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Was there Contagion in Eurozone Sovereign Bond Markets during the Greek Debt Crisis?

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Was there Contagion in Eurozone Sovereign Bond Markets during the Greek Debt Crisis?*

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Abstract

We analyze the relation between sovereign yields of Greece and Portugal, Ireland, Italy, and Spain (PIIGS) as well as other Eurozone countries (NPIIGS) during the financial crisis (7/2007 to 4/2011). Consistent with media reports we find a significant increase in the unconditional correlation between the yield spreads of Greece and other markets during the crisis. However, after we account for time-varying volatility and changes in fundamental factors, the conditional correlation in yield spreads of Greece and PIIGS and NPIIGS actually decreases during the crisis period. Thus, we find no evidence of contagion from Greece to PIIGS and NPIIGS. Banking sector stock returns are a significant factor in determining the comovement in sovereign yield spreads, suggesting that a Greek bailout will benefit Eurozone banks in part. Collectively our results point to the role of news announcements and the banking channel as transmission channels in the crisis period.

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1. Introduction

In the aftermath of the Greek debt crisis the financial press carried a number of reports about the increase in sovereign bond yields in Greece as well as in other Eurozone countries, such as Portugal, Ireland, Italy, and Spain (PIIGS). Attention centered on Greece after its government acknowledged its high debt service relative to receipts. Eurozone policymakers and multilateral organizations raised the concern that the debt crisis in Greece could spread to other countries.[1] We investigate whether there is evidence of financial contagion from Greece to the sovereign bond markets of Portugal, Ireland, Italy, and Spain and to other Eurozone countries—Austria, Belgium, France, and the Netherlands (NPIIGS)—after the onset of the crisis. Specifically, we investigate whether there is an increase in "excess" comovement between changes in the yield spreads of the Greek bond market and those of the bond market of other PIIGS and NPIIGS during the crisis. That is, in the spirit of Bekaert, Harvey and Ng (2005), Bae, Karolyi and Stulz (2003), and others we regard contagion as comovement in excess of that which is warranted by changes in fundamentals.[2]

The source of linkages between markets is of fundamental importance to market participants. Even though the Greek economy is a small component of the Eurozone (less than 3% of total GDP), the uncertainty about the ability of Greece to service its debt may have an impact on sovereign yields of other countries in the Eurozone. The literature identifies several mechanisms via which shocks in one country could be transmitted to other countries. First, investors possibly use the information from the Greek crisis to infer the likelihood of similar outcomes in similar Eurozone countries with high debt to GDP ratios. Kaminsky and Schmukler (1999) refer to this as the "wake-up call hypothesis" in which the initial crisis leads the market to reassess the

[1] See, for example, "Who's Next? Spain? Italy?", Wall Street Journal, Feb 4, 2010 by Neil Shah. However, the Managing Director of the International Monetary Fund contended that contagion from Greece to Portugal or Spain was unlikely (see, "Greek Woes 'Unlikely to Spread'," BBC News March 08, 2010. See also, "Portugal unveils a series of budget cuts" at http://news.bbc.co.uk/2/hi/business/8554899.stm.

[2] Forbes and Rigobon (2002) define contagion as a significant increase in cross-market linkages following a shock in one or more markets. This can occur with increases in contemporaneous and lagged linkages.

risks faced by countries with similar characteristics. Economic news arrival in Greece that directly pertains to asset values in other Eurozone countries will impact their asset prices. Second, negative returns in one market affects returns in other markets because of increased risk premiums required by investors (Vayanos (2004)). A third channel is the liquidity channel wherein losses in one market may translate to a lack of funding for an institution, and a downward spiral in prices because of a flight to "quality" (Allen and Gale (2000)). We shed light on the role of these factors in the debt crisis by specifically including proxies to capture channels of transmission.

To accomplish our objective we collect daily data on 5-year bonds for the pre-crisis period from 1/2003 to 6/2007, and for the crisis period up until 4/2011 using Bloomberg. We first compute sovereign yield spreads for the PIIGS and NPIIGS relative to sovereign yields of Germany. In addition to the data on yield spreads, we collect data on fundamental factors (proxies for default risk, risk aversion, liquidity) as well as news announcements regarding rating changes as well as other announcements. Figure 1 provides a graph of sovereign yields in PIIGS and NPIIGS before and during the financial crisis. The figure shows that yields on sovereign debt of the PIIGS increase sharply subsequent to mid-2007, while the increase in yields of NPIIGS is of a lower magnitude. The data also shows that yield spread volatility increases for both PIIGS and NPIIGS on average. Consistent with the claim in the financial press, the unconditional correlation between changes in the yield spreads of Greece and other PIIGS is double its value during the crisis relative to the pre-crisis period. In contrast, the correlation between changes in the yield spreads of Greece and the NPIIGS countries declines during the crisis period.

Recent papers take different approaches in examining contagion and there is ongoing controversy as to whether the approach influences the inference about the existence of contagion.[3] Bearing this in mind, we start our analysis with a popular approach, impulse responses from a basic vector autoregression (VAR) model that does not directly account for changes in fundamentals or increased volatility associated with

[3] See, e.g., Forbes and Rigobon (2002) and Bekaert, Harvey and Ng (2005), discussed below.

crises, either of which could compromise inferences about contagion. For each market we first estimate a VAR model that relates changes in yield spreads of a given country to lagged changes in yield spreads of the other countries. Estimates of impulse responses show an economically large contemporaneous response by PIIGS sovereign bond yields to a shock in the Greek market yield during, but not prior to, the financial crisis. Specifically, the response to a one-standard deviation shock to Greek sovereign bond yield spreads is nearly zero in the *pre-crisis* period but increases to about 0.19 standard deviations on average during the crisis. However, when we include the lagged values of fundamental factors that are a determinant of yield spreads, such as changes in European and US implied option volatility, and changes in credit default swap (CDS) spreads, these responses are no longer economically important, falling to about 0.04 standard deviations after the crisis. For the NPIIGS countries the responses during the crisis are much smaller in magnitude but the results are otherwise similar.

We then use a multivariate autoregressive conditional heteroskedasticity (ARCH) model to jointly estimate the conditional correlation between the unexpected component of changes in Greek yield spreads and those of the PIIGS and NPIIGS, respectively, over the full sample period. The unexpected changes in yield spreads are the error terms in the VAR model after accounting for changes in fundamentals. The conditional correlation captures the joint evolution of unexpected changes in yield spreads over time and varies as a function of changes in the fundamental factors, news announcements, and returns on bank indices. The joint estimation of the correlations and the variance process using the ARCH model obviates the criticism that the linkages depicted by the impulse responses during the crisis may be overstated because they do not explicitly account for increased volatility during the crisis (Forbes and Rigobon (2002)). Our key result is that the conditional correlation for the crisis period points to a *decrease* in comovement between PIIGS and NPIIGS sovereign bond markets during the crisis after we account for fundamental factors and time-varying volatility. The evidence points to the fact that changes in the yield spreads of PIIGS and NPIIGS were determined more by fundamentals rather than any market "irrationality". These results

cannot solely be ascribed to the nature of the markets (that they are developed markets and, therefore, there is better information flow, as that by itself would not necessarily lead to a *decline* in correlation).

Our estimate of the conditional correlation also allows us to analyze whether the comovement increases around economic news announcements and the extent to which comovement can be attributed to changes in fundamental factors such as a revaluation of country default risk. The evidence shows that there are significant spikes in correlation on announcement dates, consistent with information effects from the news as well as other fundamental factors driving some of the comovement. For example, announcements of ratings downgrades and negative news on bailouts increase comovement between Portugal and Greece, two countries that were under more scrutiny at the outset of the crisis.

Another key result is that bank returns of the PIIGS are a factor in determining the conditional correlation between spreads. The cross-contamination of the banking sector is an issue often discussed by Eurozone leaders.[4] If Greek bonds are held by a bank in another country, depreciation in the Greek bonds impacts the assets of the foreign bank and the financial sector of that country.[5] This evidence points to the role of the bailout as a mechanism to reduce the risk of spillover from Greece via the banking sector, and to quarantine Greece from its impact on other Eurozone countries.

This study contributes to the literature on financial contagion, an overview of which can be found in Kaminsky, Reinhart and Vegh (2003). It differs from previous work in its focus on contagion originating in and affecting developed financial markets. Several studies examine contagion originating in emerging markets (see, e.g., Baig and Goldfajn (1999), Bae, Karolyi and Stulz (2003), Kaminsky and Reinhart (2001)). Here greater information asymmetry drives contagion (Kodres and Pritsker (2002)) whereas contagion originating in developed markets and affecting developed markets is more likely to arise from correlated information. This study also adds to the literature on the

[4] See for example "Containing Contagion", Bloomberg Magazine, September 2011.
[5] See for example "Greece: time for a haircut", Financial Times, July 15, 2011.

role of news in the transmission of shocks (Baig and Goldfajn (1999)), and the spillover effects resulting from ratings changes (Kaminsky and Schmukler (2002) and Gande and Parsley (1990)). We also consider the impact of other countries' bank stock prices, arising from cross-holdings of distressed assets, on the correlation between Greek bond yield spreads and those of other Eurozone countries. This is similar in spirit to Kyle and Wirick (2002) who examine the effect of the Latin American debt crisis on bank equities.

The paper is also related to the strand of literature that studies the dynamics of yield spreads in the Eurozone countries. Earlier research attempts to explain persistent yield differentials between Eurozone countries by fundamental factors such as default risk and liquidity differentials (e.g., Codgno, Favero and Missale (2003), Geyer, Kossmeier and Pichler (2004), Favero, Pagano and Von Thadden (2010)). In contrast, our paper analyzes the comovement between yield spreads and the reasons why it decreased during the crisis.

The remainder of this article is organized as follows. Section 2 describes the data and Section 3 outlines the methodology. Section 4 presents the results and Section 5 concludes.

2. Data

Our sample spans the period January 2003 to April 2011. The pre-crisis or base period is 1/2003 to 6/2007, whereas the crisis period spans 7/2007 to 4/2011. The start date for the crisis period coincides with the period after the Bearn Sterns Hedge Fund collapse during the summer of 2007 and the deterioration of international real estate prices. Additionally, Greek sovereign CDS spreads increased rapidly after this date, indicating that the crisis in the US began to affect Greece and that investors were concerned about the quality of Greek sovereign debt. Even though additional data are available for both bond and CDS yields prior to the initial sample date, we begin our analysis in 2003 to allow for time between Greece's adoption of the euro in 2001 and its

integration into the Eurozone. Also, CDSs for many of the countries were infrequently traded before 2003.

We obtain daily data on yields of 5-year sovereign bonds for Germany (the benchmark), Greece, Ireland, Italy, Portugal, and Spain (PIIGS) and Austria, Belgium, France, and the Netherlands (NPIIGS) using Bloomberg. Due to unavailability of 5-year bond data for Ireland over the full sample period we use 10-year yields for Ireland matched with 10-year German yields. Although the 10-year yields are generally higher than 5-year yields because of a liquidity or term premium, we find that they co-move to a high degree with (available) 5-year Irish yields. Thus, using 10-year instead of 5-year spreads likely does not alter the results. Moreover, because 5-year and 10-year yields are likely to evolve roughly similarly over the sample period, the use of the 10-year yields is also unlikely to understate the correlations between Irish yields and those of the other markets.[6]

The yield spread of sovereign debt of country *i* relative to German debt at *t* is denoted $Y_{i,t}$. This spread reflects perceptions about the incremental sovereign default risk relative to the benchmark as well as the liquidity characteristics of each sovereign market. The corresponding change in yield spread over one time period is computed as: $\Delta Y_{i,t} = Y_{i,t} - Y_{i,t-1}$. German debt yields are selected as a reference because of Germany's relative economic stability during the recent credit crisis and its economic centrality within the Eurozone.

To proxy for fundamentals we draw on previous research that explains the behavior of spreads in the Eurozone (e.g., Longstaff, Pan, Pedersen and Singleton (2007)). These variables capture the market's perception of changes in global, regional, and country-specific risks at each point in time. We include the US implied volatility index (USVIX), a proxy for perceptions about global market risk and the European implied volatility index (EVIX) as a proxy for risk perceptions within the Eurozone as a whole. We also collect data on sovereign CDS spreads that are an estimate of a

[6] We choose the 5-year bonds partly to match the use of 5-year CDSs because, as is noted by Alexopoulou, Andersson and Georgescu (2009) and others, this is the most actively traded maturity.

country's credit quality. We include the difference between sovereign 5-year CDS spreads and 5-year German CDS spreads as a measure of the incremental default risk of each country.

In addition to the market-based fundamentals, we collected news announcements that pertain to Greece and the Eurozone by scanning the Wall Street Journal and other news outlets (see the Appendix for the announcements and announcement dates). The announcements are separated into three categories: (1) ratings outlooks from three ratings agencies (denoted ratings), (2) unfavorable announcements from "third party" agencies, such as the European Monetary Union and the International Monetary Fund (denoted bad) and (3) favorable announcements by third party agencies (denoted good). The latter two types include macroeconomic forecasts and bailout package declarations. We separate ratings agency announcements from those by other agencies because the announcements of ratings agencies may have a more substantial impact on bond yields and CDS spreads than the announcements of other agencies. For example, Kaminsky and Schmukler (1999) examine market reactions during the Asian crisis to news announcements on fiscal and monetary policy, credit ratings changes, and agreements with international organizations like the IMF or World Bank. They find that markets react negatively to ratings downgrades but positively to agreements with international agencies. Further, markets react more strongly to news by ratings agencies and international agencies than they react to political news and news on capital controls or monetary policy.

Figure 1 plots debt yield spreads for our sample of sovereign bonds. The graphs indicate that yield spreads are low, relatively stable and similar across the countries in the period prior to the crisis. However, there is a significant increase and substantial divergence in the yield spreads from mid-2007 (vertical line in the graph) after the onset of the crisis. While there is a large jump in the yields for Greece and the other crisis countries (top panel), the yields for the other countries (NPIIGS in lower panel) increase to a lesser extent.

Table I contains summary statistics of bond yields and yield spreads for each crisis country. There are a total of 2001 observations for each country with 1095 observations in the pre-crisis period and 906 in the crisis period. The top panel shows that the average yield to maturity during the pre-crisis period is comparable across the countries and ranges between 3.27% and 3.4%. An exception is Ireland where the yield is markedly higher at 3.88%.[7]

During the pre-crisis period the yield spread is highest for Greece on average (10 basis points). The standard deviation of the yield spreads is comparable across countries. In contrast, during the crisis (bottom panel), the average yield spread and the yield spread volatility are highest for Greece (yield spread of 387 basis points and spread volatility of 398 basis points). Ireland has the next highest spread and spread volatility. In general, the spreads and the volatility of the spreads in the crisis period are much higher than in the pre-crisis period for each of the countries examined. This increase in yield spread volatility during the crisis can overstate the correlation between spreads during the crisis, an issue we address via our empirical strategy described below.

Table II reports similar statistics for the non-crisis countries. The evidence indicates that prior to the crisis the yields of Austria, Belgium, France, and the Netherlands do not, on average, deviate from those of Germany by more than one basis point and the standard deviation is roughly similar to the yields on German bonds. The mean yield spreads increase to a range between 16 and 59 basis points during the crisis period. However these spreads are much smaller than those in PIIGS (82 to 387 basis points on average).

3. Methodology

Given that our objective is to examine if there is an increase in "excess" comovement between yield spreads of the Greek and other countries' bond markets during the crisis

[7] We use 10-year bonds for Ireland, with 10-year benchmarks, and we expect that on average the yields are higher than those of the 5-year bonds used for all other countries.

an immediate issue that arises is that we are forced to take a stand on what are fundamentals in this particular situation. We use proxies for fundamental factors that include global, regional, and country-specific risks.

3.1 VAR model

To provide empirical evidence on whether there is contagion from the Greek sovereign bond market to the bond markets of other countries we first estimate the following VAR model of changes in bond yield spreads in the five markets:

$$\Delta Y_{i,t} = b_{i,0} + \sum_{j=1}^{5} b_{i,j} \Delta Y_{j,t-1} + \delta_{i,1} \Delta EVIX_{t-1} + \delta_{i,2} \Delta USVIX_{t} + \delta_{i,3} \mid \Delta CDS_{i,t-1} \mid + \varepsilon_{i,t}. \quad (1)$$

The VAR model endogenizes the changes in yield spreads, $\Delta Y_{i,t}$, for each country i = Portugal, Ireland, Italy, Greece, and Spain (PIIGS). A corresponding model is also estimated for Austria, Belgium, France, Greece, and the Netherlands (NPIIGS). As is common in the literature on contagion, we use lagged values of changes in each country's yield spreads as well as those of the remaining countries as explanatory variables. We augment these lagged yield spread changes with proxies for fundamentals that include changes in the European implied option volatility index ($\Delta EVIX$), changes in the US implied option volatility index ($\Delta USVIX$), and the absolute value of changes in the credit default swap spreads of countries ($\Delta CDS_{i,}$). Given that we use changes in yield spreads and that these markets are relatively efficient, a single lag is sufficient to capture the dynamics between the yield spreads without causing any misspecification. We use changes in spreads rather than the level of spreads to account for possible non-stationarity of yields. The VAR framework thus has a setup broadly similar to, but less restrictive than, that of Favero, Pagano and Von Thadden (2010).

To determine if there is contagion we focus on the contemporaneous impulse responses to a shock in Greek yield spreads. Specifically, the model is estimated in the pre-crisis period and the crisis period separately. If we find that shocks to the changes in Greek yield spreads elicit a materially larger response from, e.g., Portugal's next

period change in yield spreads during the crisis relative to the period before the crisis, then this is evidence of contagion from Greece.[8]

Impulse response functions inform us if the change in the yield spreads of one market in response to a one-standard deviation unexpected change (shock) in the yield spreads of another is immediate, economically large, and persistent. In the estimation we use generalized impulse response functions as they are robust to the order in which the variables appear in the model (Pesaran and Shin (1998)). To determine the statistical significance of the impulse response functions we use Monte Carlo simulation to obtain 2-standard error bands around the impulse responses. For ease of presentation we do not report the standard error bands in the graphs below.

3.2 Including Time-Varying Volatility (ARCH model)

While the VAR model assumes a constant volatility of the error term, we augment the model by specifying an ARCH model wherein we use the VAR model in equation (1) as the conditional mean model and jointly estimate the following system of equations for the five countries. The conditional mean is given by:

$$\Delta Y_{i,t} = b_{i,0} + \sum_{j=1}^{5} b_{i,j}\Delta Y_{j,t-1} + \delta_{i,1}\Delta EVIX_{t-1} + \delta_{i,2}\Delta USVIX_{t} + \delta_{i,3} \mid \Delta CDS_{i,t-1} \mid + \varepsilon_{i,t} . \quad (2)$$

The conditional variance is modeled as:

$$\sigma^2_{\varepsilon i,t} = \exp\left\{ \varpi_{i,0} + \sum_{j=1}^{5} \alpha_{i,j}\varepsilon^2_{j,t-1} + \lambda_{i,1}\Delta EVIX_{t-1} + \lambda_{i,2}\Delta USVIX_{t} + \lambda_{i,3} \mid \Delta CDS_{i,t-1} \mid + \lambda_{i,4} \mid R_{Fin,i,t-1} \mid \right\}. \quad (3)$$

The correlation between countries is computed as:

$$\sigma_{ij,t} = \rho_{ij,t} * [\sqrt{\sigma^2_{\varepsilon i,t}}\sqrt{\sigma^2_{\varepsilon j,t}}] \quad (4)$$

where

[8] Taking this approach, we could have focused on the Granger causality between (lagged effects from) Greece and the other markets. We take the above approach given that impulse responses are based on the model's residuals and thus directly reflect the effect of accounting for the fundamentals in the model. Moreover, this approach is more consistent with the conditional correlations we estimate below.

$$\rho_{ij,t} = \theta_{ij,0} + \theta_{ij,1} D_{Crisis,t} + \theta_{ij,2} D_{Good,t} + \theta_{ij,3} D_{Bad,t} + \theta_{ij,4} D_{Ratings,t} + \gamma_{ij,1} Threshold_{t-1} + \gamma_{ij,2} \mid R_{Fin,i,t-1} \mid$$
$$+ \gamma_{ij,3} \mid R_{Fin,j,t-1} \mid + \gamma_{ij,4} \Delta EVIX_{t-1} + \gamma_{ij,5} \Delta USVIX_t + \gamma_{ij,6} \mid \Delta CDS_{i,t-1} \mid + \gamma_{ij,7} \mid \Delta CDS_{j,t-1} \mid . \quad (5)$$

The goal of the above model is to estimate the conditional correlations at time *t* between countries *i* and *j* ($\rho_{ij,t}$) in Equation (4). We start with the five conditional mean models for PIIGS, one for each country, in the system represented by equation (2). The changes in yield spreads in each market are a function of a constant, the first lag of the own-market changes in yield spread ($\Delta Y_{i,t-1}$), and the first lag of changes in the yield spread of each of the other four countries' market ($\Delta Y_{j,t-1}$). The lagged dependent variable is included to account for autocorrelation, and the other markets' lagged changes in yield spread capture the mean spillover between markets (e.g., Karolyi (1995)). We also include the fundamentals in this equation: the changes in the U.S. and European option volatility indices (EVIX, USVIX) and changes in the country's CDS spreads. The conditional variance of changes in yield spread in equation (3) is a function of a constant, the first lag of own-market squared errors, and the first lag of other markets' squared errors. Own-market squared errors are included in the model to account for volatility persistence whereas other market squared errors are included to account for volatility spillover among the countries' bond markets. We also add the fundamentals that were included in the conditional means. In addition we include the absolute value of the excess returns on country *i*'s bank stock index to capture the uncertainty in the banking sector arising from the effect of possible Greek default on bank assets. To ensure positive variances we estimate the exponential specification of the model. To obtain an estimate of the correlation between any two bond markets we model their covariance ($\sigma_{ij,t}$ in Equation (4)) as a product of correlation and their individual standard deviations.

The distinguishing feature of this model is that we allow the correlations to change over time as a function of several variables. These variables include a crisis

dummy variable, D_{Crisis}, a threshold variable (*Threshold*) designed to capture the incremental effect of large increases in Greek yield spreads on the correlation, the absolute values of the returns on each country's bank stock index (R_{Fin}), the fundamentals (EVIX, USVIX, and the absolute values of the changes in each country's CDS spreads), and three categories of news announcements.

For each news category we create an indicator variable defined as one on the date of an announcement, regardless of the particular crisis country it pertains to, and zero otherwise. Creating this all-encompassing dummy rather than country-specific dummies reflects the fact that while an announcement about a particular country represents information about that country's fundamentals it also serves as a potential source of contagion for all the other countries. The first news announcement indicator, $D_{Ratings}$, captures ratings downgrades and negative macroeconomic outlooks from the three rating agencies, Standard & Poor's, Fitch, and Moody's. There are no positive announcements from the rating agencies during the crisis period. The second and third announcement indicator variables, D_{Good} and D_{Bad}, capture positive and negative announcements, respectively, from the third party agencies. There is statistical evidence of contagion between any two markets *i* and *j* if $\hat{\theta}_{ij,1}$ is positive and significant, as excess comovement would have increased during the crisis.

To ensure that all conditional correlation estimates lie between negative and positive one we estimate the correlation function as follows (Tsay (2005)): $\rho_{ij,t} = \frac{[\exp(\theta_{ij,0} + \theta_{ij,1} D_{crisis} + \ldots + \gamma_{ij,7} |\Delta CDS_{j,t-1}|) - 1]}{[\exp(\theta_{ij,0} + \theta_{ij,1} D_{crisis} + \ldots + \gamma_{ij,7} |\Delta CDS_{j,t-1}|) + 1]}$. Also, the above models are estimated using a quasi-maximum likelihood (QML) approach (Bollerslev and Wooldridge (1992)) and are subject to model diagnostics. Hence the standard errors are robust to the distribution (e.g., non-normality) of the errors and there is a high probability that the models converged at the global maximum.

4. Results

4.1 Preliminary evidence of contagion from the correlation between changes in yield spreads

We begin with an examination of contemporaneous correlations of changes in sovereign bond yield spreads in Table III. Given the concern about contagion from Greece, our focus is on the correlation between yield spreads of Greece and the other countries in the Eurozone. The pre-crisis period correlations between Greece and the rest of the crisis (PIIGS) countries are statistically and economically significant, with a range of 0.11 to 0.46 and an average of about 0.31 (left side of Panel A). Overall, the correlations are consistent with the literature that there are a number of common factors in the Eurozone that drive yield spreads (see, e.g., Favero, Pagano and Von Thadden (2010)).

During the crisis period, there is a sharp increase in the correlations between Greece and the other countries with a range of 0.59 to 0.77 and an average of 0.65 (right side of Panel A). This significant increase in correlations with Greece led the financial press to conclude that there is contagion from Greece to the other markets. However, it should be noted that the volatility of Greek bond yield spreads increased from 0.05% to 3.98% from the pre-crisis to the crisis period (Table I discussed earlier). There is also a substantial increase in the volatility of yield spreads of the other crisis countries, albeit less dramatic. Thus, a legitimate concern is that any increased comovement between yields is due solely to the increased variance of these yields. Moreover, without accounting for the possibility that changes in common factors (fundamentals) drive the change in correlations, it is premature to make conclusions about the causes of increased comovement between the markets.

Similar statistics for the non-crisis Eurozone countries (NPIIGS) are reported in Panel B of Table III. Here the evidence points to the absence of a significant increase in the correlation between Greece and the non-crisis countries during the crisis. In fact, the correlation between the Greek yield spreads and those of Austria, France, and the

Netherlands declines slightly during the crisis. Thus, subject to the same caveats as above, it appears that there is no contagion from Greece to the non-crisis countries.

4.2 VAR evidence of contagion among the PIIGS

We begin with an estimation of the VAR model specified in equation (1) for the pre-crisis period. We report the generalized impulse response functions of the four non-Greek sovereign bond markets to shocks that emanate in the Greek yield spreads in Figure II. In the pre-crisis period, shocks to Greek yield spreads elicit a positive and statistically significant, though economically immaterial, response in the yield spreads of Ireland, Italy, Portugal, and Spain. These are represented as the grey unbroken line in the figures labeled Pre-VARX. For example, a one standard deviation shock in Greek yield spreads do not elicit a response of more than 0.01 standard deviation from the yield spreads of either Ireland, Italy, Portugal, or Spain. Moreover, these responses do not persist beyond one day. There is no overreaction component as there is no significant lagged impulse response of the opposite sign.

Turning to the crisis period we report the impulse response for two separate specifications to provide insight into the importance of accounting for changes in common fundamentals. The first specification, labeled Crisis-VAR, is the usual VAR model where the exogenous variables are lagged changes in yield spreads. This simpler model, which is nested in the model in equation (1), does not account for fundamentals and, as such, does not capture "excess" comovement. The impulse response functions are represented by the dashed line in Figure II. We compare this to the specification in equation (1), with impulses represented by the solid black line in Figure II (Crisis-VARX). Relative to the pre-crisis period the results from the simpler model are dramatically different and seem to provide strong support for the claim that there is contagion between the sovereign bond markets of the PIIGS, specifically from the Greek bond market to the bond markets of the other crisis countries.[9] We find that a one

[9] Although not included in the figure the pre-crisis results from the simpler VAR model are highly similar, with the impulse responses being substantially less than 0.01 standard deviations to a one standard deviation Greek shock.

standard deviation shock in Greek yield spreads results in an immediate increase of 0.18, 0.17, 0.22, and 0.17 standard deviations in Irish, Italian, Portuguese, and Spanish bond yields, respectively. These responses represent non-trivial increases in transmission intensity relative to the pre-crisis period.

Further, Figure II indicates that, beyond the initial impulse, the impact of shocks to Greek yield spreads takes more than two periods to decline to zero. The ten-day average accumulated response to shocks to the Greek market is about 0.11 for these other markets. Thus, during the crisis period, there appears to be an increase in the span of time it takes for a Greek shock to be absorbed.

However, on examining the results from the model that accounts for changes in fundamentals (Crisis-VARX), the results are substantially different. In general, the magnitude of the impulse responses is now about a quarter of that suggested by the simpler VAR model. These impulses are also less persistent.

Overall, the evidence from the impulse response functions strongly suggests that it is important to account for changes in common fundamentals that could drive higher comovement between markets. Nonetheless, after accounting for fundamentals, it appears that there is a small contagion effect from Greece to the bond markets in our sample. These results are in line with the notion that markets paid more attention to information emanating from Greece during the crisis. That is, during the crisis the Greek bond market was the center of price discovery among the bond markets of the crisis countries. Hence, the evidence seems to support the correlated information channel view of financial market contagion.

4.3 Accounting for time-varying volatility in the test for contagion

Thus far, we have presented evidence of contagion from the Greek sovereign bond market to the sovereign bond markets of other crisis countries. Specifically, using the vector autoregression (VAR) specification we show that during the crisis period the yield spreads of Ireland, Italy, Portugal, and Spain respond positively to shocks in the

yield spreads of Greece. Also, these responses are larger in magnitude than in the pre-crisis period. However, as noted earlier, increased volatility within crisis-prone markets inflate estimates of cross-market linkages during a crisis (Forbes and Rigobon (2002)). The VAR analysis does not directly account for changes in market volatility in estimating cross-market linkages. Therefore, we address this issue by estimating conditional correlations using a multivariate ARCH model that specifically accounts for time-varying volatility of the markets in question without the need to break the sample into two periods. A plot of the conditional volatility of each market in Figure III indicates an increase in volatility during the crisis, thus lending support to the use of the ARCH model.

Table IV reports the coefficient estimates of the conditional correlation using the system of equations (2) to (5) that specify the joint evolution of yields when volatility is time varying while Figure IV presents a plot of the correlation between the various markets. In Figure IV the first column of graphs shows that during the crisis the correlation between the bond markets of Greece and the other crisis countries declines from the pre-crisis period levels where it is roughly constant in each case. This result is uniform across all market pairs, including those not involving Greece. For instance, prior to the crisis the excess correlations between Greek yield spreads (graphs in first column) and those of the other four markets were relatively high, ranging from an average of about 0.55 with Spain to about 0.90 with Portugal. During the crisis there was a significant decrease in the correlations between Greek yield spreads and those of Ireland, Italy, and Spain, with only a small decline of the excess correlation between Greece and Spain. Consistent with this, the coefficient estimate on the crisis dummy variable is negative and statistically significant in all estimates of the excess conditional correlation (second row in Table IV), pointing to an average decrease in the excess correlation during the crisis. Thus, there is no evidence of contagion after we account for fundamentals and time-varying volatility.

As will be discussed shortly, several specific factors contribute to the decline in excess correlation. However, an overall interpretation of the decline in the excess

correlation during the crisis is that after accounting for the increased comovement between the bond yields of the various crisis countries brought on by changes in fundamentals, the remaining variation in Greek bond yields has a different time path from those of the other countries in the sense that the other determinants of changes in Greek yield spreads pushed these spreads upward but this was not warranted in the other countries, thus causing a decline in correlation.[10] In other words, after accounting for fundamentals investors sufficiently differentiated between the Greek bond market and those of Ireland, Italy, Portugal, and Spain such that crisis-induced increases in the residual yield spreads in Greece did not warrant similar increases in these countries. In support of the above, a glance at Figure I corroborates this assertion, indicating that Spain and, less so, Portugal had substantially less run-up in yields relative to Greece during the crisis. Similarly, the Wall Street journal article previously referenced notes that as late as February 2010 the cost to insure against default of Greek sovereign bonds was two to three times the cost to insure against default by similar bonds in Portugal and Spain.

The evidence in Figure IV and Table IV also indicates that the decline in excess correlation is not restricted to country pairs involving Greece. For instance, the correlation between Italy and Portugal declined from about 0.90 on average prior to the crisis to less than 0.5 on average during the crisis. This evidence suggests that shocks to the Greek market were transmitted to the other markets in the region, consistent with the preliminary evidence in the "raw" correlations in Table III, but as investors observed the changes in fundamentals they came to the same conclusion as the cases involving the Greek market.

Overall, the general decrease in correlation during the crisis that is depicted in the graphs indicates that there was no herding response to the Greek crisis by bond market participants in the non-Greek countries. That is, the evidence suggests that investors did not unfavorably reassess a country's yield spread merely on account of

[10] It is worth noting that changes in Greek (country-specific) fundamentals could also cause an increase in correlations if investors perceive, from observing the Greek fundamentals, a high probability of a similar crisis occurring elsewhere in the crisis countries.

the Greek debt crisis when there were no changes in that country's fundamentals. Similarly, despite the increased flow of information during the crisis it did not become too costly to assess the economic condition of each market in the group of crisis-ridden countries and, as such, investors did not find it optimal to treat each country alike and simultaneously reallocate out of all these markets given the sign of trouble in Greece. Either of the above would have led to an increase in correlation between the markets. From the overall decline in the cross-market correlations it can be inferred that in response to the Greek crisis investors assessed each market based on its own fundamentals rather than treating the crisis countries as an undifferentiated bloc. This staved off the contagion effects anticipated by the financial press and erroneously inferred from the increase in the raw unconditional correlations.

To glean further insights into the result that excess correlation declined during the crisis we turn to Table IV, which reports coefficient estimates of the variables posited to directly influence the variation in the correlations.[11] In particular, we are interested in determining how the market responded to various news announcements after observing changes in fundamentals. Complementing the graphical evidence of a sharp decline in the correlations around the start of the crisis the crisis dummy is negative and statistically significant in all cases. Thus, after accounting for fundamentals, the crisis led to not only a statistically significant decline in correlation, but also an economically large decline given the magnitude of the coefficient estimates. This evidence is remarkable in light of the strong belief by participants in the financial markets and even academia that the crisis led to an increase in correlation and, hence, contagion between the crisis countries.

News Announcements and Threshold Effects-Information Channel

[11] We do not report the coefficients in the means and volatilities given that they provide no evidence of contagion. These results are available on request. As the majority of the coefficient estimates in the conditional correlations are statistically significant, we denote parameters not statistically significant at the 5% level with a spade (♠).

The table shows that good news, such as the possibility of a bailout, reduces the correlation between the Greek and other bond markets. Thus good news about the non-Greek markets is not interpreted by market participants as good news for Greece, which was driven by its own fundamentals. Browsing the news announcements in the Appendix shows that the majority of good-news items did not pertain directly to Greece and so it appears that as the good news positively impacted the other countries it had no effect on Greece, leading to a lower correlation between Greek and other bond markets. Thus it appears that the market does not expect that bailouts or other palliative actions will have a significant positive effect on Greece in the near future. Generally, among the non-Greek markets good news similarly reduces the correlations, perhaps because the news has a positive effect on one market and not the other. Interestingly, bad news announcements during the crisis generally have the opposite effect, increasing the correlation between the markets. One explanation for the positive effect on the correlation is that the preponderance of bad news was about Greece (see Appendix) and investors were worried about whether the other markets have sufficiently strong fundamentals not to succumb to the same fate as Greece. Announcements of ratings downgrades are typically associated with lower excess correlation between the bond markets. Overall, the analysis of the news announcements indicates that they did not drive market participants to disregard reason and act irrationally.

It may be argued that small increases in Greek yield spreads during the debt crisis are unlikely to elicit a significant response in yield spreads in the other markets and, hence, the evolution of the correlations may be confounded by their presence. Bae, Karolyi and Stulz (2003), for instance, argue that correlations, because they give an equal weight to small and large changes in yields, are not an appropriate measure for contagion among markets given that they may be constrained to small values in response to large shocks that "exceed some threshold or generate panic;" that is, large changes in yields are more likely to propagate across markets by causing investors to neglect fundamentals. Given the above, we include a threshold effect in the

correlations. Specifically, we allow correlations to evolve differently when there has been a "large" increase in Greek yield spreads, defined as two standard deviations above the mean pre-crisis change in Greek yield spreads. The evidence indicates that large increases in Greek bond yields have a differential effect on correlations than small changes in yields. Specifically, during the crisis large increases in Greek yield spreads are followed on the next trading day by an economically large decline in correlation between Greece and the other markets, in the order of 0.11 to 0.33. Although the threshold effect is generally much smaller in magnitude, it has the same sign in the market pairs not including Greece. These results suggest that when market participants in the Greek bond market feel compelled to demand a large increase in yields, perhaps because of a significant change in their perception of the likelihood of a Greek default, traders in the neighboring bond markets treat this new development as essentially a country-specific phenomenon and, as such, correlations decline.

The Banking Channel

A concern noted in the financial press is that banks across several countries in the Eurozone could be severely affected if there is a Greek default.[12] Institutional investors in Eurozone bank stocks should be highly sensitive to this possibility given that failing banks, due to government default, are unlikely to be beneficiaries of the implicit "too big to fail" policy which provides bailouts. Therefore, bank stock prices should efficiently impound news about a possible Greek default. An implication of this is that information in bank stock prices might be an important factor in the correlation between Greek bond yield spreads and those of the other crisis countries. Assume that banks in both Portugal and Greece hold Greek debt and that a large institutional investor holds Portuguese and Greek bank stocks. If the institutional equity investor gleans information that indicates a greater probability of imminent default by the Greek government, then it will dispose of its bank stocks in both Greece and Portugal. If bond

[12] See, for instance, "Greek contagion fears spread to other EU banks," Financial Times June 15, 2011 by M. Murphy, K. Hope, J. Thompson, and J. Wilson (http://www.ft.com/intl/cms/s/0/ac918946-975a-11e0-9c9d-00144feab49a.html#axzz1TR8tvAUu).

traders in both countries observe the decline in bank stock prices and associate it with greater probability of Greek default, then that could lead to a joint fall in Greek and Portuguese bond prices, causing higher correlation. We find that greater volatility of returns on either the Greek or other countries' bank index is generally associated with higher correlation between Greek and the other countries' bond returns. In the cases where the impact on correlation is negative the magnitude tends to be much smaller. Among the non-Greek country pairs greater uncertainty in Greek and other countries' bank stock returns tend to lead to a small decline in bond correlations.

Role of Fundamentals

Although we have already extracted the effects of fundamentals from the individual means of the bond yield changes, we also include the fundamentals in the conditional correlations of bond yield changes. This is because fundamentals might have a residual effect on the correlation if they affect the joint evolution of a correlated pair of individual bond market yields differently from how they affect any one mean. We find that an increase in these proxies for fundamentals generally leads to a reduction in the correlation between the Greek and other bond markets. This result is consistent with the earlier finding that accounting for fundamentals lead to lower excess correlation. This points to the importance of accounting for shifts in fundamentals when assessing contagion (see, e.g., Baig and Goldfajn (1998), Bekaert et al. (2005)).

Overall, although we cannot claim that our proxies for fundamentals, measured at the daily interval, capture all the possible variation in fundamentals around the crisis, the result that the crisis dummy variable is negative, statistically significant, and has an economically large impact on the correlations between the majority of our country pairs provides robust evidence of the absence of contagion during the crisis. That is, given a rigorous examination of the change in correlation between the crisis countries around the time of the crisis the evidence indicates that the appearance of contagion that has attracted financial media attention is driven solely by changes in fundamentals around the crisis. That is, beyond the influence of changing fundamentals, there appears to be

no contagion driven by a) non-economic factors such as investor sentiment and irrationality, b) an unfavorable change in the way information about these markets is interpreted even if the information itself had not changed fundamentally, or c) concerns about how future fundamentals might deteriorate rather than about current economic conditions.

The decline in the average excess correlation between Greek yield spreads and those of the other PIIGS during the crisis are in contradiction of the positive contemporaneous impulse responses previously observed from the fully specified VAR model (equation (1)), which is the same as the conditional mean model of the ARCH model. These results can be reconciled if the volatility of the fundamentals that are included in the conditional means increased significantly during the crisis and, as such, led to a significant increase in the volatility of yield spreads. That there was an increase in the volatility of yield spreads during the crisis is confirmed by the plots of the conditional volatilities in Figure III. These results are consistent with the argument by Forbes and Rigobon (2002) that adjusting comovement for increased volatility during crises does not support the claim of the existence of contagion. However, our approach explicitly allows for increased volatility arising from common shocks whereas their adjustment does not work when common shocks drive the increase in correlation (see, e.g., Bekaert et al. (2005)).

4.4 Test for contagion from Greece to non-crisis countries (NPIIGS)

Our results indicate that there is no evidence of contagion from the Greek bond market to the bond markets of the other PIIGS during the Greek debt crisis after we account for changing fundamentals and the increase in volatility during the crisis period. In this section we examine if there is evidence of contagion from Greece to a set of the non-PIIGS countries–Austria, Belgium, France, and the Netherlands. Despite the evidence from PIIGS, we examine NPIIGS because of a possibility that the Greek debt crisis led to contagion via the ownership of Greek debt by the public or private sector in the NPIIGS.

The financial press speculated that the Greek crisis might affect markets that are not a part of the PIIGS. For instance, the Belgian Finance Minister expressed concern that the Greek debt crisis could spread to Belgium and France. Such effects might arise when either the government-led banks or private banks are exposed to Greek debt. For instance, France has the largest exposure to Greek debt among all countries; nearly double that of Germany for instance. This exposure is due to both its private sector banks as well as from the stakes held by government entities. Some of the largest French banks (BNP Paribas, Crédit Agricole, and Société Générale) have been threatened with ratings downgrades as a result of their Greek debt holdings. Though to a lower extent, Austria, Belgium, and the Netherlands have exposure to Greek debt. When this exposure is coupled with a country's own debt burden, as is the case for Belgium which has the third highest debt-to-GDP ratio in the Eurozone, it is possible that uncertainty in Greece could cause yields to rise in these other countries.[13] That is, severely depreciated Greek bonds could impair the assets of both Eurozone banks and governments. If the declining value of Greek debt were to trigger government intervention in the banking sector, then it raises the specter of financial distress for some countries.

Estimates of the impulse responses from the different specifications of the VAR model are plotted on the right vertical panel of Figure II, the coefficient estimates from the ARCH model are reported in Table V, and the estimated conditional correlations are plotted in Figure V. Overall, we obtain the same qualitative results as for the PIIGS; there is no evidence of contagion from Greece to these markets or from any market to another within this group. Again the crisis dummy is negative pointing to lower correlations during the crisis period.

5. Conclusions

[13] See http://www.forex-news.co/belgian-finance-minister-greek-debt-crisis-could-spread-to-france.html for the Finance Minister's comment and "The countries most exposed to Greek debt," The Telegraph, 15 Jun 2011.

In this paper we examine whether the sovereign debt crisis in Greece led to contagion between the sovereign bond markets of Portugal, Ireland, Italy, Greece, and Spain (PIIGS). We define contagion as an increase in excess comovement between markets during the crisis, where excess comovement is that which is beyond what is expected given changes in fundamentals. Using changes in market-based measures of global, regional, and country-specific risks as proxies for fundamentals over the period January 2003 to April 2011, we find no convincing evidence of contagion.

Bearing in mind that recent papers take different approaches in examining contagion we start our analysis with a popular approach, impulse responses from a basic VAR model that does not directly account for changes in fundamentals or increased volatility associated with crises, either of which could compromise inferences about contagion. We find evidence of contagion from Greece to other markets as the contemporaneous impulse response by the markets in Portugal, Ireland, Italy, and Spain to an unanticipated change in Greek yield spread is positive, statistically significant, and economically larger than the response prior to the crisis. When we augment this model to account for changes in fundamentals, the evidence of contagion remained, albeit of an economically small magnitude.

We then estimate time-varying correlations between changes in sovereign bond yield spreads of Greece and the other countries after accounting for changes in fundamentals and directly controlling for changes in volatility after the crisis. In this model we allow for a change in correlation during the crisis by including a crisis dummy variable. We find that the crisis dummy variable is negative and highly significant, indicating that after accounting for changes in fundamentals there is a decline in correlation during the crisis. We interpret this to mean that bond market participants perceived that, when fundamentals in the neighboring markets are considered along with global and regional economic conditions, there was no reason for yield spreads in these markets to evolve in the same manner as those in Greece.

Using similar conditional correlations, we also find that during the crisis there was no contagion from Greece to the non-crisis Eurozone countries–Austria, Belgium,

France, and the Netherlands. This is despite concerns to the contrary, especially for Belgium, which has the third highest debt level in the Eurozone, and France, given that large French banks hold a substantial amount of Greek sovereign debt.

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Table I. Summary Statistics of Yields and Yield Spreads for the PIIGS

This table contains summary statistics of 5-year sovereign bond yields for Germany, Greece, Italy, Spain, and Portugal and yield spreads relative to Germany. The yields and yield spreads for Ireland are on 10-year sovereign bonds. The full sample (1/2003 to 4/2011) is partitioned into two sub-samples: a pre-crisis period spanning 1/2003 to 6/2007 and a crisis period spanning 7/2007 to 4/2011. Data are obtained from Bloomberg and are collected on a daily basis.

Pre-Crisis Period

Yields

	Germany	Greece	Ireland	Italy	Portugal	Spain
Mean	3.30	3.40	3.88	3.36	3.33	3.27
Median	3.31	3.42	3.93	3.36	3.33	3.28
Maximum	4.06	4.17	4.59	4.14	4.10	4.06
Minimum	2.47	2.59	3.06	2.59	2.52	2.44
Std. Dev	0.38	0.38	0.37	0.39	0.39	0.38
Obs.	1,095	1,095	1,095	1,095	1,095	1,095

Yield Spreads

	Greece	Ireland	Italy	Portugal	Spain
Mean	0.10	0.04	0.06	0.03	-0.02
Median	0.12	0.02	0.07	0.05	-0.03
Maximum	0.24	0.29	0.19	0.14	0.11
Minimum	-0.01	-0.07	-0.07	-0.19	-0.16
Std. Dev	0.05	0.07	0.06	0.08	0.06
Obs.	1,095	1,095	1,095	1,095	1,095

Crisis Period

Yields

	Germany	Greece	Ireland	Italy	Portugal	Spain
Mean	2.68	6.55	5.43	3.50	4.15	3.54
Median	2.42	4.85	4.85	3.49	3.92	3.37
Maximum	4.76	15.70	10.22	5.16	10.58	4.95
Minimum	1.20	3.22	4.06	2.56	2.63	2.62
Std. Dev	0.89	3.44	1.48	0.66	1.28	0.66
Obs.	906	906	906	906	906	906

Yield Spreads

	Greece	Ireland	Italy	Portugal	Spain
Mean	3.87	2.05	0.82	1.47	0.86
Median	2.18	1.57	0.68	0.81	0.55
Maximum	12.99	6.87	2.18	7.87	3.23
Minimum	0.19	0.16	0.14	0.10	0.05
Std. Dev	3.98	1.79	0.47	1.54	0.76
Obs.	906	906	906	906	906

Table II. Summary Statistics of Yields and Yield Spreads for the NPIIGS

This table contains summary statistics of 5-year sovereign bond yields for Austria, Belgium, France, and the Netherlands (Nether) and yield spreads relative to Germany. The full sample (1/2003 to 4/2011) is partitioned into two sub-samples: a pre-crisis period spanning 1/2003 to 6/2007 and a crisis period spanning 7/2007 to 4/2011. Data are obtained from Bloomberg and are collected on a daily basis. Note that the differences in the number of observations between PIIGS and NPIIGS are due to missing data for the PIIGS.

Pre-Crisis Period

	Yields				Yield Spreads			
	Austria	Belgium	France	Nether	Austria	Belgium	France	Nether
Mean	3.35	3.37	3.37	3.36	-0.01	0.01	0.01	0.00
Median	3.37	3.37	3.36	3.36	-0.02	0.01	0.00	-0.01
Maximum	4.63	4.60	4.62	4.62	0.23	0.17	0.16	0.18
Minimum	2.44	2.48	2.44	2.45	-0.15	-0.11	-0.07	-0.14
Std. Dev	0.46	0.44	0.45	0.44	0.06	0.04	0.04	0.06
Obs.	1,171	1,171	1,171	1,171	1,171	1,171	1,171	1,171

Crisis Period

	Yields				Yield Spreads			
	Austria	Belgium	France	Nether	Austria	Belgium	France	Nether
Mean	3.19	3.41	3.02	2.97	0.38	0.59	0.21	0.16
Median	3.11	3.41	2.74	2.74	0.35	0.54	0.18	0.11
Maximum	4.90	4.99	4.93	4.88	1.28	1.67	0.59	0.81
Minimum	1.63	1.90	1.54	1.31	0.05	0.04	-0.05	-0.08
Std. Dev	0.82	0.71	0.90	0.94	0.25	0.38	0.12	0.15
Obs.	990	990	990	990	990	990	990	990

Table III. Unconditional Correlation between Changes in Yield Spreads

The table reports the unconditional (contemporaneous) correlations between changes in the sovereign yield spreads previously described. Panel A (B) reports the correlations and associated *p*-values for the PIIGS (NPIIGS) including Portugal, Ireland, Italy, Greece, and Spain (Greece, Austria, Belgium, France, and the Netherlands). The overall sample period is 1/2003 to 4/2011 and is partitioned into two sub-samples: a pre-crisis period spanning 1/2003 to 6/2007 and a crisis period spanning 7/2007 to 4/2011.

Panel A – Correlation between Yield Spreads of PIIGS

		Pre-Crisis				Crisis			
		Greece	Portugal	Ireland	Italy	Greece	Portugal	Ireland	Italy
Portugal	Corr.	0.35				0.77			
	p-Value	0.00				0.00			
Ireland	Corr.	0.11	0.10			0.62	0.75		
	p-Value	0.00	0.00			0.00	0.00		
Italy	Corr.	0.46	0.40	0.13		0.59	0.66	0.64	
	p-Value	0.00	0.00	0.00		0.00	0.00	0.00	
Spain	Corr.	0.33	0.34	0.08	0.36	0.62	0.71	0.66	0.80
	p-Value	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00

Panel B – Correlation between Yield Spreads of NPIIGS

		Pre-Crisis				Crisis			
		Greece	Austria	Belgium	France	Greece	Austria	Belgium	France
Austria	Corr.	0.25				0.24			
	p-Value	0.00				0.00			
Belgium	Corr.	0.32	0.45			0.39	0.49		
	p-Value	0.00	0.00			0.00	0.00		
France	Corr.	0.34	0.34	0.34		0.26	0.45	0.53	
	p-Value	0.00	0.00	0.00		0.00	0.00	0.00	
Nether	Corr.	0.27	0.32	0.26	0.32	0.19	0.48	0.50	0.53
	p-Value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table IV. Conditional Correlation between Changes in Yield Spreads for PIIGS

The table reports (only) coefficient estimates from the conditional correlation models in the system of equations (2) to (5):

$$\rho_{ij,t} = \theta_{ij,0} + \theta_{ij,1} D_{Crisis,t} + \theta_{ij,2} D_{Good,t} + \theta_{ij,3} D_{Bad,t} + \theta_{ij,4} D_{Ratings,t} + \gamma_{ij,1} Threshold_{t-1} + \gamma_{ij,2} \mid R_{Fin,i,t-1} \mid$$
$$+ \gamma_{ij,3} \mid R_{Fin,j,t-1} \mid + \gamma_{ij,4} \Delta EVIX_{t-1} + \gamma_{ij,5} \Delta USVIX_t + \gamma_{ij,6} \mid \Delta CDS_{i,t-1} \mid + \gamma_{ij,7} \mid \Delta CDS_{j,t-1} \mid,$$

where, for a given country i with changes in bond yield spreads ΔY_i, D_{Crisis} is an indicator variable equal to one during the crisis, and D_{Bad}, D_{Good}, and $D_{Ratings}$ are equal to one for negative third-party announcements, positive third-party announcements, and negative ratings announcements, respectively. Further, $\Delta EVIX$ and $\Delta USVIX$ are changes in European and US implied option volatility indices, respectively, ΔCDS_i is the change in credit default swap spreads, $R_{Fin,i}$ is the log returns of country i's financial sector equity index in excess of that country's broad stock market returns, and *Threshold* is a dummy variable defined as one when changes in Greek yield spreads during the crisis are at least two standard deviations above their pre-crisis mean. Also, i or j = {1,2,3,4,5} for Portugal, Ireland, Italy, Greece, and Spain, respectively. All coefficient estimates, except for those denoted by a spade (♠), are statistically significant at the 5% level. The models are estimated using previously described sovereign yield data over the full sample period, 1/2003 to 4/2011.

	Greece / Italy	Greece / Portugal	Greece / Ireland	Greece / Spain	Italy / Portugal	Italy / Ireland	Italy / Spain	Portugal / Ireland	Portugal / Spain	Ireland / Spain
Intercept	2.543	3.428	2.001	1.167	3.084	2.635	2.144	2.433	1.616	2.055
$Crisis_t$	-1.590	-2.438	-0.889	-0.052	-1.989	-1.456	-0.735	-0.945	-0.124	-0.730
$Good_t$	-0.470	-1.005	-0.646	0.144♠	-0.637	-0.819	-0.367♠	1.154	-0.468	-0.046♠
Bad_t	1.704♠	0.825	0.426♠	-0.654	3.028♠	0.806	-1.122♠	0.876♠	-0.942	-0.891♠
$Ratings_t$	-0.203♠	0.608	-0.244	-0.203	-0.880	0.189♠	-0.506	-0.976	-0.797	-0.629
$Threshold_{t-1}$	-0.508	-0.498	-0.228	-0.690	-0.177	-0.166	-0.017♠	-0.407	-0.290	-0.452
$\Delta EUVIX_{t-1}$	-0.010	0.015	-0.033	0.021	0.004	-0.026	0.032	0.009	0.027	-0.018
$\Delta USVIX_t$	-0.031	-0.033	-0.052	-0.013	0.001	0.017♠	0.035	0.011	0.012	0.060
$\lvert\Delta CDS_{i,t-1}\rvert$	-0.002	0.009	-0.001	0.001	-0.007♠	-0.005	0.002♠	-0.006	-0.014	-0.010
$\lvert\Delta CDS_{j,t-1}\rvert$	-0.016	-0.011	-0.011	-0.009	-0.010	-0.007	-0.010♠	-0.008	-0.004	-0.012
$\lvert R_{Fin,i,t-1}\rvert$	-0.030	-0.001	0.047	0.033	-0.046	-0.083	0.013♠	-0.049	-0.006	-0.011
$\lvert R_{Fin,j,t-1}\rvert$	0.166	0.123	-0.006	0.019	0.019♠	-0.032	-0.122	-0.017	-0.030	-0.050

Table V. Conditional Correlation between Changes in Yield Spreads for NPIIGS

The table reports (only) coefficient estimates from the conditional correlation models in the system of equations (2) to (5):

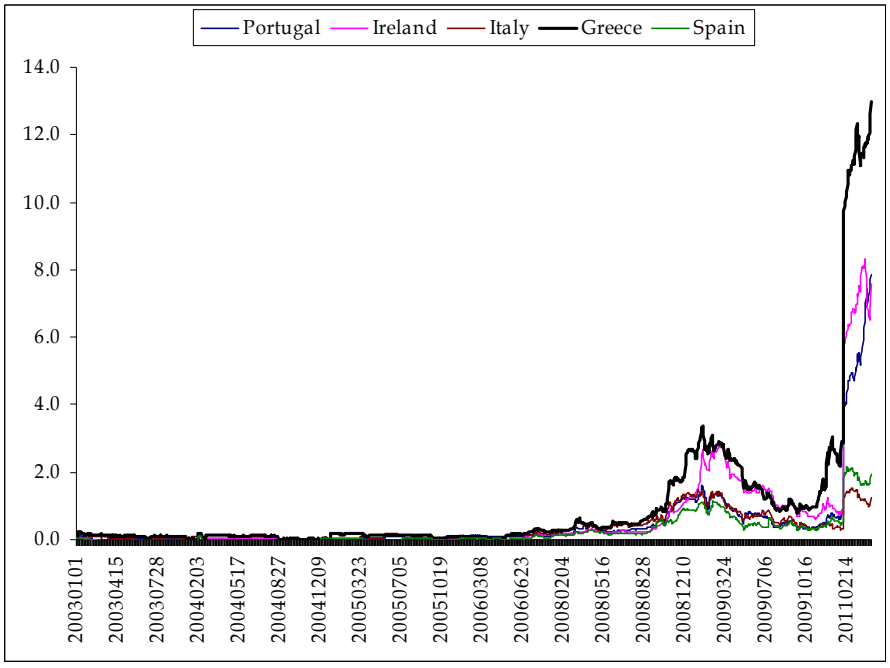
$$\rho_{ij,t} = \theta_{ij,0} + \theta_{ij,1} D_{Crisis,t} + \theta_{ij,2} D_{Good,t} + \theta_{ij,3} D_{Bad,t} + \theta_{ij,4} D_{Ratings,t} + \gamma_{ij,1} Threshold_{t-1} + \gamma_{ij,2} \mid R_{Fin,i,t-1} \mid$$
$$+ \gamma_{ij,3} \mid R_{Fin,j,t-1} \mid + \gamma_{ij,4} \Delta EVIX_{t-1} + \gamma_{ij,5} \Delta USVIX_t + \gamma_{ij,6} \mid \Delta CDS_{i,t-1} \mid + \gamma_{ij,7} \mid \Delta CDS_{j,t-1} \mid,$$

where, for a given country i with changes in bond yield spreads ΔY_i, D_{Crisis} is an indicator variable equal to one during the crisis, and D_{Bad}, D_{Good}, and $D_{Ratings}$ are equal to one for negative third-party announcements, positive third-party announcements, and negative ratings announcements, respectively. Further, $\Delta EVIX$ and $\Delta USVIX$ are changes in European and US implied option volatility indices, respectively, ΔCDS_i is the change in credit default swap spreads, $R_{Fin,i}$ is the log returns of country i's financial sector equity index in excess of that country's broad stock market returns, and *Threshold* is a dummy variable defined as one when changes in Greek yield spreads during the crisis are at least two standard deviations above their pre-crisis mean. Also, i or j = {1,2,3,4,5} for Greece, Austria, Belgium, France, and the Netherlands (Nether), respectively. All coefficient estimates, except for those denoted by a spade (♠), are statistically significant at the 5% level. The models are estimated using previously described sovereign yield data over the full sample period, 1/2003 to 4/2011.

	Greece / Austria	Greece / Belgium	Greece / France	Greece / Nether	Austria / Belgium	Austria / France	Austria / Nether	Belgium / France	Belgium / Nether	France / Nether
Intercept	2.009	2.649	2.605	2.388	3.242	3.021	2.899	3.578	3.271	3.116
$Crisis_t$	-0.126	-0.027	-0.531	-0.462	-0.722	-0.500	-0.302	-0.801	-0.600	-0.351
$Good_t$	-0.213♠	-0.982	-1.068	-1.044	-0.250	-0.393	0.061♠	-0.976	-1.275	-0.112♠
Bad_t	0.140	0.429	0.770	1.475	-0.711	-0.740♠	-0.533	2.845♠	2.111	1.922
$Ratings_t$	-0.381	-0.487	-0.632	-0.699	-0.125♠	0.114♠	-0.150	-0.991	-1.131	0.681
$Threshold_{t-1}$	-1.110	-1.417	-1.222	-1.241	-0.847	-0.678	-0.911	-0.187	-0.351	-0.122
$\Delta EUVIX_{t-1}$	0.020	0.052	0.045	0.027	-0.011	0.016	0.030	0.021	0.038	-0.030
$\Delta USVIX_t$	-0.005	-0.024	-0.005	0.011	0.011	0.008	-0.004	-0.038	0.035	0.020
$\lvert \Delta CDS_{i,t-1} \rvert$	-0.002	-0.001	0.000	0.006	-0.010	-0.009	0.002	-0.047	-0.045	0.013
$\lvert \Delta CDS_{j,t-1} \rvert$	-0.014	-0.074	-0.047	-0.099	-0.042	-0.016	-0.141	-0.055	-0.087	-0.137
$\lvert R_{Fin,i,t-1} \rvert$	-0.162	-0.221	-0.166	-0.108	-0.045	-0.073	0.028	-0.093	-0.101	-0.071
$\lvert R_{Fin,j,t-1} \rvert$	0.079	-0.043	0.024	0.005	-0.098	-0.021	-0.094	-0.024	-0.070	-0.068

Figure I. Sovereign Debt Yield Spreads

The figures below depict the spreads of PIIGS (Portugal, Ireland, Italy, Greece, and Spain) and NPIIGS (Greece, Austria, Belgium, France, and the Netherlands) sovereign bond yields relative to a German bond yield of the same maturity. The sample period spans 1/2003 to 4/2011.



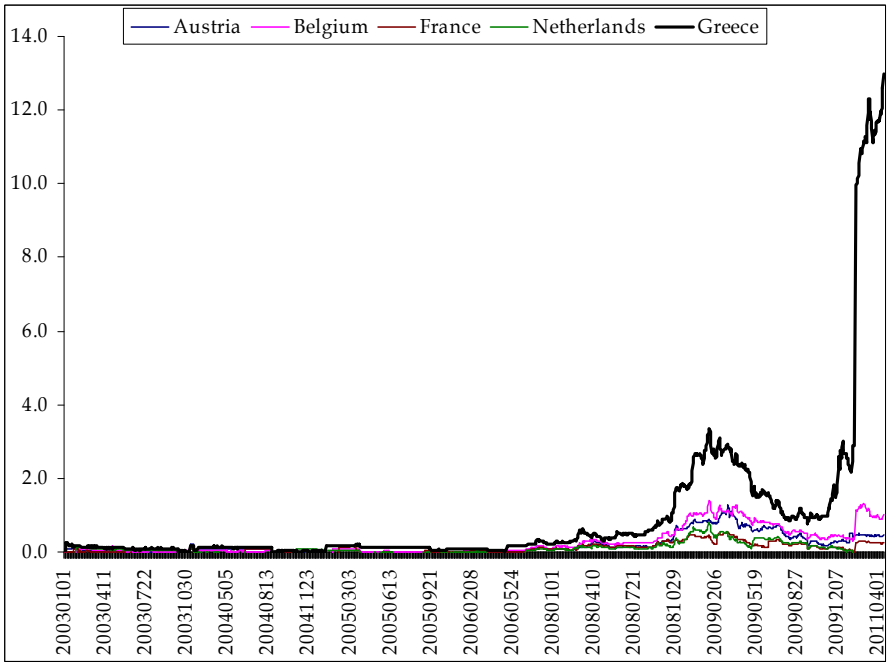


Figure II. Impulse Responses of Bond Markets to Shocks in Greek Yield Spreads

The following figures report the impulse response functions (IRF) for the following vector autoregression without (VAR) and with fundamental exogenous variables included (VARX):

$$\Delta Y_{i,t} = b_{i,0} + \sum_{j=1}^{5} b_{i,j}\Delta Y_{j,t-1} + \delta_{i,1}\Delta EVIX_{t-1} + \delta_{i,2}\Delta USVIX_t + \delta_{i,3} \mid \Delta CDS_{i,t-1} \mid + \varepsilon_{i,t},$$

where ΔY_i is the change in country i's yield spreads. $\Delta EVIX$ and $\Delta USVIX$ are changes in European and US implied option volatility indices, respectively, and ΔCDS_i is the change in credit default swap spreads. Each chart has three responses. Pre-VARX is the IRF during the pre-crisis period (1/2003 to 6/2007) using the full VARX model, Crisis-VARX is the IRF during the crisis (7/2007 to 4/2011) using the VARX model, and Crisis-VAR is the IRF during the crisis using only lagged changes in yield spreads.

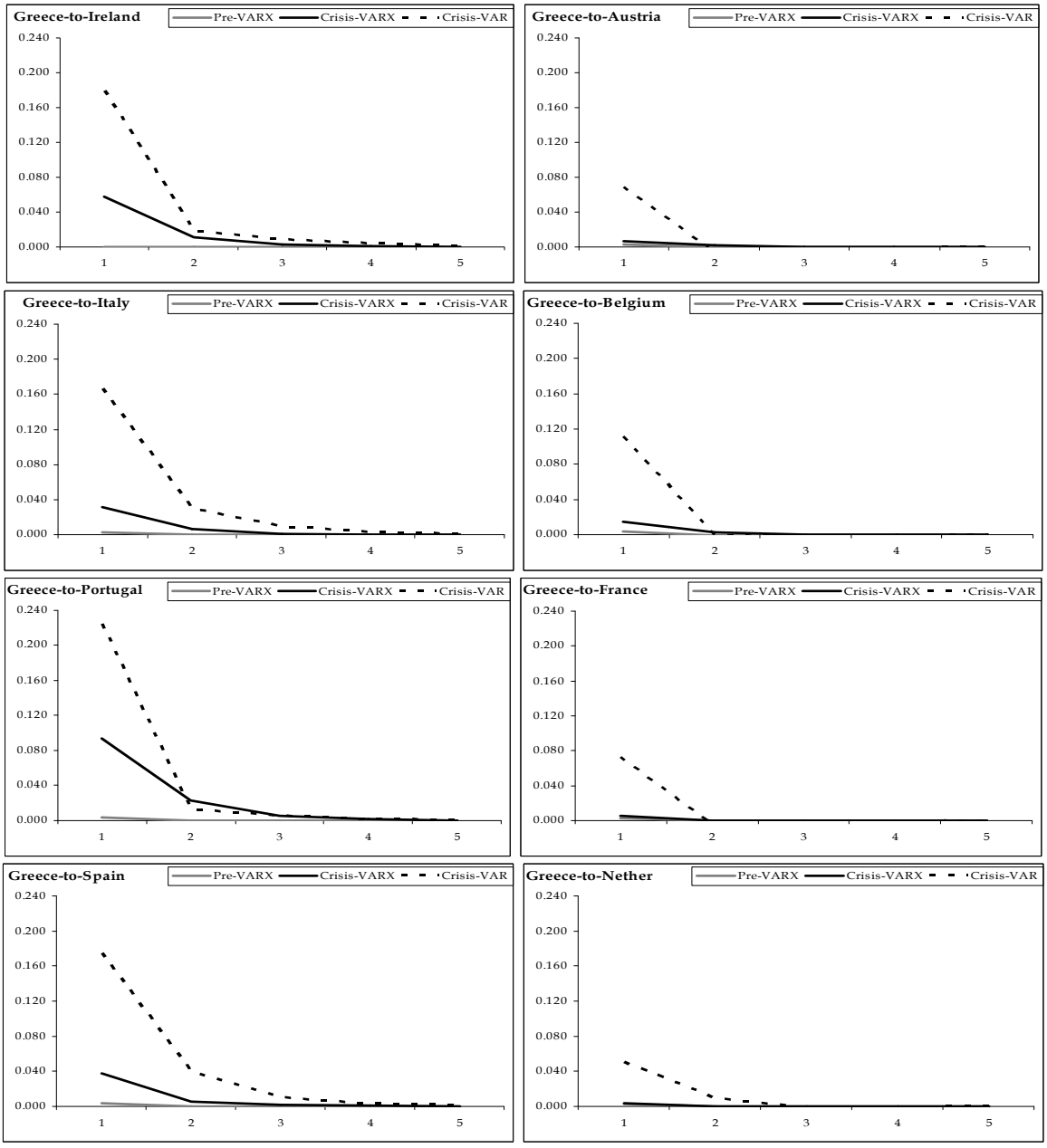
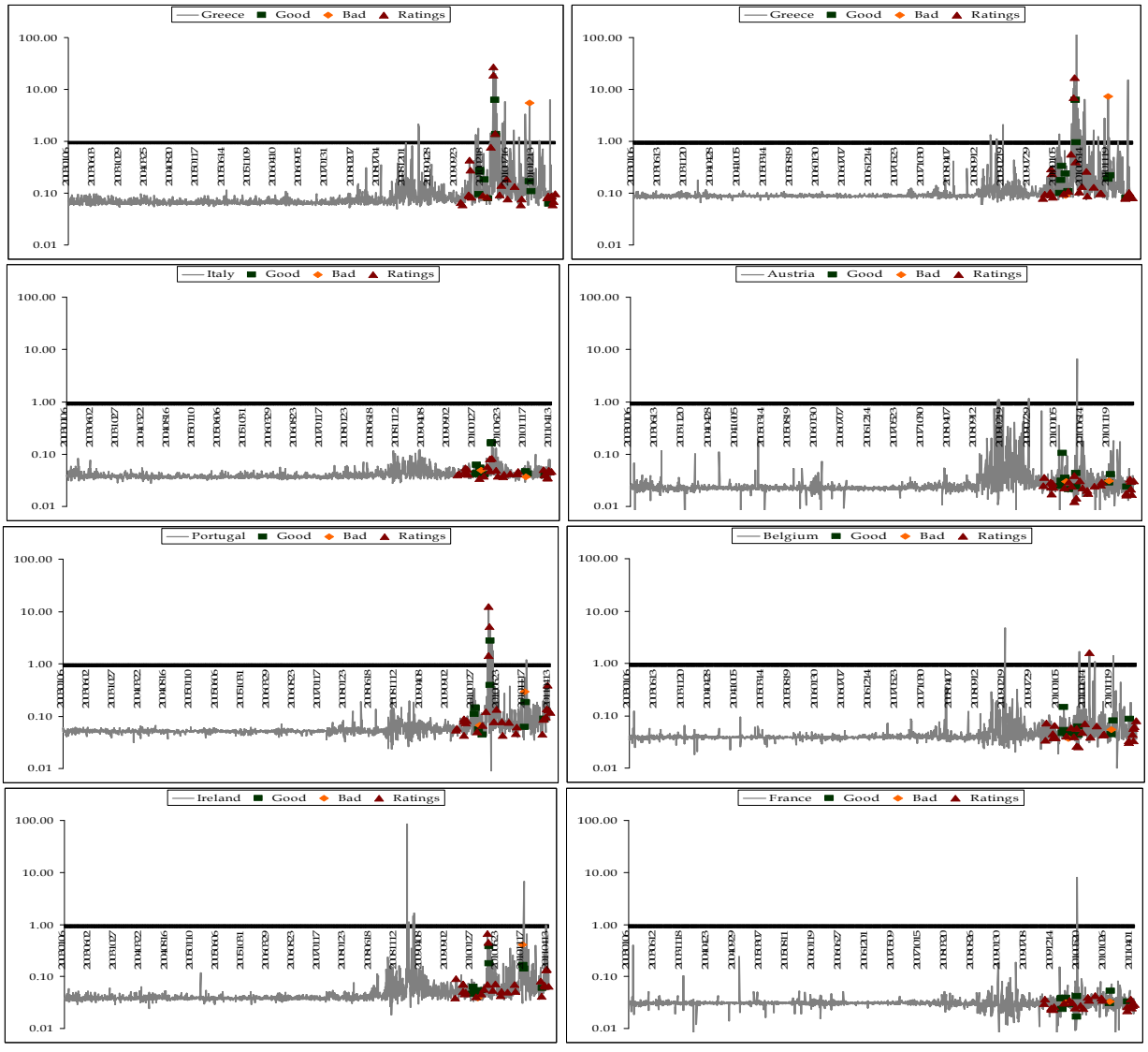


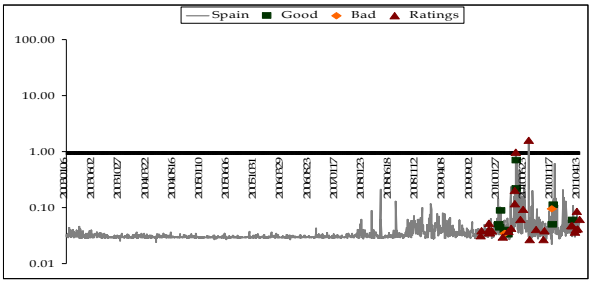
Figure III. Conditional Volatility of Changes in Yield Spreads

The figures report the estimated conditional volatilities of changes in yield spreads from the volatility models in equation (3):

$$\sigma^2_{\varepsilon i,t} = \exp\left\{\varpi_{i,0} + \sum_{j=1}^{5} \alpha_{i,j}\varepsilon^2_{j,t-1} + \lambda_{i,1}\Delta EVIX_{t-1} + \lambda_{i,2}\Delta USVIX_t + \lambda_{i,3}\,|\,\Delta CDS_{i,t-1}\,| + \lambda_{i,4}\,|\,R_{Fin,i,t-1}\,|\right\},$$

where $\Delta EVIX$ and $\Delta USVIX$ are changes in European and US implied option volatility indices, respectively, ΔCDS_i is the change in credit default swap spreads, and $R_{Fin,i}$ is the log returns of country i's financial sector equity index in excess of that country's broad stock market returns. Note that news events are plotted on each graph, but not included in the conditional volatility model, where the left (right) set of sub-plots reports the volatility responses of the PIIGS (NPIIGS).




Spain
Good
Bad
Ratings
100.00
10.00
1.00
0.10
0.01

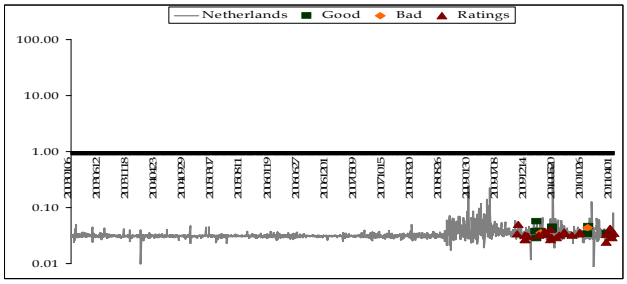

Netherlands
Good
Bad
Ratings
100.00
10.00
1.00
0.10
0.01

Figure IV. Plots of Conditional Correlation between Changes in Yield Spreads for PIIGS

The figures plot the estimated conditional correlations from the model (equation 5) described in Table IV. The correlations are based on changes in bond yield spreads. "Good", "bad", and "ratings" are days with positive third-party announcements, negative third-party announcements, and negative ratings announcements, respectively. The bond markets are those of Portugal, Ireland, Italy, Greece, and Spain, respectively. The conditional correlations models are estimated using previously described sovereign yield data over the full sample period, 1/2003 to 4/2011.

Figure V. Plots of Conditional Correlation between Changes in Yield Spreads for NPIIGS

The figures plot the estimated conditional correlations from the model (equation 5) described in Table V. The correlations are based on changes in bond yield spreads. "Good", "bad", and "ratings" are days with positive third-party announcements, negative third-party announcements, and negative ratings announcements, respectively. The bond markets are those of Greece, Austria, Belgium, France, and the Netherlands, respectively. The conditional correlations models are estimated using previously described sovereign yield data over the full sample period, 1/2003 to 4/2011.

Appendix: List of Announcements

Date	Announcement
10/22/09	Fitch reduces Greece's rating to A- from A.
10/29/09	Moody's considers possible downgrade of Greek rating.
12/07/09	S&P lowers Portugal's rating to A- from A+.
12/08/09	Fitch lowers Greek ratings to BBB+ with negative outlook.
12/09/09	S&P lowers its rating on Spain to negative.
12/16/09	S&P cuts Greece's bond rating to BBB+ from A minus.
12/22/09	Moody's lowers its rating on Greece's debt from A1 to A2.
02/03/10	The EU endorses Greece's austerity program.
02/09/10	Germany considers joint EU plan to offer loan guarantees to Euro Zone members.
02/11/10	European reach deal on stemming the Greek debt crisis.
02/23/10	Fitch downgrades four major Greek banks to BBB and considers Greek prospects as "negative".
03/04/10	ECB President endorses IMF involvement in Greece.
03/05/10	German Prime Minister avoids giving Greece a commitment of financial assistance.
03/24/10	Fitch reduces Portugal's rating to AA-.
03/25/10	The ECB announces that it will accept bonds with ratings greater than or equal to BBB-.
03/25/10	16 Euro-Zone national leaders back a joint venture with the IMF to bail out Greece.
04/09/10	Fitch lowers the Greek rating to BBB from BBB+ with negative outlook.
04/11/10	16 Euro-Zone finance ministers will allow Greece to borrow up to €30 billion.
04/22/10	Moody's reduces Greek ratings to A3 from A2 with negative outlook.
04/27/10	S&P lowers Greek ratings to Junk.
04/27/10	S&P lowers Portuguese ratings to A-.
04/28/10	S&P lowers Spanish ratings to AA with negative outlook.
05/05/10	Portugal is placed under review for a downgrade by Moody's.
05/07/10	Germany's Lower House passes Greek bailout bill.
05/05/10	Moody's placed Portugal under review for a downgrade.
05/07/10	Germany's Lower House passes the Greek bailout bill.
05/12/10	Spain announces that it will cut public-sector wages by 5% this year (2010).
05/13/10	The Portuguese government approves tax increases and salary reductions for public employees.
05/19/10	Spain will raise taxes for high-income earners to help decrease country's deficit.
05/21/10	Spain's central bank takes over Roman Catholic Church-controlled savings bank CajaSur.
05/29/10	Fitch drops Spain's AAA credit rating to AA plus.
06/14/10	Moody's cuts rating on Greece into junk territory.
07/13/10	Moody's downgrades Portugal's government bond rating from Aa2 to A1.
07/19/10	Moody's cuts Ireland's credit rating from Aa2 to A1.
07/23/10	European stress tests show that 7 of 91 banks need to raise new capital.
08/24/10	S&P reduces Irish ratings 3 notches to AA-.
09/08/10	Greek 2nd Q GDP is revised downward to -1.8% from an initial -1.5%.
09/30/10	Moody's downgrades Spain's rating by one notch to Aa1.
10/06/10	Fitch cuts Irish ratings from AA- to A+ with negative outlook.
10/26/10	Ireland's government says that budget cuts of €15 billion are needed over the next four years.
11/21/10	The EU and IMF indicate that the money requested by Ireland will be forthcoming.
11/24/10	Ireland's government outlines €15 billion in spending cuts and tax hikes over four years.
11/28/10	Europe seals a €67.5 billion bailout for Ireland.