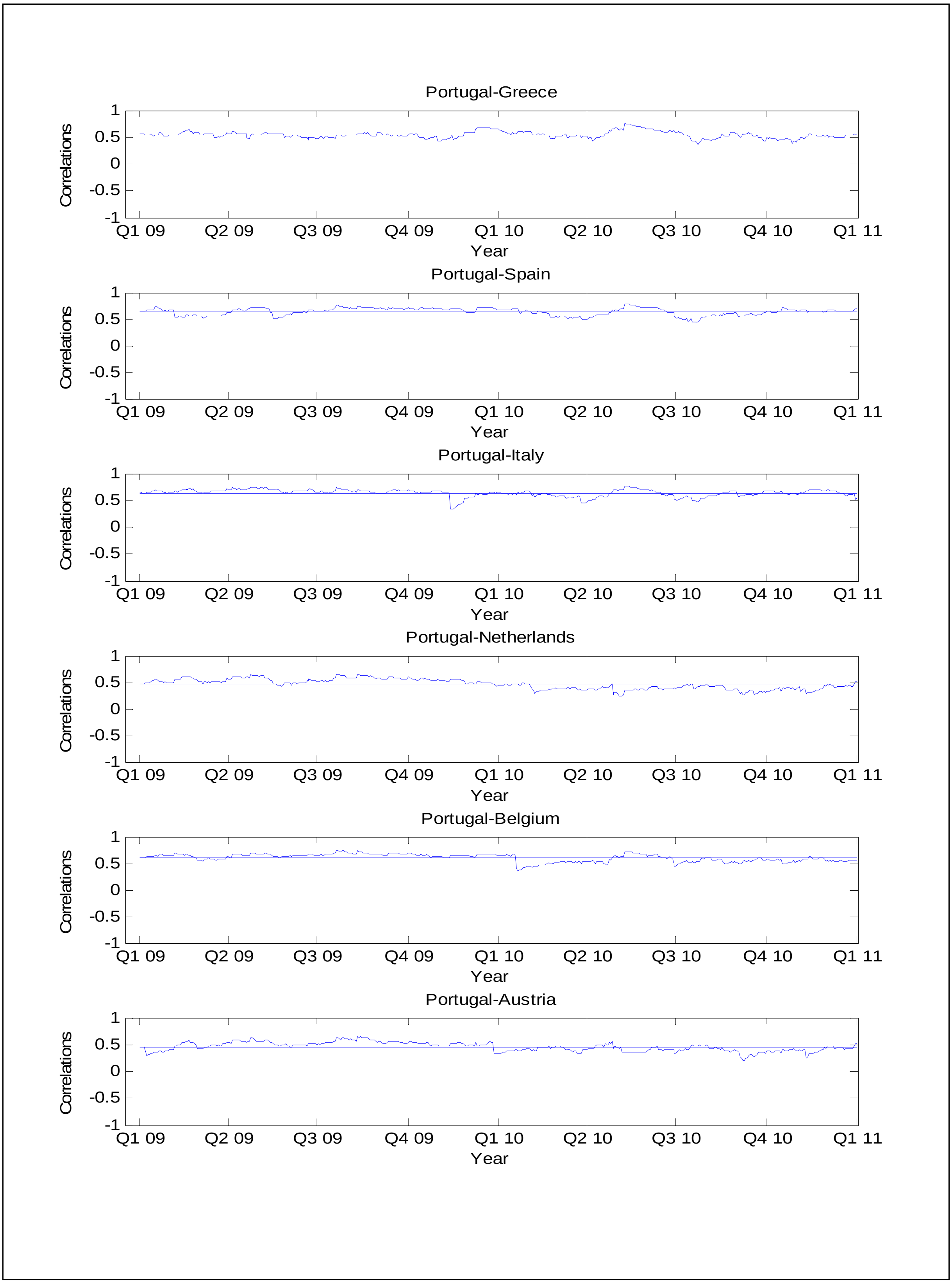
We have estimated a dynamic conditional correlation model (DCC) in order to analyse the correlation structure of Greek, Portuguese, Spanish, Italian, Dutch, Belgian and Austrian bond yield spreads over the German yield to study contagion in the Euro Area. Our results do indicate the presence of contagious effects during the Euro Crisis. In particular, Portuguese, Spanish, Italian and Beglian yield spreads do increase along with their Greek counterpart. Thus it seems likely that Greek financial problems can spread via contagion to other Euro Area countries.

The resulting policy implications are ambiguous and should be drawn very carefully. While a bail-out, as impliemented in summer 2010, can be regarded as a reasonable reaction to contagious pressures, the general development of bond markets of those countries also call for measures aiming at increasing their fiscal stance and competitiveness as well.

Finally, we studied if Greek rating downgrades generate contagious effects on other countries. We find that bad news about Greek ratings can in fact generate contagion to some other countries. However this does not hold for all countries in our sample as some are unaffected by Greek downgrades.

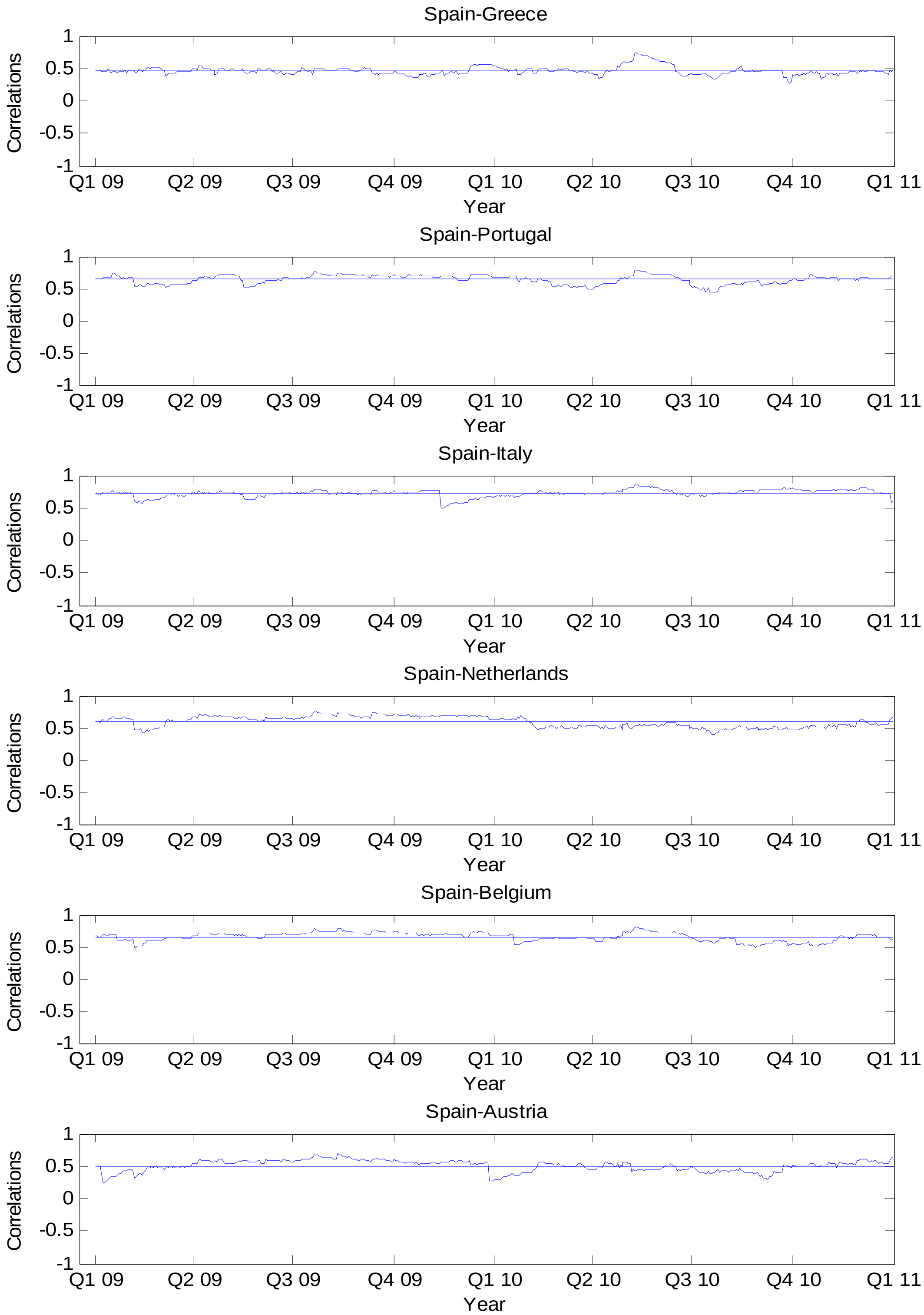
Appendix: Correlation Dynamics

1. Portugal



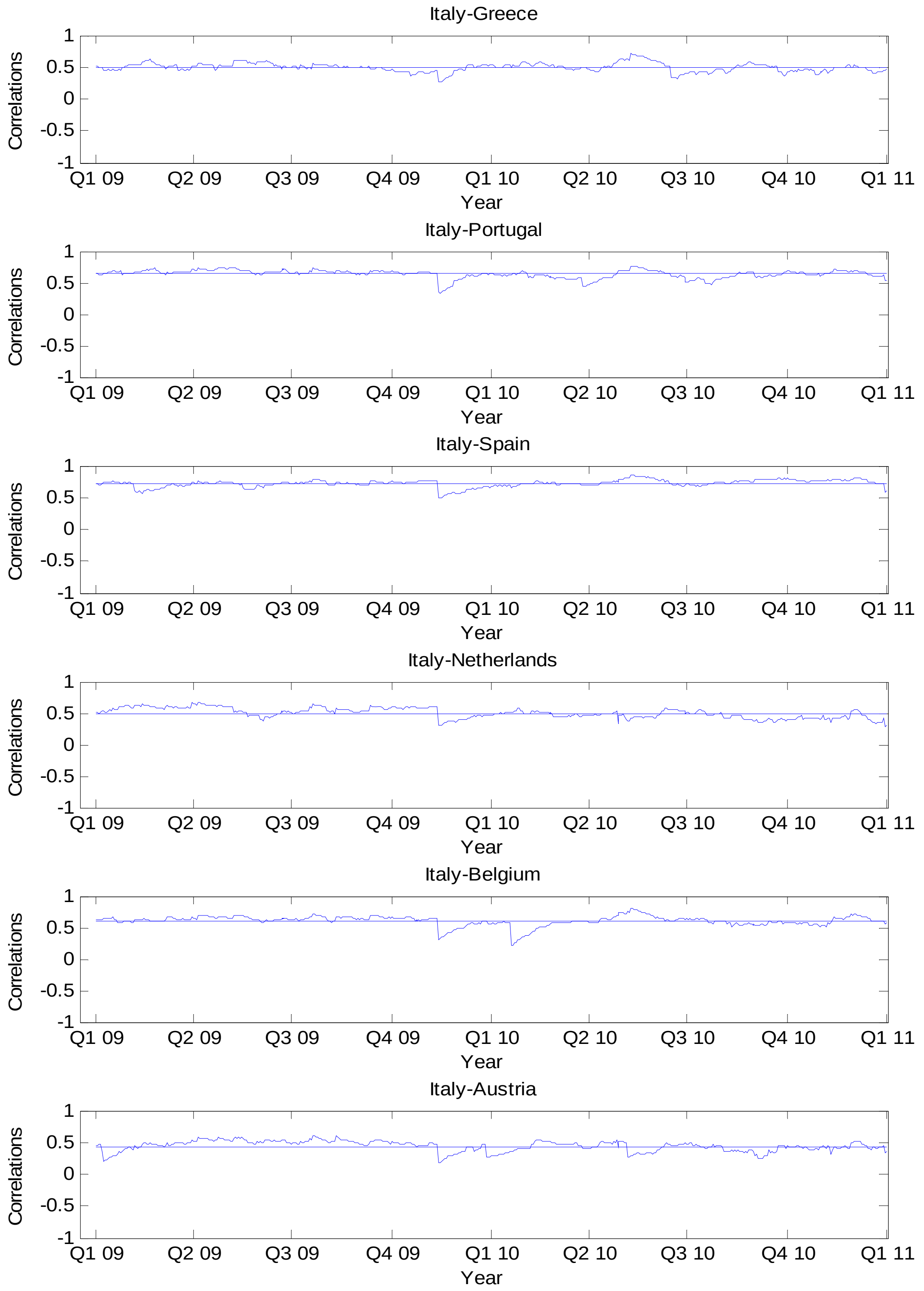
Appendix 1: Portuguese correlation dynamics

2. Spain



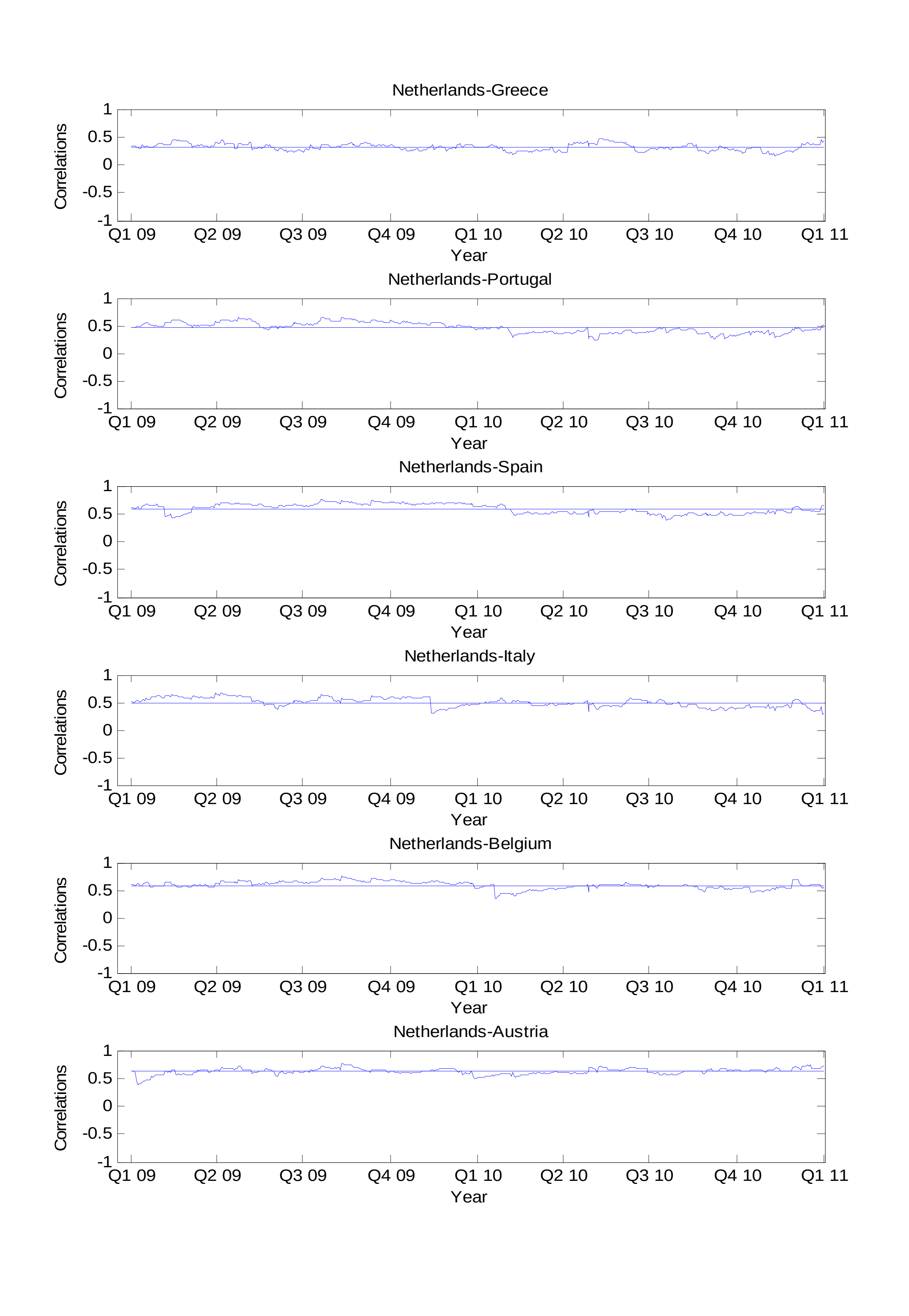
Appendix 2: Spanish correlation dynamics

3. *Italy*



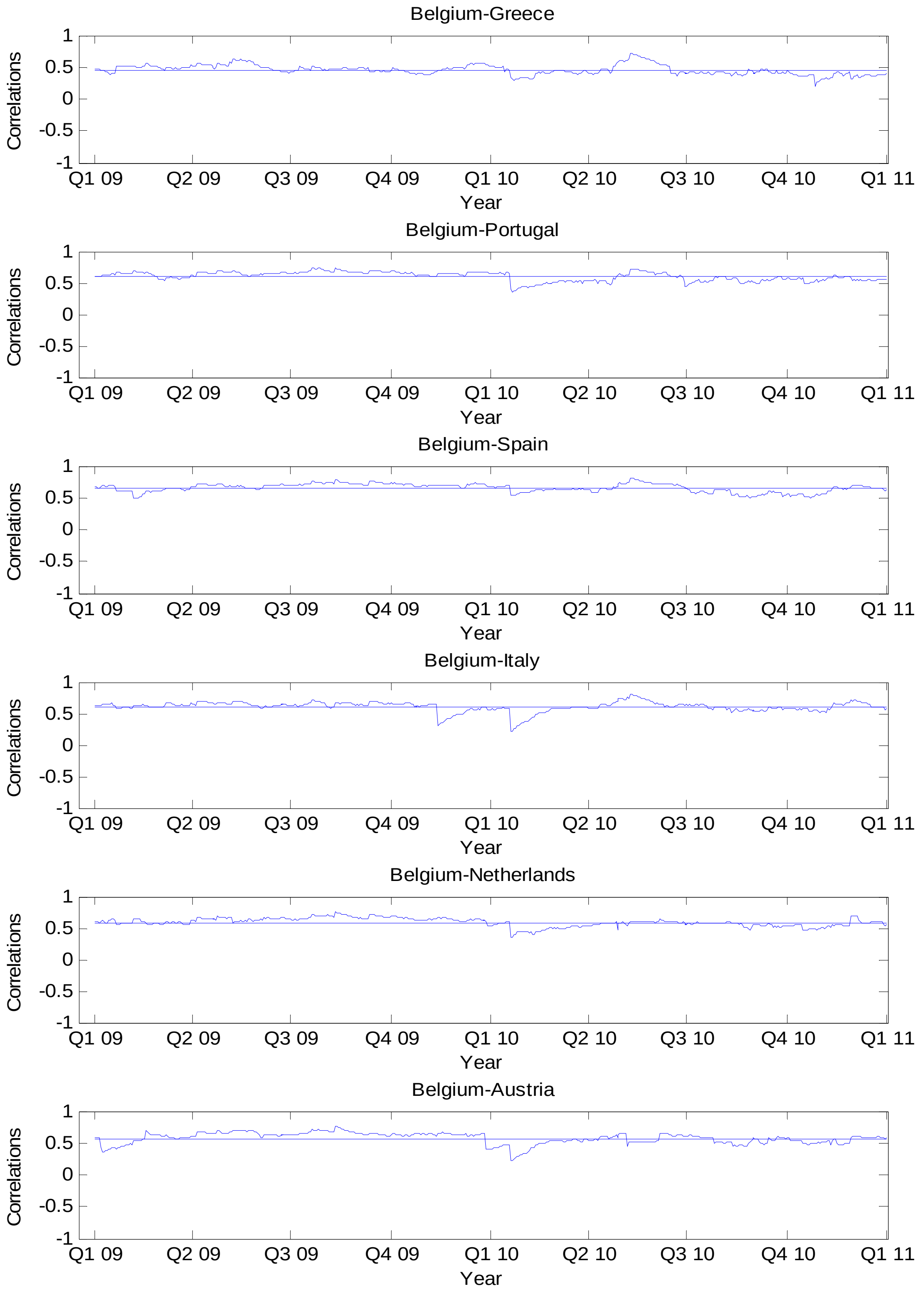
Appendix 3: Italian correlation dynamics

4. Netherlands



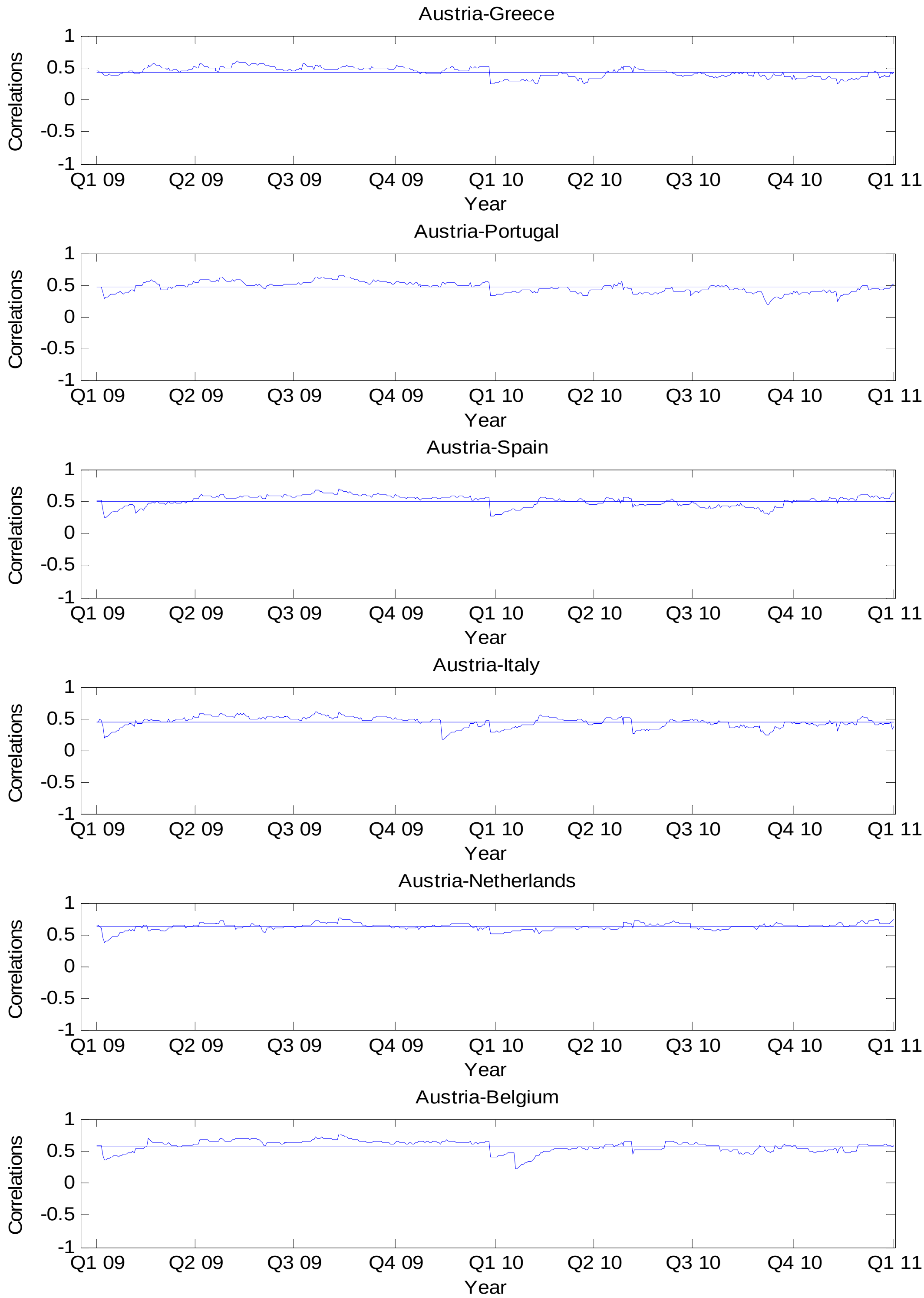
Appendix 4: Dutch correlation dynamics

5. *Belgium*



Appendix 5: Belgian correlation dynamics

6. *Austria*



Appendix 6: Austrian correlation dynamics

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