Does Contagion Have Persistent Effects?

A Novel Perspective of Contagion and the Eurozone Sovereign Debt Crisis

Dirk G. Baur
University of Technology, Sydney

&

Gunter Löffler[1]
University of Ulm

This version: January 15, 2014

Abstract

The objective of this paper is to analyze the persistence of contagion and its consequences. For the Euro debt crisis, we identify contagion through extreme co-movements of sovereign bond returns and rating downgrades. An event study analysis shows that the effects of contagion on prices and correlations are largely transitory. This result is confirmed through an analysis of investment performance. We form portfolios of Eurozone countries and find that the frequency of contagious events among portfolio constituents does not increase investment risk.

JEL classification: G010, G140, G180, G320

Key words: Euro debt crisis, financial risks, contagion, sovereign ratings, co-exceedances

[1] Corresponding author, Institute of Finance, University of Ulm, 89069 Ulm, Germany. Phone: ++49 731 5023597, facsimile: ++49 731 5023950, email: gunter.loeffler@uni-ulm.de

1 Introduction

Contagion is a frequently used term in the discussion of the Euro debt crisis. Efforts of Eurozone governments and the European Central Bank to support individual member countries are often justified by arguing that the instability or default of one country would be contagious for other countries, i.e. trigger problems in other countries.[2]

Academic research on contagion with a focus on the Eurozone is evolving but offers mixed results. Several papers (e.g. Claeys and Vasicek, 2012, Metiu, 2012 and Missio and Watzka, 2011) conclude that sovereign bond and credit markets have been affected by contagion. In contrast, Caporin, Pelizzon, Ravazzolo and Rigobon (2013) present empirical evidence for a constant propagation of shocks and thus no contagion in CDS markets. The differences in results are typical for the contagion literature and not confined to studies that focus on the Eurozone crisis. The reasons for different empirical findings are due to different definitions of contagion, different crisis period definitions and testing methodologies.

The major objective of this paper is not to test for the presence of contagion but to analyze its potential consequences. We thus add a novel perspective to the contagion literature. Specifically, we examine whether the price and risk effects associated with possible incidences of contagion are persistent. There are several reasons why such a perspective can provide additional important insights. For example, contemporaneous return spillovers could be due to a market overreaction. In consequence, an event classified as contagious by standard approaches (e.g. a co-exceedance that is not explained by control variables (Bae, Karolyi and Stulz, 2003) or an increased correlation in a crisis period relative to a tranquil, pre-crisis period (Forbes and Rigobon, 2002)) might not be persistent and not affect mid- to long-term investment risk if the price change is corrected over time.

We use either extreme co-movements of government bond returns or rating downgrades to identify (and date) possibly contagious events. Within an event-study framework, we then examine whether return effects on the event days are persistent and do not find robust evidence that they are. Volatility tends to increase after events, but correlations tend to decrease. As with returns, there is no strong statistical support for persistent effects. We also approach the problem

[2] Cf., for example, "Sovereign contagion in Europe" (speech by José Manuel González-Páramo, ECB, November 25, 2011), or "Merkel to press for `firewall' against euro contagion" (Deutsche Presse-Agentur, October 18, 2011).

from an investment perspective. We form pairwise portfolios of the Eurozone countries and find that the frequency of contagion is not associated with higher risk. In summary, we do not find evidence that contagion has lasting and harmful effects on government bond returns.

Empirical studies of financial contagion started in the aftermath of the Asian financial crisis in 1997 and 1998. Baig and Goldfajn (1999) proposed a test for contagion based on changes in the co-movement of equity returns between the crisis country (i.e. where the crisis originated) and other countries in the region. If the co-movement measured by the correlation coefficient is higher in the crisis compared to a tranquil pre-crisis period, there is evidence for contagion. Forbes and Rigobon (2002) also used this framework based on changes in the correlation coefficient but proposed an adjustment for heteroscedasticity of the correlation coefficient. The main contribution of Forbes and Rigobon (2002) is the distinction between *interdependence* and *contagion*. They argue that the joint fall of stock market valuations of countries does not per se constitute contagion but could be the result and a continuation of the pre-crisis co-movement and thus interdependence of the markets. According to Forbes and Rigobon, contagion only occurs if the volatility-adjusted co-movement[3] increased in the crisis period relative to a (tranquil) pre-crisis period.

There are many alternative testing frameworks that empirically investigate the existence of contagion.[4] For example, Favero and Giavazzi (2000) analyze contagion within a VAR framework, Bae, Karolyi and Stulz (2003) use co-exceedances to identify contagion and Baur and Schulze (2005) propose an alternative co-exceedance measure within a quantile regression framework to analyze contagion. More recently, dynamic conditional correlation models (e.g. Chiang et al., 2010 and Missio and Watzka, 2011) and copula models (e.g. Hu, 2006) are employed to analyze changes in co-movement. Finally, Boyer, Kumagai and Yuan (2006) use a Markov-switching model to study contagion and Rodriguez (2007) combines the Markov-switching model and copulas to estimate changes of (inter-)dependence in crisis periods relative to tranquil periods.

The methodologies to detect contagion can be classified into two groups with important implications for the crisis period definition. The first group is represented by Baig and Goldfajn

[3] Corsetti, Pericoli and Sbracia (2005) showed that this correction leads to an over-rejection of the ``no contagion''-hypothesis.

[4] Pericoli and Sbracia (2003) and Dungey et al. (2005) provide an overview of concepts on contagion, studies on contagion and methodologies to test for contagion.

(1999) and Forbes and Rigobon (2002), who define a crisis period and then test whether the propagation of shocks has increased in the crisis period relative to a pre-crisis period. The second group, represented by Bae, Karolyi and Stulz (2003), circumvents the critical definition of a crisis period and instead focuses on extreme joint asset price movements.[5] Whilst the first approach is subject to the problem of finding the "correct" crisis period definition, the second approach is subject to the problem of finding the "correct" definition of extreme price movements. Another issue with the latter approach is that the period of extreme joint asset price movements does generally consist of non-adjacent crisis points and thus no clearly defined crisis periods. We therefore use a mix of both approaches, i.e. we analyze co-exceedances in a clearly defined time period representing the crisis period. The mix is necessary since the crisis period associated with the Eurozone crisis is relatively long compared to the first studies of contagion that focused on much shorter crisis periods like October and November 1997 as for the Asian financial crisis. However, our contagion identification is not based on one measure only but complemented with another measure, i.e. rating downgrades.

The remainder of the paper is structured as follows. Section 2 presents the results of the event-study approach. Section 3 examines investment performance and section 4 summarizes the main findings and concludes.

2 An Event-study Analysis of Contagion

In this section, we examine government bond returns after events that are commonly associated with contagion. Bond returns are daily log returns on Datastream benchmark 10-year government bond indices. These are available for 11 members of the Eurozone and include its major markets.[6] While many other studies use credit default swap (CDS) spreads or government bond yields, government bond returns have the advantage that they can be directly used to measure investment returns. Compared to CDS markets, sovereign bond markets also seem preferable because they are less affected by liquidity frictions as shown by Badaoui, Cathcart and

[5] Another important advantage of the co-exceedance approach is that it can capture non-linear transmissions of shocks (leading to contagion) since it is not based on a linear measure like the correlation coefficient.
[6] Countries included are Austria, Belgium, Finland, France, Germany, Greece, Netherlands, Ireland, Italy, Portugal and Spain.

El-Jahel (2013). Their result is further supported by an analysis that will be presented below with the descriptive statistics.

We use data from January 2001, when Greece joined the Euro, to December 2012. For many applications, the data will be partitioned into a pre-crisis period and a crisis period. In the base case we let the crisis period start with the beginning of the global financial crisis (July 2007) but also analyze later starting dates for robustness. The choice of the 2007 start date is motivated by results from Claeys and Vasicek (2012), who find that sovereign bond spillovers increased since 2007, and by own findings presented later in this section. To identify potentially contagious events, we use co-exceedances and rating downgrades that occur in the (pre-defined) crisis period.

2.1 Methodology

Most tests of contagion are based on changes of dependence. One of the first tests of contagion (Baig and Goldfajn, 1999) representative of a large literature compares the correlation coefficient between two stock market indices in a crisis period with the correlation in a pre-crisis period.[7] If the correlation is significantly larger in the crisis period, the test result implies the existence of contagion. This test of contagion does not examine the dynamics of the correlation but just compares the unconditional correlations between two different sample periods. While later studies analyzed the dynamics of the correlations in more detail (e.g. Chiang et al., 2011) the focus remained on the dependence, i.e. the overall return effects are generally not explicitly analyzed. Since the return effects are decisive for the ultimate costs of contagion, this observation might seem surprising.[8] It can be explained through the prior literature's focus on short, well-defined crises that led to sharp declines in market values. In addition, even though the volatility of assets is important for the risk of a portfolio, changes in volatility are often controlled for, adjusted or analyzed independently (e.g. see Edwards and Susmel, 2001 and Forbes and Rigobon, 2002).

[7] H_0: correlation(crisis) ≤ correlation (pre-crisis), H_1: correlation(crisis) > correlation (pre-crisis)

[8] A focus of the analysis on correlation changes does not reveal the full picture of contagion. For example, if the return pairs are not negative for each day of the crisis period, the (aggregate) return effect of increased co-movement is not necessarily negative.

In this section we outline an event study methodology that closes this gap in the literature and analyzes the effects of contagion with respect to returns, correlations, and volatilities. We use two measures to identify contagion, a return-based measure and a rating-based measure.

Return-based Contagion

To determine exceedances, we first standardize the returns by dividing them by current exponentially-weighted moving average (EWMA) volatility estimates. For the weighting factor we employ the industry standard λ=0.94. We favor EWMA because estimated GARCH(1,1) parameters for several countries do not imply stationarity.[9]

An exceedance occurs ($I_{i,t}$=1) if the bond return of a country i falls below its respective quantile:

$$I_{i,t} = \mathbf{1}(r_{it}^s < Q_{it}(\alpha))$$

Where r_{it}^s denotes standardized returns, $\mathbf{1}()$ the indicator function, and the quantile Q_{it} is the empirical quantile of r_{it}^s in the period to which the day t is assigned. We mostly use the 5% quantile to identify an exceedance.

A day is defined to have a co-exceedance if at least two Euro countries show an exceedance on that day (t):

$$C_t = \mathbf{1}\left(\sum_{i \neq j} I_{i,t} I_{j,t} > 0\right)$$

On days on which a co-exceedance (C_t=1) between at least two countries exists and which fall into a pre-defined crisis period, we classify all countries into one of three groups:

C1 Co-exceedance and lowest return: this is the country with the lowest standardized return among the countries that show an exceedance. The group is meant to capture "trigger" countries that are the origin of contagion.

C2 Co-exceedance and return > minimum: This group contains the countries with at least one exceedance and a standardized return larger (i.e. less extreme) than the minimum return of the other countries with an exceedance. It is meant to represent infected countries.

[9] Results based on a GARCH.(1,1) model are reported below as part of the robustness checks.

C3 No co-exceedance: This group contains the countries that do not have an exceedance and thus no co-exceedance. This group is meant to identify countries that are not infected despite a contagious event.

It is obvious that the classification is only an approximation. A day with a co-exceedance in the crisis period need not necessarily be a day with contagion and the lowest return does not necessarily identify the infectious country. Therefore, we complement the return-based definition with another one based on rating changes.

Rating-based Contagion

From the web pages of the three major rating agencies Fitch, Moody's and S&P, we collect information on rating changes, outlooks and watch list designations. We treat the following rating actions as triggers that can cause a contagious event: (i) the rating is lowered; (ii) the outlook changes to negative; (iii) the issuer is set on a watch list with a negative perspective.

Rating actions are often anticipated by the market or lead to delayed responses. In addition, they may not contain major news, e.g. if a rating agency follows recent downgrades by the two other agencies. To better approximate possibly contagious events, we therefore do not classify each downgrade event as a contagious event. To qualify for inclusion, we also require that the cumulated raw return around the announcement is negative. For this purpose, we favor raw returns over abnormal returns because a downgrade could have such a strong effect on the overall market that abnormal returns would fail to capture its effects. Based on the average time patterns of anticipation and delay shown in the recent study of Michaelides et al. (2012), we cumulate returns over the days [-10, +3].

On days with a downgrade event that fulfills this requirement and lies in a crisis period, we then classify each country into one of three groups:

D1 Downgrade: this is the country with the downgrade event. The group is meant to identify "trigger" countries that are the origin of contagion.

D2 No downgrade and negative cumulative return around the downgrade of the country from D1. This group is meant to represent infected countries.

D3 No downgrade and non-negative cumulative return around the downgrade of the country from D1. This group is meant to capture countries that are not infected despite a contagious event.

Event-study Framework for the Analysis of Post-event Return Behavior

Having determined contagious events and country groupings, we study the post-event evolution of returns, return correlations and return volatilities.

Specifically, we present cumulative raw returns as well as cumulative abnormal returns. For abnormal returns, we suggest a market-adjustment with a world government bond index. Since Datastream does not compute a world government bond index, and since the relative market capitalization of the 10-year benchmark bond can deviate strongly from the relative market capitalization of a country's overall debt value, we use an index from another index family, the Citigroup World Government Bond Index for maturities of 7-10 years, denominated in Euro. Due to the large number of events, an adjustment based on market-model regressions would lead to problems with confounding estimation and event periods.

The market adjustment with the returns of the world bond index r_{wt} leads to the following definition of (cumulative) abnormal returns:

$$AR_{i,t} = r_{it} - r_{wt}$$

$$CAR_{i,t1,t2} = \sum_{t=t1}^{t2} AR_{it}$$

Our analysis of correlation is based on trailing 30-day return correlations. For each country we determine the correlation coefficients with the other ten Euro countries in the sample and examine how the average of these ten coefficients evolves after the event. Due to the large differences in the level of correlations across countries and across time, we do not examine the level of correlations but their changes relative to the pre-event period. Specifically, we subtract the correlation coefficients computed in the [-60,-31] day period. To convert these changes into abnormal changes in correlation, we compare them to the changes in the correlation coefficients of all countries for which Datastream 10-year benchmark indices are available. For each country, we determine the average correlation with the other countries, and then average over the average correlations.

The definitions of correlation changes $\Delta\overline{\rho}_{it}^{e}$ and abnormal correlation changes $A\Delta\overline{\rho}_{it}^{e}$ among the Euro countries are thus as follows:

$$\Delta\overline{\rho}_{i,t}^{e} = \overline{\rho}_{i,t,t-30}^{e} - \overline{\rho}_{i,t-31,t-60}^{e}$$

$$\Delta\overline{\rho}_{i,t}^{w} = \overline{\rho}_{i,t,t-30}^{w} - \overline{\rho}_{i,t-31,t-60}^{w}$$

$$A\Delta\overline{\rho}_{it}^{e} = \Delta\overline{\rho}_{it}^{e} - \frac{1}{N_w}\sum_{j=1}^{N_w}\Delta\overline{\rho}_{jt}^{w}$$

where $\overline{\rho}_{i,t,t'}^{e}$ ($\overline{\rho}_{i,t,t'}^{w}$) denotes the average correlation of country i with the other 10 Euro countries (N_w countries of the world), estimated over days t' to t.

For the analysis of volatility, we proceed in a similar fashion. We trace the 30-day volatility (annualized with the square root of 260), comparing it to the volatility in the [-60,-31] day period in order to benchmark its level. To determine abnormal changes in volatility, we subtract the average change in volatility of the countries for which data are available.

The definitions of volatility changes $\Delta\sigma_{it}$ and abnormal correlation changes $A\Delta\sigma_{it}$ are thus as follows

$$\Delta\sigma_{it} = \sigma_{i,t,t-30} - \sigma_{i,t-31,t-60}$$

$$A\Delta\sigma_{it} = \Delta\sigma_{it} - \frac{1}{N_w}\sum_{j=1}^{N_w}\Delta\sigma_{jt}$$

We study return behavior in the 60 trading days (3 months) following the contagious event. Confounding events are excluded. Specifically, when using the return-based definition of contagion, the return of country *i* is excluded from the analysis if it was classified as infectious (C1) or infected (C2) at some point during the 60 days preceding the event. For the rating-based classification, we eliminate confounding events in the analogous fashion.

Compared to other event-study applications, the exclusion of confounding events is of particular relevance for our study. The first event definition is based on returns, and both country groupings are based on returns as well. Confounding events could therefore affect event definitions and group classifications.

Statistical significance tests need to take into account that return effects can be cross-sectionally dependent; time-series dependencies should not lead to problems once we have eliminated confounding events in the manner described above. To deal with cross-sectional dependence, we aggregate countries belonging to one group to portfolios dated through the events, and perform the tests on the portfolio averages. When testing the significance of cumulative abnormal returns for group C2, for example, we would examine the time series of group averages of abnormal returns:

$$\overline{CAR}_{\tau,C2,0,60} = \frac{1}{N_{k,C2}} \sum_{i \in C2} CAR_{i,\tau,\tau+60}$$

where τ denotes the event dates for which there is data, and $N_{\tau,C2}$ denotes the number of countries assigned to group C2 at the event date τ, and conduct a standard t-test. In the same fashion, we test for the significance of changes in correlation or volatility. When testing the significance of differences between groups, say between C2 and C3, we use the time series of group averages for C2 and C3 and conduct a standard t-test for the difference of unpaired data with unequal variances.[10]

2.2 Descriptive Statistics

Table 1 provides descriptive statistics of the event counts. Compared to the pre-crisis period, the 2007-2012 period shows a larger number of days with return-based and rating-based contagious events. Since we use standardized returns to define exceedances, the difference in return-based events should not be attributed to an increased volatility during the crisis. Rather, it is consistent with the declining return correlation. For example, the daily return correlation of Greek and Spanish bonds declined from 95.8% in the period Jan 2001-Jun 2007 to 28.8% in the period Jul 2007 - Dec 2012. To see why a decline in correlation can lead to an increase in the frequency of co-exceedances, consider the two following extreme examples: with a perfect dependence of all countries, the co-exceedance probability is equal to the exceedance probability, here 5%. With independence, it obtains as the probability that at least two out of eleven (the number of

[10] We do not pair the data because a group may not contain countries for some dates. To examine the robustness of the test procedure, we alternatively use a regression framework. The pooled individual data are regressed on group dummies, and correlation is taken into account through a two-way clustering, with the clusters being defined through groups and event dates. Resulting p-values are similar and do not necessitate a change of conclusions.

countries) draws from a binomial distribution with success probability 5% are successful. This gives a probability of 10.2%.

The increased frequency of co-exceedances goes along with an increased heterogeneity across countries. Before the crisis, co-exceedances typically involved the majority of the countries, which is reflected in the number of assignments to group C2 and group C3, which are 798 and 142, respectively. During the crisis, by contrast, the majority of countries does not show an exceedance if there is a co-exceedance. This picture again mirrors the decline in the correlation of the countries.

Figure 1 illustrates this changing pattern in the uniformity of exceedances by plotting the number of countries that show exceedances given that there is a co-exceedance. For ease of interpretation, we also show a nine event day moving average. Before the crisis, the most frequent case is that all countries show an exceedance at the same time. During the crisis, the average number of affected countries goes down, ending up at values of around two. The downward movement already starts in the middle of 2007, when the moving average falls below its prior minimum. The observation that co-exceedance patterns already change in 2007 is a further motivation of our baseline crisis-period definition.

Table 1 also shows that the exclusion of confounding events leads to a strong decrease of usable events. For the rating-based definition, the number of countries in group D1 is just six. However, we will focus on the "infected" and "non-infected" countries, for which there are 64 and 82 observations, respectively. Also, note that the number of distinct downgrades behind these observations is larger than six; it is 17 and 25, respectively. Nevertheless, the loss of observations could be critical. We will include them in the sensitivity analysis of this section, and we will also include them in the analysis of section 3, which employs another perspective for which the exclusion of confounding events does not seem to be appropriate.

Before moving to the presentation of results we provide some evidence related to the choice of bond returns as the basis of the analysis. A central motivation is that bond returns do not only reflect changes in the funding costs of governments but also the losses that banks and other holders of government bonds suffered during the crisis. The resulting financial difficulties of banks have been a key issue in the evolution of the crisis and policy responses.[11] However, one could object that bond markets might be informationally less efficient than stock markets or markets for credit default swaps (CDS). To compare the efficiency of these markets with respect to the events that we analysis we study rating downgrades, which are known to be anticipated by the markets (cf. Michaelides et al. (2012)). We employ probit regressions, in which the dependent variable is one if there is a negative rating action as defined above, and which pool the daily observations of the Euro countries in our sample. The explanatory variables are lagged logarithmic returns of the countries' sovereign bonds (r^{bond}), the countries' stock markets (r^{equity}, we use Datastream total market indices for each country), or log changes in the countries' 5-year sovereign CDS spreads (r^{CDS}, data are also from Datastream). Lagged returns are partitioned into returns over days -11 to -1 and days -31 to -11, respectively, to take into account that the degree of anticipation could decrease with time.

Using bond and stock market information to predict downgrades, we obtain (t-statistics in parentheses):

$$Pr(Downgrade_{it}) = \underset{(-71.60)}{-2.44} \underset{(-2.67)}{- 2.30}\, r^{bond}_{i,t-1,t-11} \underset{(-3.36)}{- 2.78}\, r^{bond}_{i,t-11,t-31} \underset{(.75)}{+ .53}\, r^{equity}_{i,t-1,t-11} \underset{(.89)}{+ .44}\, r^{equity}_{i,t-11,t-31} \quad N=15796,\ Ps\text{-}R^2=0.01$$

which shows that bond markets do a better job in anticipating downgrades than equity markets. Low bond returns significantly predict downgrades, whereas low equity markets do not if bond returns are controlled for.

For CDS spreads we get a similar result (the number of observation is lower because the data available to us through Datastream end in September 2010):

$$Pr(Downgrade_{it}) = \underset{(-42.97)}{-2.66} \underset{(-5.00)}{- 10.76}\, r^{bond}_{i,t-1,t-11} \underset{(-.83)}{- 1.89}\, r^{bond}_{i,t-11,t-31} \underset{(.59)}{+ .16}\, r^{CDS}_{i,t-1,t-11} \underset{(-1.62)}{- .30}\, r^{CDS}_{i,t-11,t-31} \quad N=9092,\ Ps\text{-}R^2=0.06$$

The probit regressions thus support our focus on bond returns from the perspective of informational efficiency, conforming conclusions that Badaoui, Cathcart and El-Jahel (2013) draw from a return decomposition of bond returns and CDS spreads.

[11] See Acharya and Steffen (2013) for an analysis of banks' exposure to sovereign debt.

2.3 Estimation Results

Figure 2 shows event and post-event return behavior if events are defined with co-exceedances using 5% quantile exceedances.[12] By construction, countries in group C2, which is meant to capture the infected countries, have a relatively low return on the event day. Within the 60-day horizon, however, the return differential relative to countries in group C3 disappears. Cumulative raw returns are positive, while cumulative abnormal returns are negative. At the event day, the average 30-day correlation of group C2 is higher than in the pre-event period, but then it declines and ends up below the pre-event correlation. The volatility of group C2 tends to increase after the event. These observations hold both for raw changes and abnormal changes.

Figure 3 shows the results for the alternative event definitions based on rating downgrades. Again, the group designed to collect infected countries (D2) makes up the initially negative returns that define their group and ends up with a positive cumulative raw return after 60 days. While the raw return of group D2 does not catch up with the "non-infected" countries of group D3, its abnormal return does. Correlations do not show an upward trend, whereas volatilities do.[13] The increase in the volatility of the downgraded countries is very strong but this is mainly due to one event (Greece in April 2010). The median volatility change for group D1 on day 30 after the event date is 4.1%, much lower than the arithmetic average of 15.9% shown in Figure 3.

From these observations, there is no clear evidence for the hypothesis that contagion has persistent negative effects: (i) correlation of "infected" countries tends to decrease; (ii) volatility tends to increase; (iii) results for returns are mixed because the negative abnormal returns do not differ between "infected" and "non-infected" countries and because raw returns are positive at the end of the event window. A cautious interpretation is also warranted because of the low precision of the estimated effects. Significance levels for the cumulative 60-day effects are flagged in Table 2, 3 and 4 for returns, correlations and volatilities, respectively (in the first row of each panel, labeled *baseline*). None of the effects recorded for the "infected" countries are significant at the 5% level. Only one case (raw returns with the rating-based contagion definition) shows a significant difference between the two country groups.

---

[12] Results for the 1% quantile are discussed below.

[13] This finding is consistent with the results reported by Forbes and Rigobon (2002). The effect in volatility has important implications for portfolio diversification but is not explicitly considered in many contagion studies including Baig and Goldfajn (1999), Forbes and Rigobon (2002) and Bae, Karolyi and Stulz (2003).

In a next step, we provide several robustness checks. They are meant to check sensitivity to changes in our event definition. However, we also address one fundamental issue that could be critical for the interpretation of the results. Lack of evidence for persistent effects of contagion does not necessarily mean that contagion is irrelevant. Perhaps contagion was successfully contained by rescue packages or monetary interventions. To examine this question we

(i) identify major bailout events of the European debt crisis: the decisions on the bailouts of Greece (May 3, 2010), Ireland (Nov 29, 2010), Portugal (May 15, 2011), the second bailout of Greece (Jul 21, 2011) and the bailout of Spanish banks (Jun 11, 2012) as well as the announcement of outright monetary transactions by the European Central Bank (ECB , Sep 6, 2012);

(ii) collect data on ECB government bond purchases. The ECB might have used this instrument in order to mitigate the effects of contagious events, and it is interesting to see whether the effects vary with the usage of this instrument. We use the ECB's weekly data on transactions in "Securities held for monetary policy purposes", which we obtain from Datastream.

In two variations of the analysis conducted so far, we restrict the analysis to events that (i) do not have any of the described bailout events in [0,60] period from the event day to day 60 after the event or (ii) do not include days with ECB bond purchases in the [0,60] period.

To examine the sensitivity to our modeling assumptions, we additionally perform the following variations:

(iii) We include all observations, i.e. do not eliminate confounding events.

(iv) We vary the extremeness of the event definition. For co-exceedances, we employ the 1% instead of the 5% quantile, and for negative rating events we require a downgrade of three notches or more.

(v) In crisis periods, some countries could benefit from a safe haven effect. To check whether such "anti-contagion" influences our results, we remove the three countries that still maintain AAA ratings from Fitch, Moodys and S&P at the end of the sample period (Finland, Germany, Netherlands)

(vi) We vary the dating of the crisis period. July 2007 marks the start of the global financial crisis, but debt problems of European sovereigns took some time to become imminent. In a variation, we let the crisis period start in October 2009, when the Greek government revised its deficit figures.

(vii) We examine equity return behavior instead of bond return behavior. We use Datastream total market indices for each country. We use equity returns to define co-exceedance events, cumulative returns, changes in correlation and changes in volatility.

Results are presented in Tables 2, 3 and 4. Due to the large number of variations, results are difficult to summarize. The following observations help to assess the robustness of the results obtained so far:

- Bailouts and ECB interventions do not lead to a fundamental change of results. In the majority of the variations, the sign of the effects is the same as in the base case; if the sign is different, the effect is not significant.
- In 77% of all variations, the sign of the effect obtained for "infected" countries is the same as in the base case.
- The number of cases in which the behavior of the "infected" countries is significant on the five percent level is small. They do not reverse the sign of the effect compared to the baseline case. In one of the cases in which confounding events are not excluded, the sign reverses and is significant on the 10% level. While this particular observation (Panel B of Table 2) would indicate a persistent negative effect of contagion, the same variation also makes the decrease in correlation significant (Panel B, Table 3). Thus, this variation does not reverse the previous interpretation.
- The difference between "infected" and "non-infected" countries is mostly insignificant. Among the cases in which they turn from insignificant in the baseline specification to significant, the pattern is not uniform. Non-infected countries do not always show higher returns, lower correlation, and lower volatility.

The results are thus in line with the interpretation given above. There is no clear support for the notion that contagion could have persistent negative effects. In the next section, we will move from the isolated analysis of cumulative returns, volatilities or correlations to a more comprehensive and integrative portfolio perspective that enables us to derive statements on the overall effects of contagion.

3 Contagion and Investment Performance

The analysis of the previous section has shown that contagious events do not lead to a persistent increase in correlation. However, since results for returns were more mixed, while volatility showed an upward trend after contagion, we are not yet in a position to derive statements on the possible overall effects of contagion for the risk and risk-adjusted performance of investment portfolios. This is a question that is generally not addressed in the contagion literature. To tackle it, we examine whether portfolio characteristics depend on the magnitude of contagion between the portfolio constituents. Specifically, we form 55 unique country pairs based on the eleven Euro countries included in our sample. For each pair we examine equally-weighted bond returns. The simple returns of a portfolio composed of the bond indices of country *i* and country *j* will be denoted $R_{p(i,j)}$. As risk measures, we consider four measures of downside risk: the shortfall expectation, the shortfall volatility, the conditional value at risk (CVaR), and the maximum drawdown. We assume a target return *z* of 0 for the shortfall measures, a 5% confidence level for the CVaR, and estimate the measures using simple returns:

$$\text{Shortfall expectation} = \frac{1}{T}\sum_{t=1}^{T}(z - R_{p(i,j),t})\mathbf{1}(R_{p(i,j),t} < 0)$$

$$\text{Shortfall volatility} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(z - R_{p(i,j),t})^2\mathbf{1}(R_{p(i,j),t} < 0)}$$

$$CVaR = -\frac{1}{T}\sum_{t=1}^{T}R_{p(i,j),t}\mathbf{1}(R_{p(i,j),t} < Q_{p(i,j)}(0.05))/0.05$$

$$\text{Maximum Drawdown} = -\min_{t\in(1,T)}\left[\min_{t'\in[0,t]}\frac{V_{p(i,j)t}}{V_{p(i,j)t'}} - 1\right]$$

where $V_{p(i,j)t}$ is the value of a buy-and-hold portfolio that is put together at the end of June 2007(t=0) by investing 1 Euro in each of the two countries i and j. We choose a buy-and-hold portfolio because it reflects the situation of financial institutions with large positions in government bonds. Once bond prices start to fall, they may choose not to adjust their positions because doing so would lead to a realization of losses and put further pressure on prices.

When studying risk-adjusted performance, we determine the average portfolio return for each portfolio, subtract the average risk-free rate and divide by one of the four risk measures from above. For the risk-free rate, we use the 6-month zero yield of German government bonds provided by the Deutsche Bundesbank.

To quantify the magnitude of contagion, we use the frequency with which the two countries in a portfolio were jointly affected by a contagious event as defined in the previous section. For the return-based definition, this frequency is simply the frequency of co-exceedances:

$$\textit{Return-based contagion frequency (crisis, country pair i,j)} = \frac{1}{T_{crisis}} \sum_{t \in crisis} I_{i,t} I_{j,t}$$

Where $I_{i,t}$ is the exceedance indicator defined in the previous section, and T_{crisis} is the number of days in the crisis period July 2007 to December 2012. Note that this measure is perfectly correlated with a frequently used measure of tail dependence, the τ coefficient (e.g. Poon, Rockinger and Tawn, 2004), provided that τ is estimated with the non-parametric approach and all observations below the quantile level that was used for the exceedance indicator.

For the rating-based definition of contagion, we use the frequency of days on which countries *i* and *j* are assigned to one of the two categories D1 (downgraded countries with negative cumulative return surrounding the rating announcement) or D2 (countries with negative cumulative return surrounding the rating announcement of another country). In the definition of both measures of contagion frequency, confounding events are not excluded.

The relevance of contagion for investment performance is examined through regressions. The dependent variable is an investment measure estimated with the observations of the crisis period (July 2007 to December 2012). As explanatory variables, we include the estimate of the investment measure from the pre-crisis period (January 2001 to June 2007) as well as the two measures of contagion frequency in the crisis period. The cross-sectional regression reveals the impact of co-exceedances and downgrade-related co-movement in the crisis on investment measures in the crisis. Regressions are of the form:

Investment measure (crisis, country pair i,j) = b_0 +

+ b_1 *investment measure (pre-crisis, country pair i,j)*

+ b_2 *return-based contagion frequency(crisis, country pair i,j)*

+ b_3 *rating-based contagion frequency(crisis, country pair i,j)*

+ u_{ij}

The two measures of contagion frequency differ in one respect that can be relevant for the interpretation of the coefficients. By definition, each country has the same number of exceedances, which are the basis for the return-based contagion frequency. The frequency of downgrades, by contrast, differs strongly across countries. In the data, the rating-based contagion frequency is highly correlated with the downgrade frequencies of the two countries belonging to one country pair.[14] This could lead to an omitted variable bias, i.e. the effects of experiencing many downgrades could be attributed to the measure of contagion. To control for such effects, we include two additional variables, the frequency with which countries *i* and *j* experienced a downgrade. For country *i*, this is defined as

$$\textit{Downgrade frequency(crisis, country i)} = \frac{1}{T_{crisis}} \sum_{t \in crisis} D_{i,t}$$

Where D is a dummy variable that takes the value one on days in which country *i* saw a negative rating action.

By construction, the error terms in the regressions are likely to be dependent because shocks to one country affect several country pairs. For the computation of standard errors, we therefore employ a two-way cluster-robust estimator, with the clusters being defined by the first and the second country,

Table 5 shows the regression results for investment risk measures, while Table 6 shows the results for risk-adjusted performance. We start with the discussion of Table 5.

In many specifications, pre-crisis risk measures do not significantly predict their in-crisis counterparts. Coefficients are often negative, which implies that risk rankings tend to reverse, albeit usually not significantly so. It reflects the regime shift that occurred in the assessment of sovereign risk. Pre-crisis, the crisis countries of today, e.g. Greece and Spain, offered slightly higher yields, at a comparable or even smaller risk than countries such as Germany and Finland.

In the regressions that do not include the downgrade frequency, the coefficient of return-based contagion frequency is negative and significant. This implies that a higher frequency of contagion goes along with a *lower* investment risk. Once the downgrade frequency is controlled

[14] The R^2 in a regression of *rating-based contagion frequency (i,j)* on *downgrade frequency (i)* and *downgrade frequency (i)* is 0.475.

for, the sign changes, but now the coefficients are no longer significant. There is thus no evidence that return co-exceedances lead to higher investment risk.

The rating-based contagion measure also shows a reversal of signs. In the simple regression, coefficients are positive. When downgrade frequency is controlled for, they turn negative. In one case, the coefficient is significantly negative. Once the general downgrade activity is controlled for, co-movement induced by downgrades therefore is not associated with higher investment risk. This result does not depend on the definition of investment risk.

A similar pattern emerges for the risk-adjusted performance. The coefficients of the pre-crisis dependent variables are again mostly negative, illustrating the manifestation of risks that were latent before the crisis. Since we now study risk-adjusted performance rather than risk, a negative coefficient of contagion measures would imply that contagion damages risk-adjusted performance. In the regressions that control for downgrade frequencies, coefficients of the contagion measures are not significant. In the other regressions, their signs are either positive (return-based contagion) or negative (rating-based contagion).

The results thus do not conform to the notion that contagion has a negative impact on investment performance. The line of argument "contagion is a threat because it leads to co-movement or negative returns" is not supported by the data because contagion is not associated with higher average risk or lower risk-adjusted performance. This is consistent with the results from the previous section, which found that co-exceedances do not have clearly negative effects on subsequent returns while correlation tends to decrease after co-exceedances.

4 Summary and Concluding Remarks

In the discussion of the Euro debt crisis, policy makers and the media frequently use the term "contagion", associating it with harmful consequences. However, the literature does not provide clear evidence on the cost of contagion. Is contagion persistent or instead merely a transitory effect? Is it relevant from a risk perspective?

For the Euro debt crisis, we find that the effects of contagious events are often transitory. For example, return correlations after co-exceedances (i.e. days on which at least two countries have extremely low returns) are lower than before the co-exceedance event. Countries that experience negative returns at a time when another country experiences a rating downgrade do not show a negative cumulative performance over a 60-day horizon. We also find that the frequency of co-exceedances and the frequency of co-movement surrounding downgrades are not positively associated with higher average investment risk, or lower risk-adjustment performance. From an investment perspective, contagion does not seem to be relevant in the Euro crisis. While it would have paid off to avoid investments in countries that were hit particularly hard in the crisis, knowledge about the frequency of joint extreme returns or the frequency of rating-related co-movement would not have helped to improve performance.

Of course, we cannot immediately conclude that contagion does not pose any risk or does not have any lasting effect. If contagion leads to extreme returns over one or few days, some market participants may not survive, or may be forced to accept unfavorable conditions in order to survive. On the other hand, the rather slow evolution of the Euro debt crisis suggests that for many market participants, the 60-day horizons examined in section 2 or the average risk examined in section 3 could be more relevant than a horizon of a few days. Since the findings might be affected by rescue operations of the Euro group and the ECB we excluded such events in sensitivity analysis and find that the empirical patterns are not driven by episodes with bailout decisions or strong ECB interventions.

This analysis is confined to the European debt crisis and the results need not hold for other crises. Hence, it may be an interesting area for future research to examine the persistence of contagion in alternative crisis periods.

References

Acharya, V, and S. Steffen, 2013. The "greatest" carry trade ever? Understanding Eurozone bank risks. Working Paper No. 19039. National Bureau of Economic Research.

Badaoui, S., L. Cathcart and L. El-Jahel, 2013. Do sovereign credit default swaps represent a clean measure of sovereign default risk? A factor model approach. *Journal of Banking and Finance* 37, 2392-2407.

Bae, K.-H., G.A. Karolyi, and R.M. Stulz, 2003. A new approach to measuring financial contagion. *Review of Financial Studies* 16, 717-763.

Baig, T., and I. Goldfajn, 1999. Financial market contagion in the Asian crisis. *IMF Staff Papers* 46, 167-195.

Baur, D.G., and N. Schulze, 2005. Co-exceedances in financial markets - a quantile regression analysis of contagion. *Emerging Markets Review* 6, 21-43.

Boyer, B.H., T. Kumagai, and K. Yuan, 2006. How do crises spread? Evidence from accessible and inaccessible stock indices. *Journal of Finance* 61, 2, 957-1003.

Caporin, M., L. Pelizzon, F. Ravazzolo, and R. Rigobon, 2013. Measuring sovereign contagion in Europe. *NBER Working Paper* 18741.

Chiang, T.C., B.N. Jeon and H. Li, 2010, Dynamic correlation analysis of financial contagion: Evidence from Asian markets. *Journal of International Money and Finance* 26, 1206-1228.

Claeys, P. and B. Vasicek, 2012. Measuring sovereign bond spillover in Europe and the impact of rating news. *IREA Working Papers* 201219

Corsetti, G., M. Pericoli, and M. Sbracia, 2005. Some contagion, some interdependence: More pitfalls in tests of financial contagion. *Journal of International Money and Finance* 24, 1177-1199.

Dungey, M., Fry, R., Gonzalez-Hermosillo B. and V. L. Martin, 2005, Empirical modelling of contagion: A review of methodologies, *Quantitative Finance* 5, 9-24.

Edwards, S. and R. Susmel, 2001, Volatility dependence and contagion in emerging equity markets, *Journal of Development Economics*, 66 (2), 505-532

Favero, A. and F. Giavazzi, 2000, Looking for contagion: Evidence from the ERM, *NBER Working Papers* 7797.

Forbes, K., and R. Rigobon, 2002. No contagion, only interdependence. *Journal of Finance* 57, 2223-2261.

Hu, L., 2006. Dependence patterns across financial markets: a mixed copula approach. *Applied Financial Economics* 16, 717-729.

Longin, F., and B. Solnik, 2001. Extreme correlation of international equity markets. *Journal of Finance* 56, 649-676.

Metiu, N., 2012. Sovereign risk contagion in the Eurozone. *Economics Letters* 117, 35–38.

Michaelides, A., A. Milidonis, G.P. Nishiotis, and P. Papakyriacou, 2012. Sovereign Debt Rating Changes, Institutional Quality and the Stock Market. *Centre for Economic Policy Research* No. DP8743. Available at SSRN: http://ssrn.com/abstract=1973556

Missio, S. and S. Watzka, 2011. Financial contagion and the European debt crisis. *LMU Working Paper*.

Pericoli, M., and M. Sbracia, 2003. A primer on financial contagion. *Journal of Economic Surveys* 17, 571-608.

Poon, S.-H., M. Rockinger, and J. Tawn, 2004. Extreme Value Dependence in Financial Markets: Diagnostics, Models, and Financial Implications. *Review of Financial Studies* 17, 581-610.

Rodriguez, J.C., 2007. Measuring financial contagion: A copula approach. *Journal of Empirical Finance* 14, 401-423.

Table 1: Number of contagious events and country groupings on event days

Contagious event days are either (i) days on which at least two Euro countries have extremely low standardized bond returns or (ii) days on which there are negative rating events and affected countries have a negative cumulative return over days [-10, 3]. On return-based event days, countries are assigned to one of the following groups: the country with the lowest standardized returns among the countries that show an exceedance is assigned to C1; the other countries with a co-exceedance are assigned to C2; countries with no co-exceedance are assigned to C3. On rating-based event days, countries are assigned to one of the following groups: downgraded countries are assigned to D1; remaining countries are assigned to D2 (D3) if the cumulative return over days [-10, 3] is negative (positive). Confounding events (denoted by included or excluded) are ones in which a country was allocated to C1, C2, D1 or D2 in the prior 60 days.

			Country count in groups		
	Confounding events	Number of events	C1 / D1 "contagious"	C2/D2 "infected"	C3/D3 "non-infected"
Panel A: Crisis period 07/2007-12/2012					
Return-based event definition	Included	130	130	483	817
	Excluded	16	16	47	140
Rating-based event definition	Included	61	68	331	272
	Excluded	5	6	64	82
Panel B: Pre-crisis period 01/2001-06/2007					
Return-based event definition	Included	94	94	798	142
	Excluded	6	6	32	12
Rating-based event definition	Included	3	3	28	2
	Excluded	3	3	28	2

Table 2: Cumulative returns after contagious events – sensitivity analysis

The table presents variations of assumptions underlying Figure 2 and Figure 3. Contagious event days are either (i) days on which at least two Euro countries have extremely low standardized bond returns or (ii) days on which there are negative rating events. Average cumulative abnormal returns are given for the countries classified as "infected" (groups C2 and D2 in Figure 2 and 3) or "not infected" (groups C3 and D3 in Figure 2 and 3). Tests for significance of the group means and their difference Δ are t-tests constructed on the time series of cumulative returns, aggregated per event for each group to accommodate clustering. Due to space considerations, t-statistics are not reported but indicated through stars that flag significance at the 1% (***), 5% (**) or 10% (*) levels. Cumulation starts in *t=0* for co-exceedance events and in *t-10* for rating events, and ends at day *60*.

	Cumulative returns			Abnormal cumulative returns		
Event definition [Baseline]	"Infected"	"Not infected"	p(Δ=0)	"Infected"	"Not infected"	p(Δ=0)
Panel A: Events based on co-exceedances						
Baseline	1.47	1.91**	0.60	-1.17	-1.06	0.22
Bailout events excluded [included]	0.65	-1.15	0.69	-0.29	-3.68*	0.49
SMT transactions excluded [included]	2.57*	3.47***	0.39	-1.04	-0.17	0.09*
All observations [confounding excluded]	0.36	1.19**	0.02**	-1.57***	-0.49	0.01**
1% Co-exceedance [5%]	2.66**	0.36	0.10	-2.28	-2.94***	0.13
200910-201212 [200707-201212]	-0.28	0.85	0.35	-2.78**	-2.11	0.15
Euro ex DE,FIN,NL [Euro]	1.58	1.74	0.90	-1.56	-0.85	0.34
Equity returns [bond returns]	-1.56	-4.55***	0.01**	-3.07	-6.27***	0.00***
Panel B: Events based on rating actions						
Baseline	0.29	3.68***	0.00***	-1.09*	-2.13**	0.54
Bailout events excluded [included]	1.68**	2.19**	0.63	0.26	-1.23*	0.34
SMT transactions excluded [included]	1.23	3.91***	0.01**	-0.99	-2.20**	0.48
All observations [confounding excluded]	-1.19*	3.58***	0.00***	-3.13***	-0.14	0.00***
3-notch change [1 or outlook/watch]]	-0.14	6.99**	0.03**	-2.02	0.79	0.26
200910-201212 [200707-201212]	-0.81	4.05***	0.00***	-2.31**	-2.39***	0.30
Euro ex DE,FIN,NL [Euro]	0.12	2.56***	0.05*	-1.52*	-2.56**	0.59
Equity returns [bond returns]	-1.41	-0.64	0.76	-3.44**	-0.43	0.21

Table 3: Return correlations after contagious events – sensitivity analysis

The table presents variations of assumptions underlying Figure 2 and Figure 3. Contagious event days are either (i) days on which at least two Euro countries have extremely low standardized bond returns or (ii) days on which there are negative rating events. Average changes in average 30-day correlation relative to the pre-event period are given for the countries classified as "infected" (groups C2 and D2 in Figure 2 and 3) or "not infected" (groups C3 and D3 in Figure 2 and 3). Tests for significance of the group means and their difference Δ are t-tests constructed on the time series of cumulative returns, aggregated per event for each group to accommodate clustering. Due to space considerations, t-statistics are not reported but indicated through stars that flag significance at the 1% (***), 5% (**) or 10% (*) levels.

	Change in correlation			Abnormal change in correlation		
Event definition [Baseline]	"Infected"	"Not infected"	p(Δ=0)	"Infected"	"Not infected"	p(Δ=0)
Panel A: Events based on co-exceedances						
Baseline	-5.36	0.80	0.25	-3.49	-0.14	0.38
Bailout events excluded [included]	-2.94	-2.28	0.76	-1.79	-2.45	0.70
SMT transactions excluded [included]	-5.66	0.74	0.28	-2.00	0.44	0.55
All observations [confounding excluded]	-6.99***	-5.06***	0.64	-4.04***	-2.32***	0.56
1% Co-exceedance [5%]	-4.19	-3.90**	0.45	-1.39	-2.81	0.48
200910-201212 [200707-201212]	-10.79	0.75	0.24	-8.73	0.37	0.29
Euro ex DE,FIN,NL [Euro]	-4.01	-0.65	0.43	-1.60	-0.91	0.62
Equity returns [bond returns]	0.86	1.31	0.34	-2.72	1.35	0.35
Panel B: Events based on rating actions						
Baseline	-2.19	-4.38	0.97	-0.84	-0.25	0.94
Bailout events excluded [included]	2.06	-3.08	0.95	-1.12	0.87	0.70
SMT transactions excluded [included]	-1.15	-6.45	0.79	-3.30	-1.73	0.66
All observations [confounding excluded]	-8.94***	-8.49***	0.64	-5.42***	-4.33**	0.70
3-notch change [1 or outlook/watch]]	-3.97	-0.95	0.69	-4.95	-2.07	0.72
200910-201212 [200707-201212]	-7.10	-4.99	0.78	-0.58	-0.53	0.64
Euro ex DE,FIN,NL [Euro]	-4.44	-2.46	0.56	-1.58	1.85	0.63
Equity returns [bond returns]	0.88	3.73	0.88	2.06	-3.37**	0.10

Table 4: Return volatilities after contagious events – sensitivity analysis

The table presents variations of assumptions underlying Figure 2 and Figure 3. Contagious event days are either (i) days on which at least two Euro countries have extremely low standardized bond returns or (ii) days on which there are negative rating events. Average changes in 30-day volatility relative to the pre-event period are given for the countries classified as "infected" (groups C2 and D2 in Figure 2 and 3) or "not infected" (groups C3 and D3 in Figure 2 and 3. Tests for significance of the group means and their difference Δ are t-tests constructed on the time series of cumulative returns, aggregated per event for each group to accommodate clustering. Due to space considerations, t-statistics are not reported but indicated through stars that flag significance at the 1% (***), 5% (**) or 10% (*) levels.

	Change in volatility			Abnormal change in volatility		
Event definition [Baseline]	"Infected"	"Not infected"	p(Δ=0)	"Infected"	"Not infected"	p(Δ=0)
Panel A: Events based on co-exceedances						
Baseline	2.18*	0.51	0.47	0.51	0.06	0.77
Bailout events excluded [included]	1.80	1.78	0.85	1.78	2.32*	0.92
SMT transactions excluded [included]	1.53	-0.67	0.04**	-0.74	-1.29**	0.36
All observations [confounding excluded]	0.97***	0.26	0.02**	0.62***	0.10	0.01**
1% Co-exceedance [5%]	2.30	0.05	0.23	1.15	-0.03	0.22
200910-201212 [200707-201212]	3.48*	0.79	0.28	1.71	0.47	0.47
Euro ex DE,FIN,NL [Euro]	2.74*	0.09	0.20	1.33	-0.22	0.46
Equity returns [bond returns]	0.00	1.68**	0.11	0.65	1.26*	0.46
Panel B: Events based on rating actions						
Baseline	0.51	1.81	0.73	1.54	0.57	0.14
Bailout events excluded [included]	-0.35	1.08	0.70	1.23	0.70	0.38
SMT transactions excluded [included]	0.57	1.66	0.84	1.91*	0.43	0.07*
All observations [confounding excluded]	0.22	0.80	0.75	0.48	-0.06	0.45
3-notch change [1 or outlook/watch]]	0.78	1.63	0.81	0.53	-0.67	0.88
200910-201212 [200707-201212]	1.04	1.76	0.97	1.22	0.26	0.18
Euro ex DE,FIN,NL [Euro]	0.82	1.50	0.93	1.77	0.88	0.58
Equity returns [bond returns]	-4.23	-1.01	0.47	0.96**	1.61	0.86

Table 5: Does the frequency of contagious events explain investment risk in the crisis?

55 unique country pairs based on eleven Euro countries are formed. For each pair we examine shortfall risk (return target = 0) and conditional value-at-risk (CVaR, 5% confidence) of equally weighted returns, and maximum drawdown for a buy-and-hold portfolio. Each measure is estimated for both the January 2001 to June 2007 period ("pre crisis") and the July 2007 to December 2012 period ("in crisis"). For each pair, we also determine the frequency of days in which the two countries show a return co-exceedance ("return-based contagion frequency"), or are negatively affected by a rating action ("rating-based contagion frequency"). The frequency of days with downgrades for country 1 or 2 is added as control. The table contains the coefficient estimates and t-stats (in parentheses) based on two-way clustered standard errors, with the clusters being defined by the first and second country of each country pair. Constants are not reported.

	In-crisis risk measure							
	Shortfall Expect.		Shortfall Volatility		CVaR		Max. Drawdown	
Dependent variable pre-crisis	-3.140	-3.849	-4.046	-6.634	4.953	-2.150	3.424	-8.702
	(-1.01)	(-5.13)	(-0.96)	(-2.89)	(1.61)	(-1.08)	(0.57)	(-2.00)
Return-based contagion frequency in crisis	-0.034	0.021	-0.105	0.059	-0.424	0.195	-7.336	1.833
	(-3.41)	(1.57)	(-3.21)	(1.40)	(-3.04)	(1.25)	(-4.21)	(0.85)
Rating-based contagion frequency in crisis	0.054	-0.033	0.139	-0.129	0.631	-0.436	16.047	-0.553
	(2.94)	(-1.71)	(2.32)	(-2.02)	(2.46)	(-1.85)	(4.22)	(-0.26)
Downgrade frequency in crisis (country 1)		0.079		0.240		0.864		15.030
		(6.07)		(5.48)		(5.33)		(11.56)
Downgrade frequency in crisis (country 2)		0.067		0.195		0.676		11.238
		(2.58)		(2.25)		(2.13)		(2.54)
Adj. R^2	0.470	0.766	0.414	0.712	0.419	0.699	0.598	0.789
N	55	55	55	55	55	55	55	55

Table 6: Does the frequency of contagious events explain risk-adjusted performance in the crisis?

55 unique country pairs based on eleven Euro countries are formed. For each pair we determine performance measures by relating average returns over 6-month German government bond yields to a measure of risk. We consider shortfall measures (return target = 0), conditional value-at-risk (CVaR, 5% confidence) of equally weighted returns, and maximum drawdown for a buy-and-hold portfolio. Each measure is estimated for both the January 2001 to June 2007 period ("pre crisis") and the July 2007 to December 2012 period ("in crisis"). For each pair, we also determine the in-crisis frequency of days in which the two countries show a return co-exceedance ("return-based contagion frequency"), or are negatively affected by a rating action ("rating-based contagion frequency"). The frequency of days with downgrades for country 1 or 2 is added as control. The table contains the coefficient estimates and t-stats (in parentheses) based on two-way clustered standard errors, with the clusters being defined by the first and second country of each country pair. Constants are not reported.

	In-crisis risk-adjusted performance based on							
	Shortfall Expect.		Shortfall Volatility		CVaR		Max. Drawdown	
Dependent variable pre-crisis	-0.260 (-0.86)	0.136 (0.47)	-0.476 (-1.36)	-0.051 (-0.14)	-0.463 (-0.90)	0.031 (0.06)	-0.517 (-2.94)	-0.415 (-1.42)
Return-based contagion frequency in crisis	1.324 (4.92)	-0.304 (-0.57)	0.818 (5.16)	-0.035 (-0.10)	0.271 (5.09)	0.002 (0.02)	0.030 (4.49)	0.010 (0.84)
Rating-based contagion frequency in crisis	-1.901 (-4.21)	0.265 (0.34)	-0.997 (-3.78)	0.146 (0.29)	-0.335 (-3.67)	0.042 (0.26)	-0.044 (-7.78)	-0.017 (-1.23)
Downgrade frequency in crisis (country 1)		-2.188 (-3.13)		-1.161 (-2.58)		-0.377 (-3.02)		-0.024 (-1.92)
Downgrade frequency in crisis (country 2)		-2.310 (-2.33)		-1.207 (-1.87)		-0.366 (-1.80)		-0.027 (-1.45)
Adj. R^2	0.526	0.725	0.546	0.695	0.542	0.696	0.594	0.642
N	55	55	55	55	55	55	55	55

Figure 1: The number of countries involved in co-exceedances

A co-exceedance is defined to occur on days on which at least two Euro countries have standardized bond returns below their respective 5% quantiles. For each co-exceedance event, the figure shows the number of countries that showed an exceedance on the event day. The centered moving average also shown in the figure is computed over nine adjacent event days.

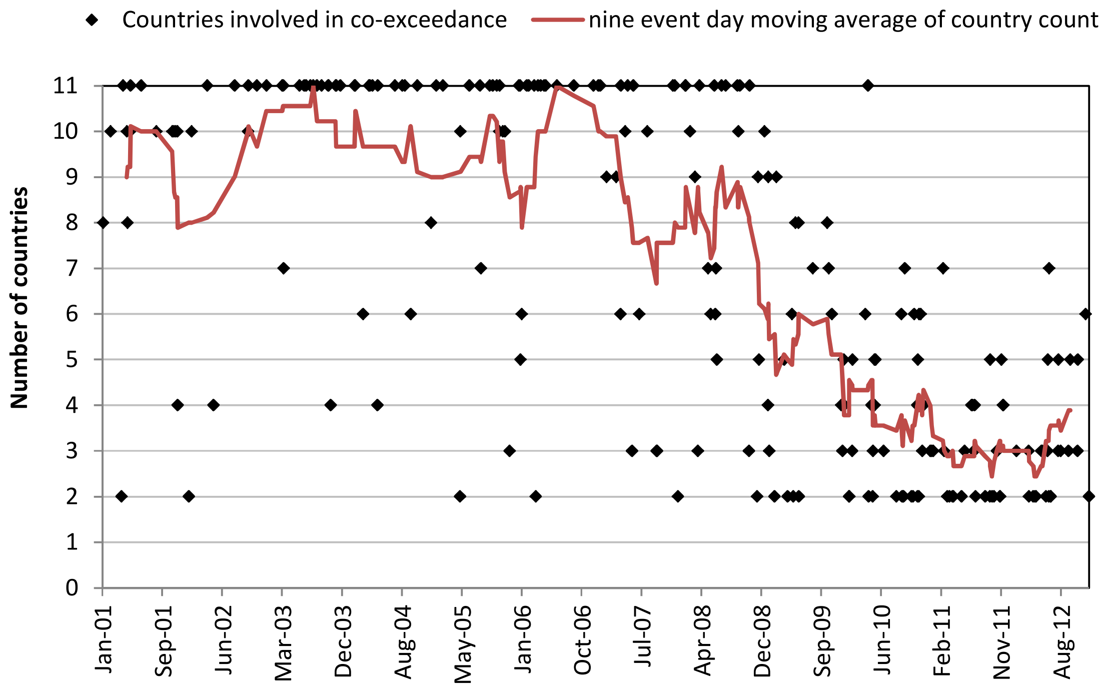
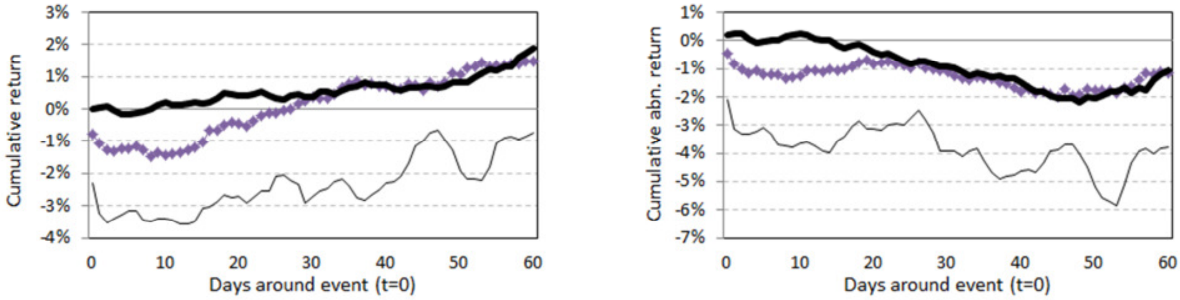


Figure 2: Return behavior after days with a co-exceedance of at least two countries in the crisis period

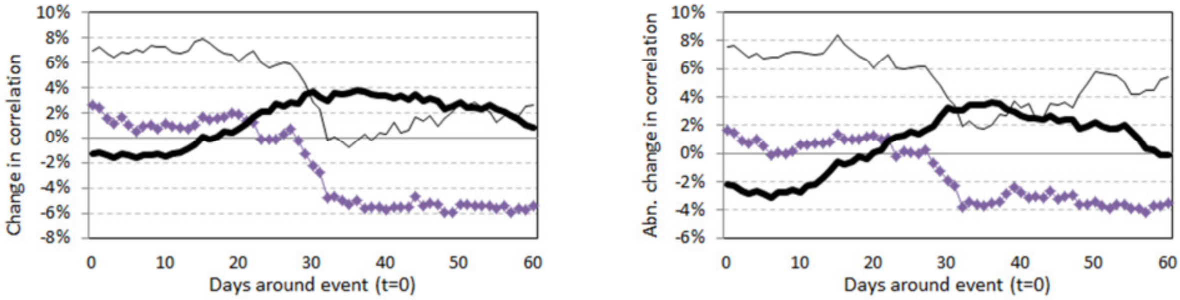
Event days are days on which at least two Euro countries have standardized bond returns below their respective 5% quantiles. On event days, countries are assigned to one of three groups, C1, C2, or C3. The country with the lowest standardized returns among the countries that show an exceedance is assigned to C1. The other countries with a co-exceedance are assigned to C2. Countries with no co-exceedance are assigned to C3. We analyze cumulative returns, the average 30-day correlation of a country with the other Euro countries, and 30-day volatilities. To avoid confounding events, countries with a C1 or C2 assignment in the preceding 60 days are excluded.

Legend: — C1: Coexceedance & minimum return; ━ C3: No exceedance = No coexceedance; ◆ C2: Coexceedance & return > minimum

Cumulative returns. Abnormal returns are market-adjusted with a world government bond index



30-day correlation relative to pre-event period ending in t-30. Abnormal changes are adjusted with a world average



30-day volatility relative to pre-event period ending in t-30. Abnormal changes are adjusted with a world average

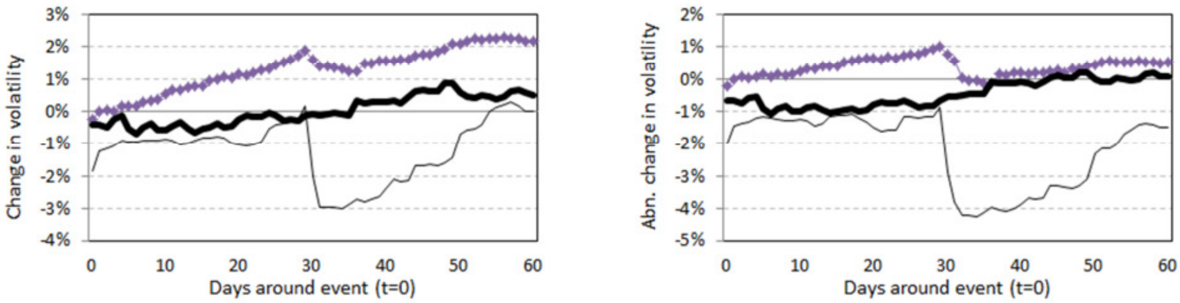
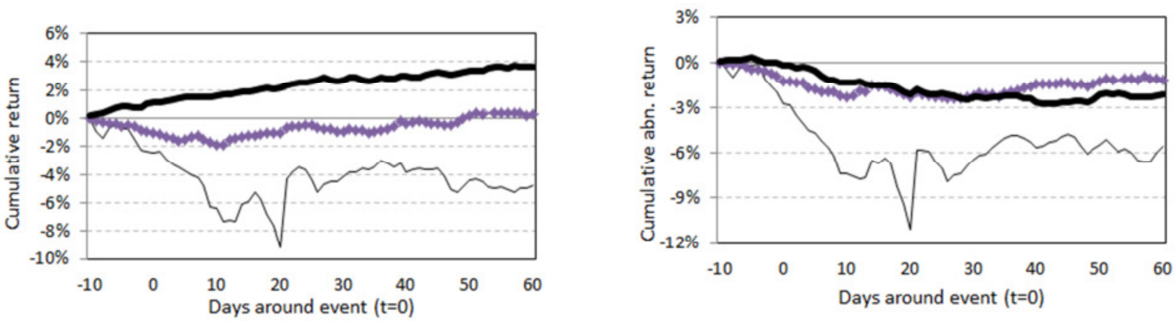


Figure 3: Return behavior after days with a negative rating action in the crisis period

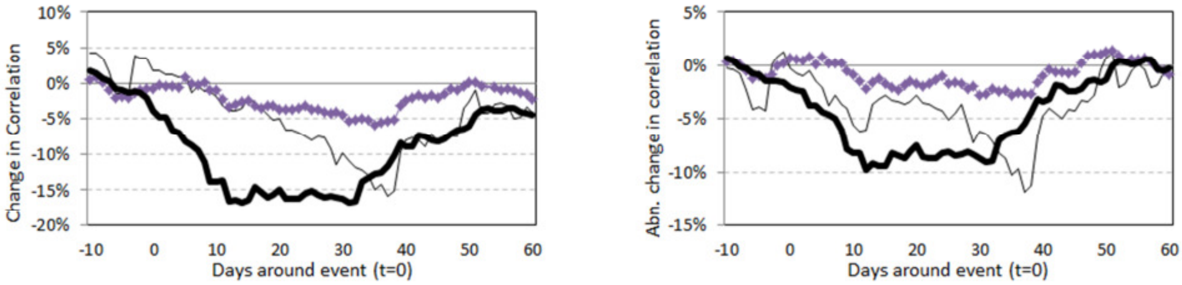
Event days are days on which Fitch, Moody's or S&P downgrade a country or change the outlook/watchlist to negative; in addition, we require affected countries to have a negative cumulative return over days [-10, 3]. On event days, countries are assigned to one of three groups. Downgraded countries are assigned to D1. Remaining countries are assigned to D2 (D3) if the cumulative return over days [-10, 3] is negative (positive). We analyze cumulative returns, the average 30-day return correlation with the other Euro countries, and 30-day volatilities. To avoid confounding events, countries with a D1 or D2 assignment in the preceding 60 days are excluded.

Legend: —— D1: Downgrade; ━━ D3: No downgrade & return[-10,3] ≥ 0; ◆ D2: No downgrade & return[-10,3] < 0

Cumulative returns. Abnormal returns are market-adjusted with a world government bond index



30-day correlation relative to pre-event period ending in t-30. Abnormal changes are adjusted with a world average



30-day volatility relative to pre-event period ending in t-30. Abnormal changes are adjusted with a world average