Contagion Dynamics in EMU Government Bond Spreads*

Christian Leschinski§ and Philip Bertram

Institute of Statistics, Faculty of Economics and Management,
Leibniz University Hannover, D-30167 Hannover, Germany

First version: December 19, 2014

Abstract

We conduct a rolling window analysis of Economic and Monetary Union (EMU) government bond spreads before and during the subprime mortgage crisis and the EMU debt crisis. This allows us to monitor the evolution of pure contagion effects as well as the changing influence of exogenous factors over time. Importantly, this is done without an ex-ante specification of the contagion window. In contrast to the existing literature on contagion in the EMU debt crisis, this approach allows us to establish that the main sources of pure contagion in the later phase of the EMU debt crisis are Italy and Spain and not Greece, Ireland and Portugal. Furthermore, we find that substantial contagion effects among EMU government bond spreads already arise during the subprime mortgage crisis and not only during the EMU debt crisis, as one might expect.

JEL codes: C22, C26, E43, G01, G15

Keywords: contagion, sovereign risk, bond spreads, rolling window, instrumental variables

---

*We are grateful for many helpful discussions with our colleagues as well as particiants of the SNDE Syposium 2013, German Statistical Week 2013, Amsterdam-Bonn Workshop 2013 and the NIW Workshop in Applied Econometrics 2014.

§Corresponding author:
Phone: +49- 511- 762-5636,
Fax: +49- 511- 762-3923
E-mail: leschinski@statistik.uni-hannover.de

1 Introduction

Since the beginning of the subprime mortgage crisis, financial markets have been experiencing a long ongoing period of turmoil. After starting in early 2007, the subprime mortgage crisis intensified with the bank run on the British bank Northern Rock and reached its climax with the bankruptcy of Lehman Brothers in September 2008. Later, in October 2009, after the Greek deficit figures were revised, the Economic and Monetary Union government debt crisis (EMU crisis) began. Since then, not only Greece, but also Ireland, Portugal, Spain and Cyprus requested help by the Eurozone members.

The emerging consensus in the literature on contagion during the EMU debt crisis is that there was a wake-up-call effect, after which bond spreads of countries with weaker fiscal and macroeconomic fundamentals were assigned a higher default risk relative to countries with more sustainable debt and deficit levels. Furthermore, the overwhelming majority of contributions finds additional effects originating from Greece, Portugal and Ireland. These effects follow various definitions of contagion such as increases in dependence, news spillovers or pure contagion. Usually, these results are obtained with econometric models that treat the yield spreads as persistent but stationary variables and contagion windows are determined ex-ante, either through the selection of the sample itself or through the use of dummy variables.

We contribute to this literature by conducting a rolling window analysis of pure contagion effects between 2005 and 2014. The advantage of this method is that we do not need to make any ex-ante assumptions about the time frame in which contagion might have occurred. Instead, we can monitor the evolution of shock transmission channels from one country to another over time. This allows us to compare the findings on contagion effects from the EMU crisis with those in the subprime mortgage crisis and before.

Our econometric methodology is based on the canonical contagion framework of Pesaran and Pick (2007) that is designed to avoid endogeneity bias and we treat spreads as near-integrated processes to avoid spurious regressions due to the near non-stationarity of the spread series.

Using this specification, we are able to establish several new findings that complement the existing literature. Even though there are contagion effects originating from Greece and Portugal in the beginning of the EMU crisis, we find that Italy and Spain are the main sources of pure contagion after the establishment of the European Financial Stability Facility (EFSF) in May 2010. Also, contagion does not only arise after the Greek deficit revision in October 2009, as often assumed. In fact, contagion effects originating from all five crisis countries (Greece, Portugal, Ireland, Italy and Spain) can already be observed during the subprime mortgage crisis. The very first evidence for a transmission of extreme shocks from Ireland and Portugal is found even earlier: in the beginning of 2006, following the first interest rate increases of the ECB after five years of decreasing or constant interest rates. These findings imply that the EMU debt crisis is more closely connected to financial sector risk than one would conclude from the usual analysis of the levels of the spreads in a fixed time window.

The rolling window estimations also allow us to monitor the changing influence of international risk factors and liquidity risk over time. In particular, we find that volatility expectations and liquidity premiums become significant for the majority of crisis as well as non-crisis countries during the subprime mortgage crisis. During the EMU debt crisis however, liquidity premiums do not have a significant impact on the spreads of the crisis countries whereas they remain an important determinant for the spreads of the non-crisis countries.

Hereafter, our analysis will proceed as follows. First, we motivate our choice of the pure contagion definition and we provide an overview of the related literature. Afterwards, in Sections 3.1 and 3.2, we explain the selection of explanatory variables and discuss why spreads should be treated as near-integrated processes. A detailed discussion of the econometric methodology follows in Section 3.3. Section 4 presents and discusses the main results. Several robustness checks are conducted in Section 5, before the implications of our findings are outlined in the conclusion (Section 6).

2 Literature Review

2.1 Definitions of Contagion

There is a multitude of competing definitions that could be used to characterize contagion in the EMU debt crisis. In general, contagion between two assets is understood as some form of change in their dependence structure and the definitions typically differ in the specification of this change. Early contributions, such as King and Wadhwani (1990), Calvo and Reinhart (1996) or Baig and Goldfajn (1999), define contagion as an increase in the co-movement of two countries conditional on a crisis in one of them. Later authors, such as Masson (1999), argue that increasing correlations between two countries might be caused by so called monsoonal effects - i.e. by an increase in the variance of common factors. This is why Masson suggests the notion of **pure contagion** that is defined as a significant increase in co-movements across countries (conditional on a crisis in one of them) that cannot be explained by the countries fundamentals. Today this is the definition of contagion that is most widely used in the literature on the EMU debt crisis and it is also adopted by the World Bank as the “restrictive definition of contagion”.

The second concept that is particularly prominent in the context of the EMU debt crisis is **wake-up-call contagion**, that was put forward by Goldstein (1998) in the context of the Asian crisis. It occurs if events in one country prompt investors to re-evaluate the risks of other countries with similar properties. Both concepts - wake-up-call contagion and pure contagion - are special cases of shift contagion, which was introduced by Forbes and Rigobon (2002) and refers more broadly to any change in cross-market linkages conditional on a crisis in one of the markets.

Other contagion definitions that are commonly used focus on the existence of spillover effects from news or increases in volatilities. For a more comprehensive survey of different contagion definitions as well as of the econometric methodologies used in the earlier contagion literature, confer Pericoli and Sbracia (2003) and Dungey et al. (2005). For a more recent one, that also covers contagion channels and policy measures to mitigate contagion effects, confer Forbes (2012).

Since our main interest is to investigate the evolution of contagion effects over time, we focus on pure contagion and wake-up-call contagion because those are the most commonly used definitions in the literature on contagion during the EMU debt crisis.

2.2 Contagion in the EMU Debt Crisis

Since the literature is vast and growing rapidly, we focus on those contributions that deal with bond yield spreads or credit default swap spreads (CDS spreads) of Euro area countries. Yield spreads and CDS spreads are closely connected and they both reflect sovereign default risk. CDS spreads are considered to be less noisy, but their disadvantage is that they are only available for the more recent period.

With respect to the EMU crisis, Bernoth and Erdogan (2012) present one of the first contributions that finds evidence for a wake-up-call effect by applying a time varying coefficient model to assess the changing influence of financial and fiscal variables over time. Interestingly, this change already appears between 2006 and 2007, when markets start to price the spread between US T-bills and BBB corporate bonds, as well as debt-to-GDP ratios more heavily. Similar results are found (among others) by De Grauwe and Ji (2013), who find a structural break in the pricing of macroeconomic and fiscal fundamentals in 2008 and Aizenman et al. (2013), who report a change in the pricing of fundamentals in their 2008-2010 subsample compared to the period from 2005 to 2007.

The timing of these wake-up-call effects would suggest that they are connected to the subprime mortgage crisis, since they occur long before the revision of the Greek deficit figures in October 2009, which is usually regarded as the starting point of the EMU debt crisis. Only Giordano et al. (2013) find evidence for a wake-up-call effect after the revision of the Greek deficit figures, but they determine this breakpoint ex-ante using interaction terms with a crisis dummy.

With regard to pure contagion, Metiu (2012) applies the canonical contagion framework of Pesaran and Pick (2007) in a sample period from January 2008 until February 2011. He finds that Greece, Ireland and Portugal are the main sources of contagion effects. Independent from our work, Ludwig (2014) recently applied the same framework in a rolling window analysis starting after the bankruptcy of Lehman Brothers and ending in December 2012. He confirms Greece, Ireland and Portugal as the main sources of contagion.[1] Beirne and Fratzscher (2013), on the other hand, identify pure contagion through a clustering of large residuals and conclude that these effects do not play a major role, since they only occured in 2008.

There is also a number of studies that use other definitions of contagion. Gómez-Puig and Sosvilla-Rivero (2014) use Granger causality tests and the Bai-Perron procedure to endogenously determine changes of causal relationships. Since the majority of these changes occurs after October 2009, they interpret this as evidence for contagion during the EMU crisis. Gündüz and Kaya (2014) analyze volatility spillovers between CDS spreads of EMU countries and find that these also appear after the collapse of Lehman Brothers and last until the end of 2010. De Santis (2014) finds that there are spillover effects of rating changes for Greece on the spreads of other countries in a sample from January 2006 to December 2012 and interprets this as contagion. Arghyrou and Kontonikas (2012) use the second principal component of the spreads as a global risk factor and interpret it as a proxy for core-periphery divergence between the EMU countries. They conclude that there is contagion arising in the subperiod from August 2007 to February 2010 and intensifying in the subperiod from March 2010 to August 2011, because the core-periphery divergence factor becomes significant in these periods. The only contribution known to

[1] Even though his general approach is closely related to ours, Ludwig makes some econometric choices that lead to different results. A detailed discussion of these issues is given in Section 3.3.

us that does not find evidence for contagion is Caporin et al. (2014) who follow Bae et al. (2003) in defining contagion as a difference in the shock propagation mechanism across quantiles.

Overall however, there is a consensus arising that there were contagion effects (according to several definitions) during the EMU debt crisis and that the main sources of these effects were the smaller crisis countries Greece, Ireland and Portugal, whereas the larger countries Italy and Spain only play a minor role. This evidence is particularly strong if the pure contagion definition is used.

Note, however, that most of these contributions use a sample period that overlaps both the subprime mortgage crisis and the earlier EMU debt crisis. It might therefore be wrong to attribute these effects to contagion in the EMU debt crisis alone. Furthermore, it seems counterintuitive that wake-up-call effects should appear already early in the financial crisis, whereas pure contagion appears only later in the EMU debt crisis. This motivates our investigation regarding the exact timing of pure contagion effects.

3 Empirical Modelling Strategy

3.1 Selection of Explanatory Variables

In the context of contagion analyses, a careful selection of the control variables is particularly important because pure contagion is considered a residual effect after controlling for the influence of fundamental factors. The omission of relevant regressors can therefore cause omitted variable bias. This problem affects most econometric frameworks that are used to measure contagion. We thus have to select the explanatory variables carefully and assume that no relevant regressors have been omitted. Like most of the contributions on the EMU crisis, we motivate our variable selection by drawing from a large body of literature that is concerned with the determinants of spreads in the Euro Area before and during the subprime mortgage crisis. For a recent survey of this literature, confer Bernoth and Erdogan (2012).

Evidence suggests that the main influencing factor during the subprime mortgage crisis is a common **international risk factor** (cf. for example Attinasi et al. (2009), Favero et al. (2010), Codogno et al. (2003) or Manganelli and Wolswijk (2009), among others). Secondly, as i.a. confirmed by Faini (2006), Bernoth et al. (2004), Manganelli and Wolswijk (2009) and Bernoth and Wolff (2008), credit risk proxied by **fiscal and macroeconomic factors** is priced. The evidence for the third factor, **liquidity risk**, is mixed. While Favero et al. (2010), Manganelli and Wolswijk (2009) and Beber et al. (2009) find the influence to be strong, others, such as Codogno et al. (2003) and Bernoth et al. (2004), find that liquidity plays only a minor role.

Most of these studies are conducted using panel analyses on monthly data. In contrast to that, we conduct a rolling window IV regression which requires a larger amount of data. This is why we use daily observations of the yield spreads of ten EMU countries relative to Germany, which has the disadvantage that the fiscal and macroeconomic variables, that are usually used to proxy for country specific default risk, are not available at this frequency. However, studies by Longstaff et al. (2011) and Ang and Longstaff (2013) show that, especially at these high frequencies, financial variables are the main drivers of systemic sovereign default risk, so the error incurred by excluding the lower frequency variables can be expected to be small. We hence focus on the set of variables discussed below.

- **International risk factors**: As customary in this literature we use the change of the VSTOXX volatility index as an international risk factor. The VSTOXX index reflects the implied volatilities from at-the-money options on the EURO STOXX 50 with 30 days maturity. As the European equivalent of the VIX, it reflects market uncertainty and it is sometimes referred to as an indicator for market risk aversion. Its coefficient is expected to have a positive sign during the crisis, because higher risk is associated with higher uncertainty about general economic conditions - and thus higher default probabilities of the government bonds.

As a second international risk factor, we include the change of the spread between 3-month Euribor and German T-bills with 3-month maturity. This factor was proposed by Metiu (2012) and it is appealing because it can be interpreted as a measure for distress in the banking sector. We will therefore refer to it as our financial sector risk variable and abbreviate it in graphs and tables as **RP** for risk premium. The reasoning behind the construction of this variable is that if the German 3-month T-bills are considered to be riskless, then the spread relative to the 3-month Euribor is driven by a premium for the default risk in the banking sector and a possible liquidity risk premium. Both of these factors are negatively affected during a crisis. The spread is thus expected to appear with a positive sign for the bond spreads, because a higher default risk in the banking sector leads to a higher likelihood that new rescue packages are required, which further erode public finances.

- **Macroeconomic and fiscal variables**: Since we cannot include macroeconomic and fiscal variables at this high frequency, we include lagged stock market log-returns to proxy for the general development of the macroeconomy. The rationale for this is based on arguments of Forbes (2012), who reasons that stock prices reflect expectations about future profitability of companies which in turn depend on the macroeconomic conditions. Stock market returns should therefore capture changes in the expectations about the development of the macroeconomic environment. We expect a negative sign of the stock market coefficient, because positive stock market returns imply a higher GDP, which in turn implies a lower default risk and thus lower spreads. This would also be in line with Ang and Longstaff (2013), who find that stock market returns are the most important factor in determining systemic sovereign risk and that they enter with a negative sign.

- **Liquidity risk**: Even though there is a debate about the right way to measure liquidity, the most common approach is to use bid-ask spreads of the respective bonds. This has the drawback that bid-ask spreads also depend on other factors, such as the volatility of the respective asset, so that they are at best a noisy measure for liquidity premiums. We therefore use a different measure and include the spread between on-the-run 10-year-maturity bonds of the Kreditanstalt für Wiederaufbau (KfW) and the relevant German 10-year-maturity government bonds. This approach was suggested by De Santis (2014), because the KfW is a state owned bank and its bonds are backed by the German government. Theoretically, that means that the two bonds have the same default risk and any difference between their prices should reflect the higher liquidity of the government bonds. If liquidity is a driving factor for the spreads of the EMU countries, an increase in the KfW spread should lead to an increase in the yield spread.

Additional to the factors discussed above, we include a constant and the lagged spread change as additional country specific regressors. To avoid endogeneity issues, we use the first lag of the country specific stock market log-returns, while the international factors are used contemporaneously. Especially during the crisis, stock markets are likely to react to spread changes of the crisis countries so that causality runs in both directions. For the international risk factors, on the other hand, it seems reasonable to assume that the effect of a single country on these aggregate factors is limited, so that they can be used contemporaneously.

3.2 Stationarity of Country Spreads and Explanatory Variables

Studies analyzing contagion among government bond yield spreads or CDS spreads usually follow the earlier literature on determinants of yield spreads in treating them as persistent but stationary variables. They then try to account for the persistence by including lagged

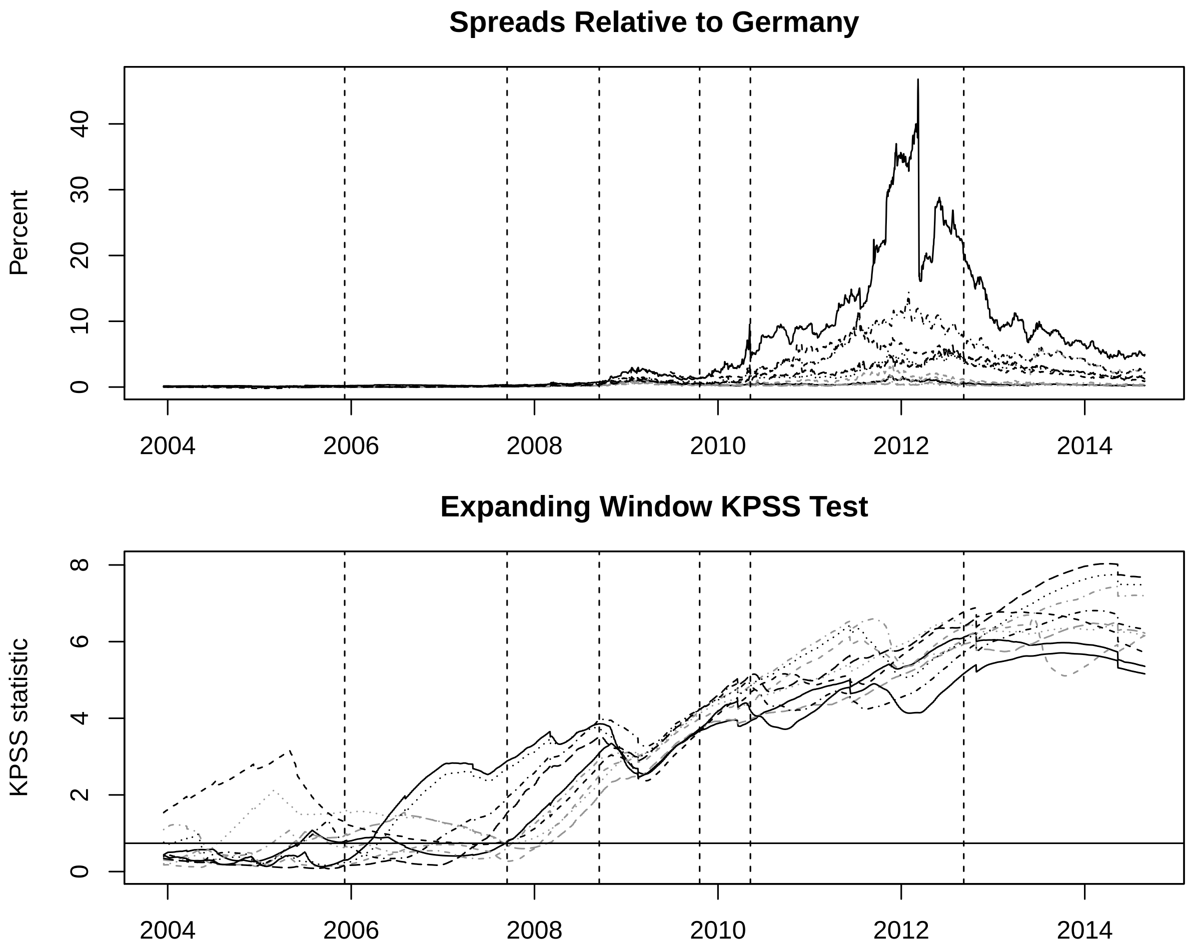

Figure 1: Level of 10-year-maturity government bond yield spreads relative to Germany and expanding window KPSS test. The horizontal line in the lower panel marks the asymptotic critical value at the 1-percent level that is 0.739.

spreads as additional regressors. A visual inspection of the yield spread series depicted in Figure 1 however, suggests that they might well be generated by a unit root process. In fact, there is evidence for a break in the persistence of the spreads. Sibbertsen et al. (2014) test the hypothesis of equal persistence in a long memory framework and find evidence for a break from long memory to a unit root process. This change in persistence is illustrated in Figure 1, that shows the evolution of an expanding window KPSS test for each of the countries considered. One can observe that the stationarity assumption might have been justified before the financial crisis, but it is clearly rejected thereafter.

To provide further evidence, we conduct full sample tests for unit roots in the spreads using

	AT	BE	FI	FR	NL	GR	IE	IT	PT	ES
ADF^{OLS}	-1.76	-2.09	-1.82	-1.58	-1.97	-1.87	-1.25	-1.27	-1.01	-1.17
MZ^{OLS}	-1.70	-2.11	-1.77	-1.51	-1.84	-1.83	-1.16	-1.15	-0.87	-1.04
ADF^{GLS}	-1.33	-1.56	-0.88	-1.11	-1.26	-1.50	-0.94	-0.74	-0.60	-0.69
MZ^{GLS}	-1.35	-1.62	-0.84	-1.13	-1.28	-1.51	-0.95	-0.75	-0.61	-0.70
$KPSS$	**5.35**	**6.16**	**6.15**	**7.19**	**6.22**	**5.16**	**5.70**	**7.48**	**6.31**	**7.67**

Table 1: Unit root tests for daily government bond yield spreads relative to Germany for the period from January 1, 2003 to August 29, 2014 ($T^* = 4022$). Approximate asymptotic critical values at the 5-percent level are -2.866 and -2.455 for the OLS versions of *ADF* and *MZ*, -1.966 for their GLS versions and 0.46 for the KPSS test. Significant values are printed bold.

the t-type version of the *ADF* test and the *MZ* test of Perron and Ng (1996). Both tests are conducted in their OLS-detrended version and the GLS-detrended version suggested by Elliott et al. (1996). The number of lags to account for higher order autocorrelations is selected using the MAIC criterion introduced by Ng and Perron (2001).[2] Since the presence of trends would imply that future interest rates would become infinitely negative or infinitely positive, all tests are conducted under the assumption that no trend is present. We can observe that none of the unit root tests is able to reject its I(1) null hypothesis. The full sample KPSS tests, on the other hand, clearly rejected the null hypothesis of stationarity.[3]

These results give evidence that the country spreads are I(1) variables. In consequence, contagion effects between them should be analyzed with respect to possible cointegration relatonships. De Santis (2014), for example, argues that spreads are involved in a cointegration relationship that includes the KfW spread, the country's credit rating and the Greek credit rating.

Note, however, that unit root tests typically have low power against local alternatives and theoretical arguments preclude that spreads are non-stationary. Non-stationarity of the spreads would imply, for example, that they can become infinitely negative or positive.

[2]Tests are conducted using codes provided by Martin et al. (2012).

[3]Since Perron (1989) showed that breaks in trend affect the size and power of unit root tests, we also applied the tests of Zivot and Andrews (1992) and M-tests using the method of Carrion-i Silvestre et al. (2009). This did not change the results.

Another argument is based on the relation between interest rates and spreads. Since the spreads are the difference between the German yield and the respective country yield, the properties of the spread series are directly related to those of interest rate series. For spreads to be cointegrated, interest rates would have to be integrated of order I(1), but not cointegrated among each other. Empirically, the interest rate series behave similarly to our spread series. Early contributions, such as Stock and Watson (1988) or Perron (1989), could not reject the unit root hypothesis for interest rate series, but more powerful panel tests such as Wu and Zhang (1996) do. Hence the previous non-rejections can probably be attributed to the low power against local alternatives. In economic models such as that of Vasicek (1977), interest rates are usually assumed to be stationary.

Taking these arguments together, we conclude that cointegration among the spreads can be disregarded. Instead, spreads are most likely to be near-integrated processes. Nevertheless, treating these processes as if they would be clearly stationary can lead to serious econometric problems. Phillips (1988) derived properties of regression analysis with near-integrated variables and showed that spurious results are found if the variables are used in levels (as in the unit root case). Like unit root processes, near-integrated processes should therefore be analyzed in first differences to avoid spurious findings. This is why we will consider the spreads in first differences when we conduct our subsequent analysis.

3.3 Econometric Model Specification

Since we are interested in pure contagion effects, we use the canonical contagion framework developed by Pesaran and Pick (2007), which is tailored to estimate these effects consistently. In this setup, the change of the spread Δs_{it} of country $i = 1,...,N$ at time $t = 1,...,T$ is determined by a vector of country specific variables denoted by x_{it}, a vector of common factors denoted by z_t and a number of indicator variables C_{jt} that indicate whether a potential contagious event occurred in country $j \neq i$ at time t.

In accordance with the literature, we assume that contagion effects can only originate from the subset $\mathbb{C}$ = {Greece, Ireland, Italy, Portugal and Spain} of the crisis countries, to avoid unnecessary efficiency losses for the non-crisis countries.

The regression equation for each country i is thus given by

$$\Delta s_{it} = \alpha_i' x_{it} + \beta_i' z_t + \sum_{\substack{j\in\mathbb{C} \\ j\neq i}} \gamma_{ij} C_{jt} + \varepsilon_{it}. \tag{1}$$

In this specification the transmission of extreme shocks from country j to country i is directly incorporated in the regression model through the indicator variables C_{jt}, while the influence of other transmission channels is controlled for by incorporating the country specific and common factors x_{it} and z_t. We thus conclude that pure contagion from country j to country i takes place, if the coefficient estimate $\hat{\gamma}_{ij}$ is significant. As discussed in the preceeding section, our specification of x_{it} includes a constant, the lagged spread change $\Delta s_{i,t-1}$ and the lagged stock market log-return. The common factors in z_t include the first difference of the VSTOXX and the first difference of our financial sector risk variable RP discussed in Section 3.1. The respective coefficient vectors are given by α_i and β_i.

Note that there is a clear endogeneity issue in (1) for the crisis countries, because the spreads of country i depend on those in country j through the distress indicator C_{jt} and vice versa. Therefore, we follow the suggestion of Pesaran and Pick (2007) to use the first three powers of the lagged spread changes $\Delta s_{j,t-1}$ as instrumental variables for the respective C_{jt}. For the non-crisis countries, on the other hand, we can use OLS, since we assume that there is no feedback from the non-crisis countries to the crisis countries that would induce endogeneity.

Model (1) was also used by Metiu (2012), but for the levels of the spreads and in a fixed sample. We on the other hand use it in a rolling window. The obvious advantage of applying a rolling window regression is that we do not need to specify the timing of structural changes discretionary by including dummy variables or by splitting the sample into subsamples before starting the analysis. Instead, the rolling window regression adopts to changes in the parameters. In every window a new observation (obeying the changed relationship) enters the sample, while at the same time, an old observation (that shows the pre-break behavior) is dropped so that we can observe how the outcome of our analysis depends on the choice of the sample.

This enables us to analyze two issues. First, we can determine the timing and direction of pure contagion effects, which is the main contribution of this paper. Second, we can also monitor the changing influence of the stock market returns, volatility expectations, liquidity risk premiums and financial sector risk. A change in the pricing of these factors would constitute a form of shift contagion. Whether it also fits the more narrow definition of wake-up-call contagion depends on the characteristics of the country that is affected. Wake-up-call contagion is usually associated with a changed pricing of country specific factors, such as macroeconomic or fiscal variables. But volatility expectations, liquidity risk premiums and financial sector risk are considered as common factors. A change in the pricing of these factors only qualifies as wake-up-call contagion if the countries for which it occurs have similar characteristics as the seed country of the crisis (in this case, Greece). We will investigate whether this is the case in the later part of our analysis.

If the canonical contagion framework in (1) is supposed to be used in a rolling window regression, the main issue is the specification of the distress indicators C_{jt}. Here lies one of the main differences of our specification to that of Metiu (2012) and Ludwig (2014). They specify the distress indicators C_{jt} to be 1 if the innovations to the level of the spreads exceed their 99-percent Value-at-Risk (VaR) and to be 0 otherwise. Since the C_{jt} are not specified a priori, the innovations cannot be estimated consistently. Instead, a complicated stepwise proceedure is used. First, they regress the spreads s_{it} on x_{it} and z_t and determine the recursive residuals from this regression. These recursive residuals and their squares are then included as additional regressors in a new regression of s_{it} on x_{it} and z_t. The residuals from this second regression are then used to estimate the conditional volatility using a GARCH(1,1). This whole procedure is carried out in a rolling window to obtain one-day-ahead 99-percent VaR estimates by combining these estimates with the quantile function of a Students' t-distribution.

Even though a thorough description of our data is left to the following Section 4, a first look at the descriptive statistics in Table 7 (in the appendix) shows that the spread changes exhibit extremely high kurtosis values. This is why we choose to specify the distress indicators C_{jt} slightly differently. First, we use a nonparametric estimate of the quantile function instead of assuming a Student's t-distribution, because the kurtosis values observed in Table 7 are much higher than those implied by a Student's t-distribution.[4] Second, due to the high kurtosis, the conditional expectation of the spread changes can be expected to have only limited influence on the one-step-ahead VaR. We therefore base our distress indicators C_{jt} directly on the empirical quantile function of the spread changes. This has the advantage that it is much easier to implement, it does not involve any approximations through recursive residuals and it avoids possible error accumulations through iterative estimations.

Formally, our financial distress indicator is specified as

$$C_{jt} = C(\Delta s_{jt}) = \mathbf{I}\left(\Delta\tilde{s}_{jt} > \hat{F}^{-1}_{j,t-1}(q)\right). \tag{2}$$

Here $\mathbf{I}(\cdot)$ is the indicator function and $\Delta\tilde{s}_{jt} = (\Delta s_{jt} - \overline{\Delta s_{jt}})/\hat{\sigma}_{j,t|t-1}$ are the standardized spread changes obtained using the estimated mean value of the spread changes $\overline{\Delta s_{jt}}$ and the GARCH(1,1) estimate $\hat{\sigma}_{j,t|t-1}$ of the conditional standard deviation of Δs_{jt} at time t. The function $\hat{F}^{-1}_{j,t-1}(q)$ denotes the empirical quantile function of the standardized spread changes $\Delta\tilde{s}_{jt}$ at the respective quantile q. So our distress indicator variable C_{jt} has a value of one if the spread change of country j is larger than its $100q$-percent VaR and zero otherwise. To keep the notation simple, the dependence of the indicator variables C_{ij} on the quantile q is not denoted explicitly. Both, the GARCH(1,1) model and the empirical

[4] Metiu (2012) used a Student's t-distribution with $\nu = 5$ degrees of freedom. This would imply a kurtosis of 9.

quantile function are estimated recursively in a rolling window of 500 observations to obtain a one-step-ahead VaR.

An important difference of our specification to the related study of Ludwig (2014), mentioned in Section 2, lies in the choice of the quantile q that determines which VaR is used. The two-stage-least-squares estimators are based on asymptotic theory that require a certain number of observations to work satisfactory. At the same time, the window size in the rolling window estimations should not be too large to avoid to smooth out parameter changes. Consequently, there is a trade off between the choice of the size T of the estimation window and the quantile q that defines the distress indicators. The expected number of distress events in a window of length T is given by $(1-q)T$. We thus use a 95-percent VaR instead of a 99-percent one and a window size of 500 observations in our baseline specification and include the usage of other quantiles in our robustness checks. Unfortunately, Ludwig (2014) does not take this trade off into account so that his IV estimates are carried out with an expectation of just 5 distress events per estimation window.

4 Empirical Findings

Our empirical analysis proceeds in four main steps. First, we introduce our main finding on the timing of pure contagion effects by looking at the evolution of the total number of active contagion channels. This allows us to judge how widespread contagion effects were at each point in time. In the second step, we repeat the analysis for pure contagion from subgroups and individual countries to identify the source countries of these effects. In the third part, we track the number of significant relationships between the spread changes and the international risk factors, liquidity premiums and stock market returns. Finally we run subsample regressions to assess the intensity of the documented effects and their economic significance.

All data is obtained from Thomson Reuters Datastream and it covers the period from

January 1, 2003 to August 29, 2014. Daily yield spreads are calculated relative to the German yield from ten-year-maturity benchmark bonds.[5] The lagged stock market log-returns are calculated from the respective MSCI country indices. As mentioned before, descriptive statistics of all variables are shown in Table 7 in the appendix. What is most striking is the extreme kurtosis of the spread changes discussed in the previous section. It should also be noted that there are high skewness values in the pre-crisis period, but not in the later subsamples.

As customary in the literature, we subdivide the countries into the five crisis countries $\mathbb{C}$ = {Greece, Ireland, Italy, Portugal and Spain} and the five non-crisis countries $\mathbb{N}$ = {Belgium, the Netherlands, Austria, Finland and France}. We then estimate model (1) equation by equation using two-stage-least-squares for the crisis countries and ordinary least squares for the non-crisis countries. All tests are carried out using heteroscedasticity and autocorrelation consistent standard errors.

4.1 Overall Timing of Pure Contagion

Since our main contribution is to analyze the timing of contagion effects and many of our arguments are based on the timing of specific events during the crisis, we include Table 6 in the appendix that contains a timeline of selected key events of the two crisis periods. Some of these events are depicted as dashed vertical lines in the Figure 2 that summarizes our findings. Events that are marked in Figure 2 are shaded in gray in Table 6. The figure shows the total number of contagion coefficients $\hat{\gamma}_{ij}$ that are significant at the 5-percent level in the estimation window ending at the respective date. If every crisis country would be a source of contagion effects to every other country, there would be 45 significant relationships.

The first event marked is the increase of the interest rate on the main refinancing operations of the ECB on December 6, 2005. One can already observe a first increase in the

[5] We exclude one observation for Greece from March 12, 2012 when the spread dropped by 27.45 percent after the second rescue package for Greece was agreed upon.

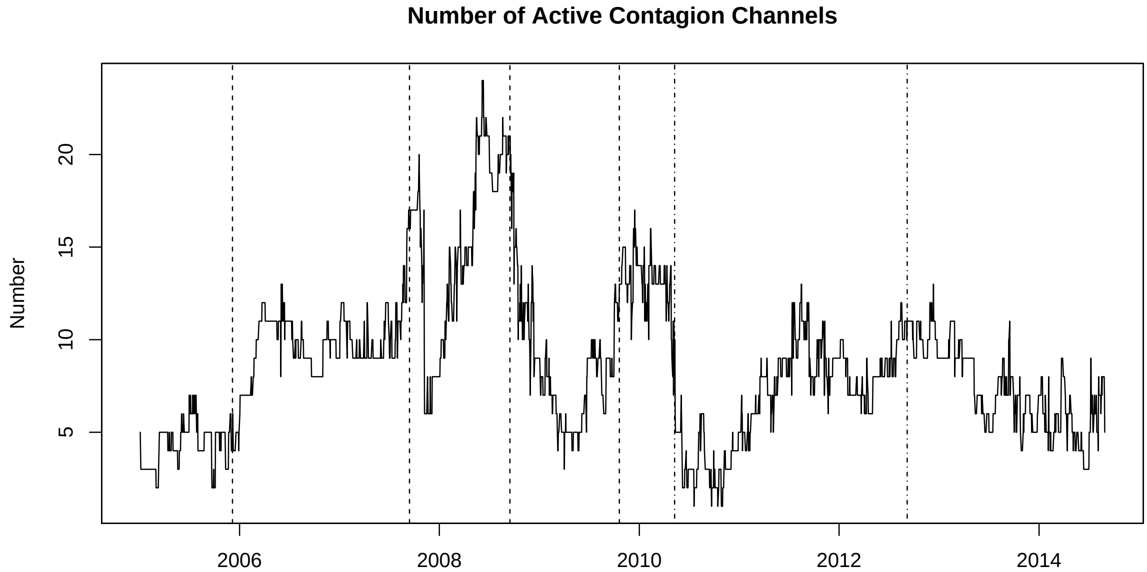

Figure 2: Total number of contagion coefficients $\hat{\gamma}_{ij}$ that are significant at the 5-percent level in model (1).

number of active contagion channels after this event, that was before the beginning of the subprime mortgage crisis. The second and third event are the bailout for the British bank Northern Rock and the bankruptcy of Lehman Brothers on September 14, 2007 and September 15, 2008, respectively. This is the period when the total number of active contagion channels reaches its climax - which is the high point of the subprime mortgage crisis. The EMU debt crisis, on the other hand, does not start until the revision of the Greek deficit figures on October 20, 2009, which is marked by the fourth vertical dashed line. We can see that there is another increase in the number of active channels after this event and then a sudden drop after the fifth event, which is the agreement of the Eurozone leaders to establish the EFSF on May 10, 2010. Spreads converge again after the announcement of the Outright Monetary Transactions (OMT) program on September 6, 2012 - which is the last event included. Of course the total number of active contagion channels does not contain any information about the intensity of pure contagion effects or their direction, but it measures how widespread they are and how the prevalence of contagion developed over time. This leads us to the somewhat surprising result that pure contagion was most prevalent during the subprime mortgage crisis while it was confined to a relatively small number of active channels during the climax of the EMU debt crisis in 2011 and 2012.

4.2 Source Countries of Pure Contagion Effects

In order to gain insights into the sources of these pure contagion effects, we now subdivide the set of crisis countries into two groups. The smaller crisis countries Greece, Portugal and Ireland on the one hand, and Italy and Spain as the larger ones on the other hand. We then conduct F-tests for the joint significance of the contagion coefficients of the respective subgroup for each country. Similar to Figure 2, the number of countries for which the subgroups are jointly significant is plotted in Figure 3. The maximal number of possibe significant relationships is now ten. One can observe a clear distinction between the two groups. Whereas the effects originating from the smaller countries arise in 2006 and vanish after the establishment of the EFSF and the bailout for Greece, the bulk of the effects from Italy and Spain only appears after the establishment of the EFSF and they begin to disappear after the announcement of the OMT program.

With regard to the subprime mortgage crisis and the early EMU crisis, we can observe that both country groups become significant during these periods. Some of the contagion effects vanish after the bankruptcy of Lehman Brothers, but they re-appear after the Greek deficit revision in the early phase of the EMU crisis.

These patterns are unexpected, since the majority of studies on the EMU debt crisis has identified Greece, Portugal and Ireland as the main sources of pure contagion effects. Our results reveal, however, that these effects do indeed appear, but only in the very early phase of the EMU debt crisis, after the Greek deficit revision and before the establishment of the EFSF. After that, when the levels of the spreads kept widening, Italy and Spain are the only sources of pure contagion effects.

In Figure 4, we consider the effect of every single crisis country separately. One can observe

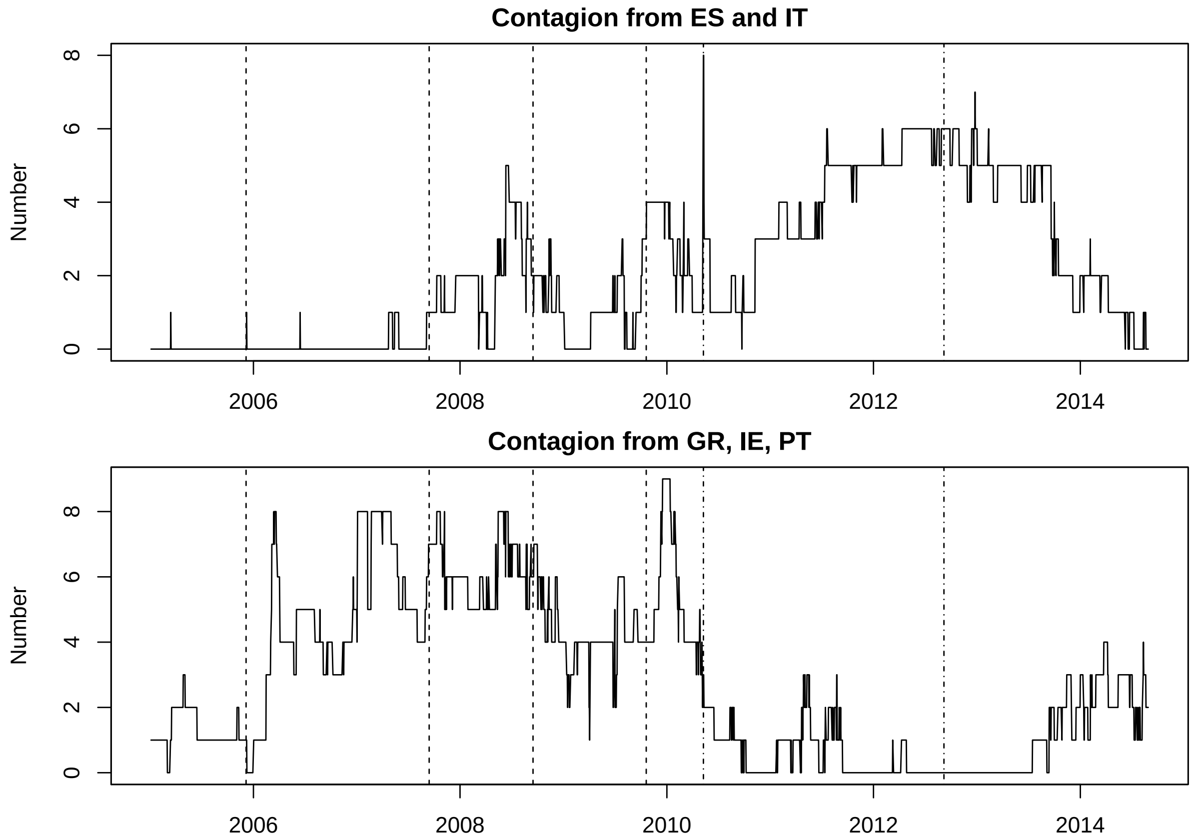

Figure 3: Total number of countries for which the contagion effects from the respective countries are jointly significant at the 5-percent level in model (1).

that the pattern of Greece is very different from that of the other countries. There are only two brief periods, around the bankruptcy of Lehman Brothers and before the bailout for Greece, when there was pure contagion originating from Greece. For the other countries, we observe some commonality in the patterns of Portugal and Ireland and also among Italy and Spain. The effects originating from Ireland appear a bit earlier than those from Portugal and they vanish directly after the bankruptcy of Lehman Brothers whereas contagion from Portugal only abates after the establishment of the EFSF. Nevertheless, both countries are sources of pure contagion effects for the majority of countries from the beginning of 2006 on and both countries do not cause contagion after the establishment of the EFSF. Italy and Spain, on the other hand, show a very different pattern. Both cause some contagion during the subprime mortgage crisis and especially Italy plays a role in the early EMU crisis. After May 2010, these two countries are the only ones that cause

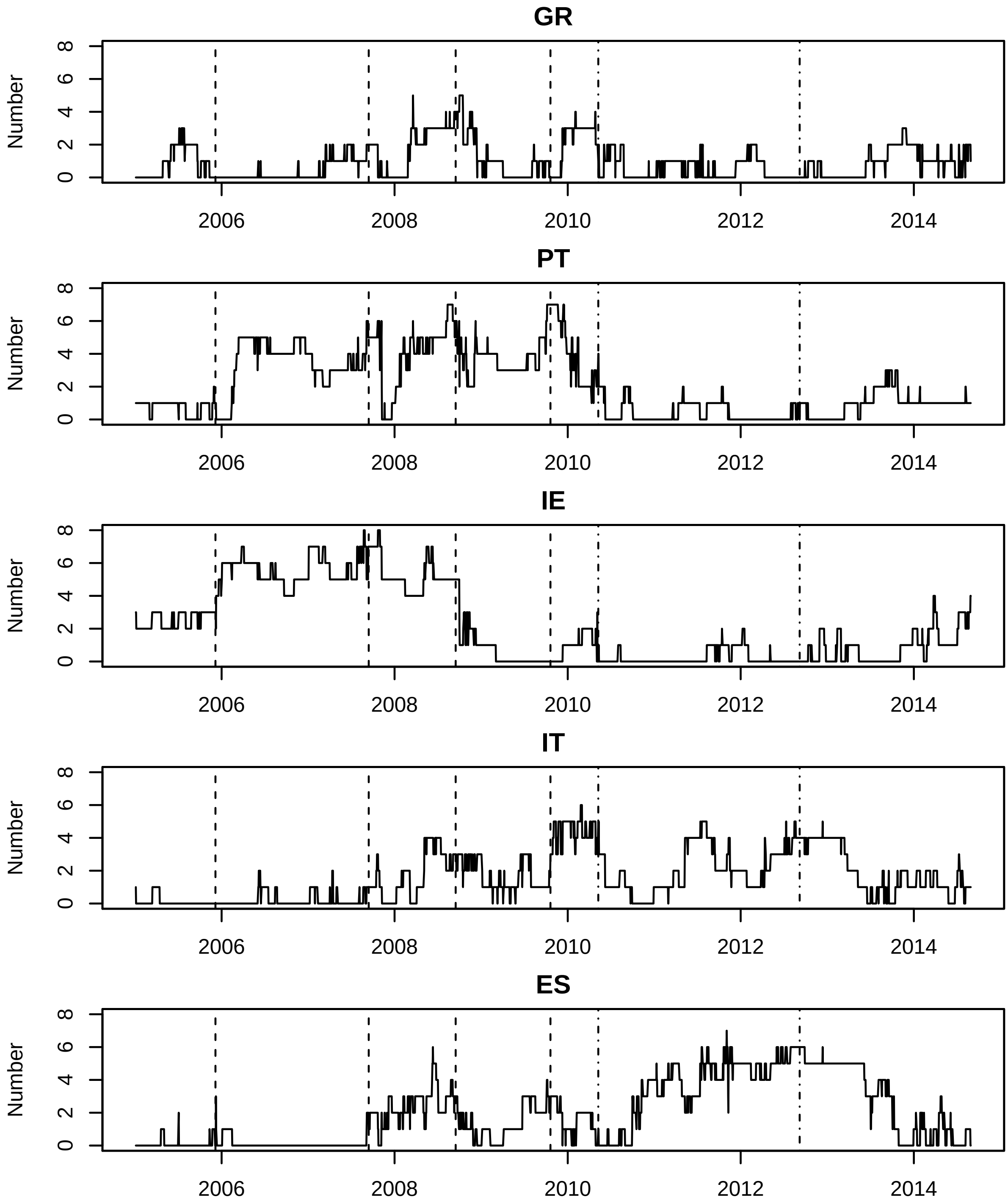

Figure 4: Number of countries for which the contagion effects from the respective country are significant at the 5-percent level in model (1).

significant contagion effects, which gives further support to our findings in Figure 3.

4.3 Influence of Exogenous Factors

We will now turn to the influence of international risk factors, liquidity premiums and stock market returns. Similar to Figure 4, the number of countries for which the respective exogenous factor is significant on the 5-percent level is plotted against time in Figure 5. To gain further insights about the underlying dynamics, we distinguish between all countries (dashed line) and the crisis countries (solid line), so that the difference between the two series reflects the results for the non-crisis countries.

We find that the Euribor spread (RP), that is assumed to proxy for financial sector risk, only becomes significant for a limited number of countries and only during three periods. The first effects appear during a brief period in the beginning of 2006. More effects from financial sector risk can be observed during the subprime mortgage crisis and then again around 2012, when spreads in the EMU reached their peaks. These effects disappear after the announcement of the OMT program. Since the levels of the solid and the dashed lines largely coincide, we can conclude that the Euribor mainly affects the crisis countries.

The VSTOXX has a significant effect on the majority of countries from the beginning of the subprime crisis on until the peak of the EMU crisis in 2012. After the announcement of the OMT program, it only remains significant for around four non-crisis countries. When we look at the subgroup of the crisis countries, we find the VSTOXX to be the most prevalent factor driving the spreads. Especially from the beginning of the subprime crisis until early 2012, it is continuously active for the majority of crisis countries. The VSTOXX is also significant for three of the crisis countries in 2006.

The KfW spread, that is assumed to proxy for liquidity risk, becomes significant for both subgroups during the subprime mortgage crisis. But whereas the effects on the crisis countries abate from 2010 on, liquidity premia continue to be significant for all non-crisis countries. It is interesting to note, that the KfW spread is also significant for all ten countries in the beginning of 2006, following the interest rate increases of the ECB. At this time we also observe significant effects of the VSTOXX.

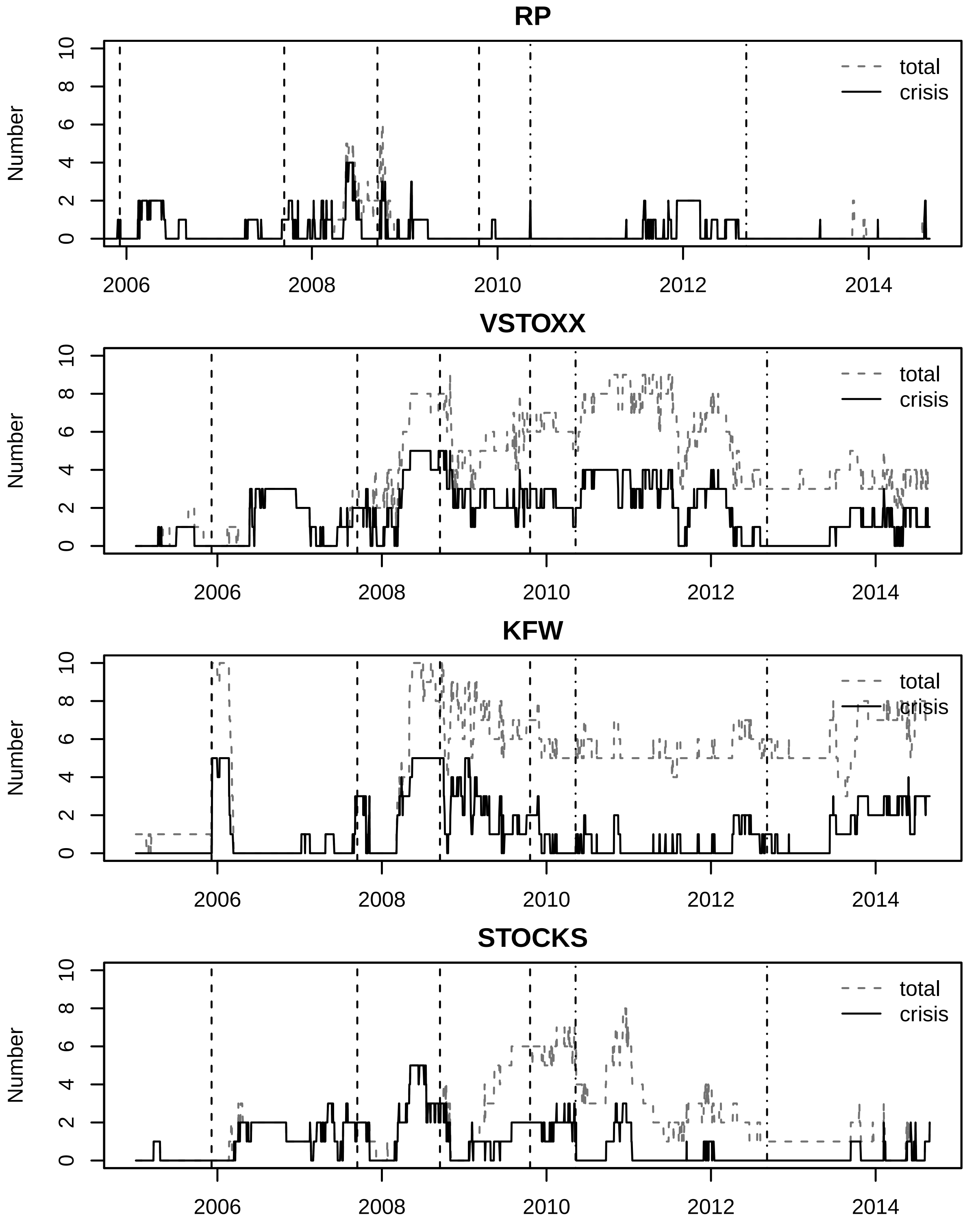

Figure 5: Number of countries for which the respective regressor is significant at the 5-percent level in model (1). The number of crisis countries is solid and black and the total number of countries for which the variable is significant is gray and dashed.

Finally, with regard to the stock markets, we find that lagged stock market returns become significant for some of the crisis countries from 2006 to 2010, with the peak before the bankruptcy of Lehman Brothers, when all five crisis countries depend on lagged stock returns. The spreads of non-crisis countries, on the other hand, are influenced by lagged stock market returns from the bankruptcy of Lehman Brothers until the establishment of the OMT program.

As discussed in Section 3.3, since the VSTOXX and the KfW spread are common factors and not country specific, it depends on the affected country groups whether or not their changing influence qualifies as wake-up-call contagion. Since the VSTOXX becomes significant for the majority of countries in both subgroups, we cannot conclude that this effect is connected to similarities of these countries with Greece. Also, the KfW spread is significant for both subgroups at first and then only for the non-crisis countries. Consequently, these effects cannot be interpreted as wake-up-call contagion. Nevertheless, both variables turn out to have a significant impact. This is especially interesting for the effect of the liquidity premium on the non-crisis countries, because it implies that there was a flight-to-liquidity effect even among the latter.

4.4 Direction and Intensity of Pure Contagion

We will now turn to the countries that are affected by contagion and the economic significance of these effects. To do so, we consider the results of subsample regressions. The choice of the subsamples is motivated by our findings on the overall timing of pure contagion effects discussed in Section 4.1. As a benchmark we consider the **pre-crisis period** from January 1, 2003 to December 5, 2005 - the day before the ECB increased the main refinancing rate. The period from December 6, 2005 to the bankruptcy of Lehman Brothers is labelled the **subprime mortgage crisis period**. Historically, this is not accurate. Usually HSBC's statement on February 8, 2007 is considered to be the starting point of the crisis. This was when they announced that they required higher provisions for losses

	const	lag	RP	VSTX	KFW	Stock	GR	IE	IT	PT	ES	R^2
AT	-0.06	**-12.70**	3.79	0.00	**0.73**	-1.68	0.22	0.15	-0.02	0.38	0.24	0.2726
	(0.04)	(**0.03**)	(0.43)	(0.82)	(**0.01**)	(0.53)	(0.25)	(0.11)	(0.96)	(0.14)	(0.21)	
BE	**-0.09**	-2.14	6.64	0.01	0.49	0.20	-0.13	**0.70**	0.49	0.31	-0.06	0.1749
	(**0.00**)	(0.33)	(0.24)	(0.83)	(0.07)	(0.91)	(0.42)	(**0.03**)	(0.18)	(0.29)	(0.66)	
FI	-0.01	-1.27	0.95	-0.05	**0.96**	-3.35	-0.16	**0.34**	0.23	-0.13	0.00	0.2334
	(0.84)	(0.54)	(0.86)	(0.13)	(**0.02**)	(0.29)	(0.32)	(**0.01**)	(0.59)	(0.59)	(0.98)	
FR	**-0.04**	-2.70	5.63	-0.02	**0.55**	0.79	0.03	**0.42**	0.05	0.15	-0.10	0.2645
	(**0.03**)	(0.31)	(0.29)	(0.25)	(**0.03**)	(0.51)	(0.87)	(**0.01**)	(0.65)	(0.35)	(0.41)	
NL	-0.06	-2.96	7.02	-0.03	0.48	-5.20	0.13	0.39	0.05	0.29	0.10	0.1423
	(0.06)	(0.18)	(0.23)	(0.19)	(0.09)	(0.34)	(0.61)	(0.07)	(0.81)	(0.32)	(0.68)	
GR	0.04	-1.36	3.80	0.02	**0.63**	0.61	-	1.80	-0.51	-0.61	-1.49	0.1282
	(0.67)	(0.41)	(0.50)	(0.31)	(**0.03**)	(0.83)	-	(0.11)	(0.69)	(0.48)	(0.10)	
IE	-0.05	-0.68	9.04	-0.02	0.44	5.57	0.37	-	0.16	0.27	-0.33	0.0705
	(0.82)	(0.69)	(0.22)	(0.72)	(0.23)	(0.58)	(0.81)	-	(0.92)	(0.76)	(0.77)	
IT	-0.21	-5.74	5.86	-0.01	0.56	-9.07	0.31	4.57	-	0.17	-1.29	0.1535
	(0.23)	(0.32)	(0.30)	(0.75)	(0.07)	(0.07)	(0.74)	(0.13)	-	(0.79)	(0.18)	
PT	0.03	-3.25	2.46	0.02	**0.84**	0.08	0.37	1.35	-0.00	-	-2.17	0.1790
	(0.83)	(0.70)	(0.72)	(0.56)	(**0.02**)	(0.98)	(0.78)	(0.29)	(1.00)	-	(0.04)	
ES	-0.14	**-37.81**	**29.64**	-0.01	**0.50**	4.24	0.04	2.20	2.03	**-2.81**	-	0.2689
	(0.38)	(**0.00**)	(**0.04**)	(0.66)	(**0.05**)	(0.25)	(0.98)	(0.19)	(0.14)	(**0.01**)	-	

Table 2: Regression results of model (1) during the **pre-crisis period** from January 1, 2003 to the first interest rate increase of the ECB (December 5, 2005). P-values are given in parentheses. Bold values indicate significance at the 5-percent level.

on bad mortgage loans. Nevertheless, we are interested in the sign and magnitude of the contagion effects that we measured - and those already appear earlier. Finally, our **EMU crisis period** begins with the revision of the Greek deficit figures on October 20, 2009 and ends with the announcement of the OMT program on September 6, 2012, after which the contagion effects started to disappear.

To evaluate the relative strengths of the effects, coefficients are interpreted as the reaction to a one-standard-deviation increase in the independent variable measured in standard deviations of the dependent variable.

The results for the pre-crisis period are shown in Table 2. We find that the main determinant of the spreads during this time frame is the KfW spread that proxies for liquidity premiums. For those countries where the KfW spread is significant, a one standard deviation increase in the KfW spread leads to an average increase of between 0.22 and 0.59

	const	lag	RP	VSTX	KFW	Stock	GR	IE	IT	PT	ES	R^2
AT	**-0.06**	**-24.33**	0.99	0.00	0.04	-2.86	0.11	**0.57**	0.14	**0.55**	0.06	0.1912
	(**0.02**)	(**0.01**)	(0.06)	(0.97)	(0.19)	(0.18)	(0.61)	(**0.00**)	(0.51)	(**0.03**)	(0.69)	
BE	**-0.11**	-10.75	**1.50**	0.09	0.07	**-6.46**	**0.49**	**0.90**	0.16	0.43	0.36	0.2171
	(**0.00**)	(0.38)	(**0.01**)	(0.06)	(0.08)	(**0.03**)	(**0.01**)	(**0.01**)	(0.41)	(0.22)	(0.12)	
FI	**-0.06**	**-24.48**	0.68	-0.02	0.06	-2.05	0.12	**0.75**	0.03	**0.71**	-0.01	0.2064
	(**0.05**)	(**0.00**)	(0.22)	(0.61)	(0.11)	(0.25)	(0.48)	(**0.00**)	(0.87)	(**0.02**)	(0.96)	
FR	**-0.08**	**-22.93**	0.55	**0.06**	0.06	-1.43	0.22	**0.37**	0.03	**0.81**	0.33	0.2351
	(**0.00**)	(**0.01**)	(0.21)	(**0.02**)	(0.08)	(0.65)	(0.24)	(**0.05**)	(0.84)	(**0.01**)	(0.12)	
NL	**-0.07**	-20.11	**1.06**	0.04	0.05	-2.04	0.05	**0.51**	0.32	**0.72**	0.02	0.1966
	(**0.02**)	(0.06)	(**0.02**)	(0.18)	(0.13)	(0.43)	(0.83)	(**0.01**)	(0.15)	(**0.01**)	(0.91)	
GR	0.24	-7.76	-2.47	0.25	**0.20**	**-20.86**	-	-0.57	-0.26	**8.48**	-9.39	0.2417
	(0.48)	(0.27)	(0.12)	(0.22)	(**0.00**)	(**0.00**)	-	(0.88)	(0.95)	(**0.00**)	(0.02)	
IE	-0.30	4.01	**-3.07**	-0.15	0.07	1.03	**-10.05**	-	**6.56**	**12.77**	-1.54	0.1902
	(0.10)	(0.58)	(**0.00**)	(0.14)	(0.07)	(0.75)	(**0.00**)	-	(**0.03**)	(**0.00**)	(0.64)	
IT	0.34	**-12.78**	-2.86	**0.26**	**0.21**	**-26.21**	-0.11	-2.68	-	**9.24**	**-9.83**	0.2066
	(0.19)	(**0.03**)	(0.08)	(**0.02**)	(**0.00**)	(**0.01**)	(0.97)	(0.45)	-	(**0.00**)	(**0.00**)	
PT	**-0.47**	-1.65	1.60	0.24	0.02	3.88	2.12	**10.29**	-8.23	-	4.57	0.2198
	(**0.03**)	(0.88)	(0.19)	(0.21)	(0.80)	(0.63)	(0.50)	(**0.00**)	(0.11)	-	(0.48)	
ES	-0.08	-16.29	-0.77	0.09	0.06	-2.81	-1.39	-5.72	1.12	**8.91**	-	0.1581
	(0.74)	(0.12)	(0.48)	(0.54)	(0.10)	(0.59)	(0.66)	(0.06)	(0.78)	(**0.00**)	-	

Table 3: Regression results of model (1) during the **subprime crisis period** from the first interest rate increase of the ECB (December 5, 2005) to the bankruptcy of Lehman Brothers (September 15, 2008). P-values are given in parentheses. Bold values indicate significance at the 5-percent level.

standard deviations of the respective country spread. There are no significant effects of the VSTOXX. Some pure contagion effects can be measured from Ireland to Belgium, Finland and France. If a distress event of the Irish spread is realized, this leads to an average increase between 0.33 and 0.87 standard deviations for these 3 countries. For Spain we observe that there are significant effects from Portugal with a negative sign. This can be interpreted as a portfolio shift from Portuguese to Spanish bonds that occurs if a distress event of the Portuguese spread is realized. In this situation, the average decrease of the Spanish spread is about 2.19 standard deviations.

The picture changes, if we consider the results for the subprime crisis period in Table 3. The KfW spread only remains significant for Greece and Italy, whereas the VSTOXX has a significant positive influence on the French and Italian spreads. We also observe a positive and significant impact of the financial sector risk premium (RP) on Belgium

	const	lag	RP	VSTX	KFW	Stock	GR	IE	IT	PT	ES	R^2
AT	**-0.51**	**14.27**	2.14	**0.38**	**0.20**	**-17.87**	0.94	0.14	**2.15**	-0.19	**1.24**	0.2420
	(**0.00**)	(**0.00**)	(0.46)	(**0.00**)	(**0.00**)	(**0.04**)	(0.09)	(0.73)	(**0.00**)	(0.62)	(**0.02**)	
BE	**-0.88**	**24.12**	3.64	**0.93**	**0.24**	-24.91	1.18	0.79	**3.60**	-0.22	**2.49**	0.3555
	(**0.00**)	(**0.00**)	(0.38)	(**0.00**)	(**0.00**)	(0.21)	(0.17)	(0.24)	(**0.00**)	(0.70)	(**0.00**)	
FI	**-0.26**	-0.17	-1.29	-0.02	**0.13**	**-21.42**	**0.60**	0.29	0.64	-0.08	0.44	0.1419
	(**0.00**)	(0.97)	(0.28)	(0.78)	(**0.00**)	(**0.00**)	(**0.03**)	(0.25)	(0.06)	(0.73)	(0.23)	
FR	**-0.43**	5.77	1.87	**0.38**	**0.21**	**-30.62**	1.14	0.04	**1.85**	-0.41	**1.33**	0.2053
	(**0.00**)	(0.28)	(0.50)	(**0.00**)	(**0.00**)	(**0.02**)	(0.07)	(0.93)	(**0.00**)	(0.32)	(**0.01**)	
NL	**-0.20**	-4.17	0.16	**0.11**	**0.15**	-6.84	0.48	-0.00	**0.89**	-0.04	0.44	0.1509
	(**0.03**)	(0.29)	(0.90)	(**0.04**)	(**0.00**)	(0.30)	(0.05)	(0.99)	(**0.01**)	(0.86)	(0.23)	
GR	-6.70	7.80	-34.17	-0.07	-0.54	-24.42	-	29.49	126.27	-119.31	44.32	0.0824
	(0.37)	(0.05)	(0.49)	(0.98)	(0.66)	(0.84)	-	(0.59)	(0.22)	(0.28)	(0.68)	
IE	-4.27	**19.63**	-14.29	0.57	-0.53	21.95	2.74	-	27.35	-4.95	12.43	0.1566
	(0.10)	(**0.00**)	(0.26)	(0.52)	(0.26)	(0.73)	(0.86)	-	(0.34)	(0.79)	(0.43)	
IT	-0.58	**19.21**	**19.94**	**1.48**	0.30	5.83	-25.35	**-13.32**	-	6.23	**31.27**	0.2506
	(0.78)	(**0.00**)	(**0.04**)	(**0.02**)	(0.17)	(0.87)	(0.10)	(**0.02**)	-	(0.64)	(**0.01**)	
PT	**-9.34**	**24.26**	-17.56	-0.55	-0.62	70.37	37.92	9.34	77.17	-	-27.04	0.1719
	(**0.00**)	(**0.02**)	(0.18)	(0.55)	(0.18)	(0.14)	(0.09)	(0.82)	(0.10)	-	(0.38)	
ES	-1.57	**20.17**	2.67	0.29	0.11	51.50	6.34	**-15.31**	**51.87**	-20.81	-	0.2727
	(0.58)	(**0.00**)	(0.81)	(0.77)	(0.69)	(0.22)	(0.69)	(**0.02**)	(**0.00**)	(0.10)	-	

Table 4: Regression results of model (1) during the **EMU crisis period** from the Greek deficit revision (October 20, 2009) to the announcement of the Outright Monetary Transactions program (September 6, 2012). P-values are given in parentheses. Bold values indicate significance at the 5-percent level.

and the Netherlands, but these are of relatively small magnitude (less than 0.1 standard deviations increase in response to a one-standard-deviation shock). The lagged stock market return now has a negative significant effect on the spreads of Belgium, Greece and Italy, but these are also relatively weak (decrease between 0.07 and 0.22 standard deviations).

All non-crisis countries are now affected by pure contagion from Ireland and all but Belgium are affected by pure contagion from Portugal. All these effects are in an order of magnitude between 0.36 and 0.83 standard deviation increases in response to the occurrence of a contagious event. With regard to the crisis countries, we find that they are all affected by contagion from Portugal. The lagged stock market returns now have a negative impact on the spreads of France, Austria and Finland.

The results for the EMU crisis are displayed in Table 4. As in the pre-crisis period, the KfW spread has explanatory power for the spreads of the non-crisis countries, with responses of around 0.2 standard deviations to a one standard deviation change of the KfW spread. The same holds true for the VSTOXX that now becomes significant for all non-crisis countries but Finland and Italy. With regard to the contagion coefficients, we observe that, in the EMU crisis period, Italy and Spain are the main sources of contagion and mostly non-crisis countries are affected. A distress event in the Italian spreads causes increases of around half a standard deviation in the spreads of the affected non-crisis countries. The response to a distress event in the Spanish spreads is an increase of around 0.3 standard deviations.

In addition to these effects from Italy and Spain on France, Austria, Belgium and the Netherlands, there is also mutual contagion between Italy and Spain. On average the Italian spread changes by 2.6 standard deviations if a distress event is realized in Spain. The average response of the Spanish spread change to a distress event in Italy is estimated to be 4.3 standard deviations. These effects appear to be extremely strong, but their magnitude can be explained by the heavy tails of the distribution of the spread changes. A distress event in one of the crisis countries is likely to be in the order of magnitude of three or four standard deviations. Consequently, the estimated coefficients simply imply that the spread changes of these two countries correlate strongly if a distress event is realized.

Note that across all subperiods, the overall model fit is quite good considering that the model is estimated in first differences. The R^2 values typically vary between 15 percent and 30 percent, suggesting that the selected specification is indeed well suited to model the behavior of spread changes.

Overall these results support our findings from the previous sections that Italy and Spain are the main sources of contagion effects during the EMU debt crisis. The estimated effects of distress events in the Italian and Spanish spreads, on each other as well as on the non-crisis countries, are not only significant, but also in an order of magnitude to be economically relevant. This is also true for the KfW spread, which underlines the importance of liquidity premiums discussed by De Santis (2014).

5 Specification Testing and Robustness Checks

Since our results imply a different interpretation of the events during the subprime mortgage crisis and the EMU debt crisis, we need to carefully examine the model specification and its robustness.

First, we use the Hausman-Wu test to check, whether the IV estimation is really necessary for the crisis countries. In addition to that, we run the overidentification test of Sargan (1958) to test for the exogeneity of the regressors in the IV regression. The results are displayed in Table 5.

The results of the Hausman-Wu test indicate endogeneity for the full sample and all subsamples with the exception of the pre-crisis period, where no endogeneity is detected. This is consistent with our finding that there was little to no contagion during this period. For the subprime crisis period as well as the EMU crisis period, on the other hand, the tests find endogeneity, so that it is indeed neccessary to use the IV framework of Pesaran and Pick (2007) to obtain consistent estimates. With the exception of Greece during the EMU crisis, the Sargan test does not indicate any problems regarding the exogeneity of the instruments. Also, tests of the residuals show no indication of remaining autocorrelation.

Our modeling strategy involves two discretionary choices that might affect the validity of our results. First, we set the window length to 500 observations for our rolling window regressions. Furthermore, we specify $q = 0.95$ for $\hat{F}^{-1}_{j,t-1}(q)$ in (2), i.e. we utilize the 95%-VaR in our empirical quantile function specification. The robustness of our findings with regard to these choices is demonstrated in Figure 6 that replicates Figure 2, conducting the same rolling window regression but with a window length of 350 observations and with a VaR of 90% as well as 97.5%.

As one can see, in all cases the development of the number of active contagion channels

Test	Country				
	GR	**IE**	**IT**	**PT**	**ES**
			- Full Sample -		
Hausman-Wu	**10.53**	**12.07**	5.32	**17.94**	**23.54**
	(**0.03**)	(**0.02**)	(0.26)	(**0.00**)	(**0.00**)
Sargan	3.55	0.31	**15.66**	3.52	2.29
	(0.90)	(1.00)	(**0.04**)	(0.90)	(0.97)
			- Pre-Crisis-		
Hausman-Wu	8.50	0.87	4.25	3.92	**11.16**
	(0.08)	(0.93)	(0.37)	(0.42)	(**0.03**)
Sargan	7.23	13.26	3.92	4.16	3.50
	(0.51)	(0.10)	(0.86)	(0.84)	(0.90)
			- Subprime-Crisis-		
Hausman-Wu	**155.43**	**49.51**	**55.81**	**52.39**	**38.78**
	(**0.00**)	(**0.00**)	(**0.00**)	(**0.00**)	(**0.00**)
Sargan	1.12	4.79	2.19	6.93	6.19
	(0.99)	(0.78)	(0.97)	(0.54)	(0.63)
			- EMU-Crisis-		
Hausman-Wu	1.36	3.72	**31.89**	**13.93**	**20.41**
	(0.85)	(0.45)	(**0.00**)	(**0.01**)	(**0.00**)
Sargan	**20.78**	10.76	2.77	2.81	9.81
	(**0.01**)	(0.22)	(0.95)	(0.95)	(0.28)

Table 5: Specification test results for subsample regressions. P-values are given in parentheses. Bold values indicate significance at the 5-percent level.

is very similar. In all specifications we can observe the peak around the climax of the subprime crisis followed by a temporary decrease until 2009. With the beginning of the EMU crisis, the prevalence of pure contagion increases again, decreases after the establishment of the EFSF and is lower during the climax of the EMU crisis than it was during the climax of the subprime mortgage crisis. That means that all our main findings in Section 4 are robust to the choice of the window length as well as the specification of the VaR that determines the indicator variables C_{jt}.

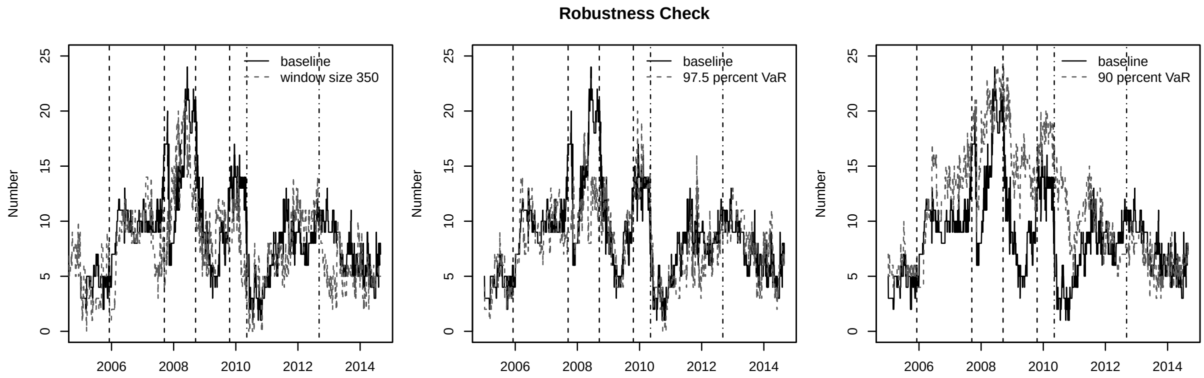

Figure 6: Total number of significant contagion coefficients $\hat{\gamma}_{ij}$ at the 5-percent level using our baseline specification compared to the results obtained with a window size of 350 observations (left panel), contagious events defined as exceedances of a 97.5 percent VaR (middle panel) and a 90 percent VaR (right panel).

6 Conclusion

Our results show that the evidence supporting that Greece, Portugal and Ireland are the main sources of pure contagion is less clear than it seems from the literature.

If spreads are treated as near integrated processes and a rolling window analysis is applied, the main findings change substantially. Using this setup, we find that not Greece, Portugal and Ireland, but Italy and Spain are the main sources of pure contagion effects during most of the EMU debt crisis. Contagion from Greece and Portugal only occurred in the very beginning of the EMU debt crisis (after the new Greek government revised the deficit figures). After the establishment of the EFSF in May, 2010, only Italy and Spain were sources of pure contagion effects. This was also the case around the end of 2011 and in the beginning of 2012, when the EMU debt crisis reached its climax and the levels of the spreads peaked. Another important finding is that the occurrence of pure contagion is not limited to the EMU debt crisis. In fact, pure contagion is most prevalent shortly before the bankruptcy of Lehman Brothers in the summer of 2008, when we observe contagion from all five crisis countries.

These results do not stand alone, but complement other findings reported in the literature. The timing of the pure contagion effects coincides with the evidence in the literature on the timing of wake-up-call effects as discussed in Section 2. Also, studies on contagion in stock markets such as Samitas and Tsakalos (2013), who consider Dynamic Conditional Correlations among EMU stock indices, find that there is a substantial increase in inter-market correlations during the subprime mortgage crisis but less so during the EMU debt crisis. In a recent working paper González-Hermosillo and Johnson (2014) find that there is a significant relationship among German, Spanish and Italian CDS between 2009 and 2012, but Greece has no significant impact on either of them.

Taken together, these results imply a somewhat different interpretation of the events during the crisis. The usual reading is that the countries' debt levels increased because of expansive bailout programs during the subprime mortgage crisis. The EMU debt crisis was then triggered by the Greek deficit revision in October 2009, that created concerns about the sustainability of government finances. Our results however, show that the dynamics in EMU bond markets already changed in the early phase of the subprime mortgage crisis. This implies that there is a much closer connection between these two crisis periods than assumed so far. Consequently, further research is required to identify the transmission channels at work. The timing of the first contagion effects from Ireland and Portugal also suggests that there might be an influence of monetary policy, since they appeared directly after the ECB started to increase interest rates in December 2005.

With regard to the evaluation of policy measures during the EMU debt crisis, our findings imply that the establishment of the EFSF was effective in containing contagion from the small countries but it was not sufficient to prevent contagion from the larger economies Spain and Italy. These effects were only curbed after the announcement of the OMT program and subsequent interest rate cuts by the ECB. The introduction of the OMT program also ended the influence of financial sector risk on the country spreads.

7 Appendix

Date	Event
06.12.2005	ECB increases main refinancing rates for the first time in 5 years
08.02.2007	HSBC announces higher provisions for bad mortgage loans
14.09.2007	Northern Rock needs emergency funding from BoE
15.09.2008	Bankruptcy of Lehman Brothers
15.10.2008	ECB switches to fixed rate tender with full allotment and decreases interest rate by 0.5 percent
20.10.2009	Greek deficit revision
23.04.2010	Greece seeks support of Eurozone
09.05.2010	Agreement on establishment of EFSF
22.11.2010	Ireland asks for support by the Eurozone
06.04.2010	Portugal asks for support by the Eurozone
13.10.2011	EFSF becomes operational
09.12.2011	Euro leaders agree on stronger fiscal controls
21.02.2012	Second rescue package for Greece, including restructering of private debt
01.03.2012	Greek bonds re-approved as collateral
27.06.2012	Spain requests support
06.09.2012	Outright Monetary Transaction program is introduced
27.09.2012	European Stability Mechanism is created
08.05.2013	ECB decreases main refinancing rate to 0.5 percent
07.11.2013	ECB decreases main refinancing rate to 0.25 percent

Table 6: Shows key dates of subprime mortgage and EMU crisis. The events represented by vertical dashed lines in the figures are marked in gray.

	Spread Changes										Common Factors			Stock Returns									
	AT	**BE**	**FI**	**FR**	**NL**	**GR**	**IE**	**IT**	**PT**	**ES**	**RP**	**VSTX**	**KfW**	**AT**	**BE**	**FI**	**FR**	**NL**	**GR**	**IE**	**IT**	**PT**	**ES**
	- Full Sample: 2003-01-01 to 2014-08-29 -																						
mean	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	-0.01	-0.00	0.00	0.00	0.00	0.00	0.00	-0.00	-0.00	-0.00	-0.00	0.00
sd	0.03	0.08	0.02	0.03	0.02	0.29	0.08	0.07	0.12	0.07	0.06	1.76	2.73	0.02	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.01
skew	0.78	25.66	2.92	0.06	1.11	4.83	-0.90	-0.49	1.02	-1.02	0.61	1.71	0.65	-0.19	-0.70	-0.28	0.02	-0.09	0.09	-0.55	-0.04	-0.08	0.17
kurtosis	24.22	1071.31	48.78	25.03	22.30	165.08	41.54	27.33	56.26	23.27	47.02	28.78	38.52	10.38	16.14	8.19	9.63	9.89	6.78	13.08	8.96	11.71	10.57
0%	-0.28	-0.41	-0.12	-0.29	-0.12	-4.51	-1.24	-0.78	-1.66	-0.82	-0.66	-13.98	-34.10	-0.11	-0.16	-0.13	-0.09	-0.09	-0.10	-0.18	-0.09	-0.11	-0.10
1%	-0.08	-0.15	-0.04	-0.08	-0.05	-0.68	-0.24	-0.18	-0.38	-0.20	-0.14	-4.44	-7.67	-0.05	-0.04	-0.05	-0.04	-0.04	-0.06	-0.06	-0.04	-0.04	-0.04
99%	0.09	0.16	0.05	0.08	0.05	0.84	0.26	0.20	0.30	0.23	0.16	5.14	7.42	0.04	0.03	0.05	0.04	0.04	0.06	0.05	0.04	0.03	0.04
100%	0.24	3.33	0.25	0.27	0.15	7.03	0.86	0.59	1.76	0.42	0.74	22.64	34.00	0.13	0.10	0.10	0.10	0.10	0.16	0.13	0.11	0.10	0.15
	- Pre-Crisis: 2003-01-01 to 2005-12-06 -																						
mean	-0.00	-0.00	0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.00	-0.05	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
sd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1.22	0.55	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
skew	8.41	8.29	14.71	1.95	8.79	9.07	19.29	5.12	10.01	1.99	2.86	0.87	-5.94	-0.42	1.12	-1.04	0.01	0.12	0.06	-1.03	-0.37	-0.31	-0.13
kurtosis	152.13	133.14	291.30	67.60	143.53	170.42	490.93	89.81	158.78	39.50	78.29	7.65	149.92	5.15	17.77	12.01	7.81	8.03	4.37	12.93	6.46	5.11	5.90
0%	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.09	-0.12	-4.70	-9.90	-0.04	-0.05	-0.13	-0.06	-0.06	-0.04	-0.09	-0.05	-0.04	-0.04
1%	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.05	-0.03	-2.87	-0.90	-0.02	-0.03	-0.05	-0.03	-0.04	-0.03	-0.03	-0.03	-0.02	-0.03
99%	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.03	4.39	1.04	0.02	0.03	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.03
100%	0.13	0.12	0.22	0.05	0.12	0.14	0.25	0.11	0.16	0.12	0.14	6.14	4.70	0.03	0.10	0.08	0.07	0.08	0.04	0.04	0.04	0.03	0.04
	- Subprime mortgage crisis: 2005-12-07 to 2008-09-15 -																						
mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.07	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.00
sd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.06	1.25	2.87	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01
skew	0.03	1.66	-0.15	-0.79	-0.28	0.83	2.35	1.08	0.23	-1.62	0.29	1.28	2.11	-0.52	-0.48	0.15	-0.38	-0.21	0.05	-0.01	-0.42	-0.38	-0.40
kurtosis	91.96	57.20	70.88	71.23	70.87	25.40	70.96	27.01	32.57	29.95	7.11	10.65	37.95	5.12	6.95	8.23	5.90	5.85	6.58	6.76	5.09	7.87	8.19
0%	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.09	-0.28	-5.38	-19.50	-0.06	-0.08	-0.08	-0.07	-0.06	-0.06	-0.09	-0.05	-0.06	-0.08
1%	-0.02	-0.03	-0.02	-0.02	-0.02	-0.03	-0.02	-0.04	-0.03	-0.03	-0.14	-2.66	-6.88	-0.04	-0.04	-0.04	-0.03	-0.03	-0.04	-0.05	-0.03	-0.03	-0.03
99%	0.02	0.03	0.02	0.03	0.03	0.05	0.03	0.04	0.04	0.03	0.16	4.00	7.78	0.04	0.03	0.04	0.03	0.03	0.04	0.05	0.02	0.03	0.03
100%	0.12	0.13	0.12	0.12	0.12	0.12	0.14	0.12	0.12	0.06	0.40	9.52	34.00	0.05	0.06	0.10	0.06	0.06	0.08	0.09	0.04	0.05	0.07
	- EMU debt crisis: 2009-10-20 to 2012-09-06 -																						
mean	0.00	0.00	-0.00	0.00	0.00	0.06	0.00	0.00	0.01	0.01	-0.00	-0.00	-0.02	-0.00	0.00	-0.00	-0.00	0.00	-0.00	-0.00	-0.00	-0.00	-0.00
sd	0.04	0.07	0.02	0.04	0.02	0.54	0.16	0.12	0.21	0.12	0.05	2.00	3.61	0.02	0.01	0.02	0.02	0.01	0.03	0.02	0.02	0.01	0.02
skew	0.33	0.08	0.27	-0.05	0.52	2.64	-0.67	-0.55	0.50	-0.79	0.30	0.93	1.28	-0.06	0.21	-0.19	0.04	0.03	0.43	-0.12	0.01	0.21	0.52
kurtosis	10.36	6.88	9.03	9.95	10.80	50.16	13.82	11.06	20.32	9.44	13.63	10.05	20.85	5.42	7.15	4.76	5.82	5.44	4.98	5.22	5.52	7.90	8.67
0%	-0.28	-0.29	-0.11	-0.29	-0.12	-4.51	-1.24	-0.78	-1.66	-0.82	-0.28	-10.94	-19.80	-0.07	-0.05	-0.07	-0.06	-0.05	-0.09	-0.10	-0.07	-0.05	-0.07
1%	-0.12	-0.21	-0.07	-0.12	-0.07	-1.24	-0.46	-0.34	-0.60	-0.32	-0.18	-4.64	-10.10	-0.05	-0.03	-0.04	-0.04	-0.04	-0.07	-0.05	-0.05	-0.04	-0.05
99%	0.13	0.22	0.06	0.12	0.07	1.71	0.39	0.33	0.56	0.31	0.18	6.35	8.74	0.04	0.03	0.04	0.04	0.03	0.07	0.04	0.04	0.03	0.05
100%	0.24	0.32	0.13	0.27	0.15	7.03	0.86	0.59	1.76	0.42	0.36	12.79	30.90	0.10	0.09	0.07	0.09	0.07	0.16	0.09	0.10	0.10	0.15

Table 7: Descriptive statistics of spread changes, first differences of the VSTOXX (VSTX), KfW spread, financial sector risk (RP), and country stock market returns in different subsamples.

Bibliography

Aizenman, J., Hutchison, M., and Jinjarak, Y. (2013). What is the risk of European sovereign debt defaults? Fiscal space, CDS spreads and market pricing of risk. *Journal of International Money and Finance*, 34(C):37–59.

Ang, A. and Longstaff, F. (2013). Systemic sovereign credit risk: Lessons from the U.S and Europe. *Journal of Monetary Economics*, 60(5):493–510.

Arghyrou, M. and Kontonikas, A. (2012). The EMU sovereign-debt crisis: Fundamentals, expectations and contagion. *Journal of International Financial Markets, Institutions and Money*, 22(4):658–677.

Attinasi, M.-G., Checherita, C., and Nickel, C. (2009). What Explains the Surge in Euro Area Sovereign Spreads during the Financial Crisis of 2007-09? European Central Bank Working Paper No. 1131.

Bae, K.-H., Karolyi, G., and Stulz, R. (2003). A new approach to measuring financial contagion. *Review of Financial Studies*, 16(3):717–763.

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

Beber, A., Brandt, M., and Kavajecz, K. (2009). Flight-to-quality or flight-to-liquidity? Evidence from the euro-area bond market. *Review of Financial Studies*, 22:925–957.

Beirne, J. and Fratzscher, M. (2013). The pricing of sovereign risk and contagion during the European sovereign debt crisis. *Journal of International Money and Finance*, 34:60–82.

Bernoth, K. and Erdogan, B. (2012). Sovereign bond yield spreads: A time-varying coefficient approach. *Journal of International Money and Finance*, 31(3):639–656.

Bernoth, K., von Hagen, J., and Schuknecht, L. (2004). Sovereign risk premia in the European government bond market. European Central Bank Working Paper No. 369.

Bernoth, K. and Wolff, G. (2008). Fool the markets? Creative Accounting, Fiscal Transparency and Sovereign Risk Premia. *Scottish Journal of Political Economy*, 55(4):465–487.

Calvo, S. and Reinhart, C. (1996). Capital flows to Latin America: Is there evidence of contagion effects? World Bank Policy Research Working Paper 1619.

Caporin, M., Pelizzon, L., Ravazzolo, F., and Rigobon, R. (2014). Measuring sovereign contagion in Europe. Technical report, Syrto Working Paper Series.

Carrion-i Silvestre, J. L., Kim, D., and Perron, P. (2009). Gls-based unit root tests with multiple structural breaks under both the null and the alternative hypotheses. *Econometric Theory*, 25(06):1754–1792.

Codogno, L., Favero, C., and Missale, A. (2003). Yield spreads on EMU government bonds. *Economic Policy*, 37:503–532.

De Grauwe, P. and Ji, Y. (2013). Self-fulfilling crises in the Eurozone: An empirical test. *Journal of International Money and Finance*, 34:15–36.

De Santis, R. (2014). The euro area sovereign debt crisis: Identifying flight-to-liquidity and the spillover mechanisms. *Journal of Empirical Finance*, 26:150–170.

Dungey, M., Fry, R., González-Hermosillo, B., and Martin, V. (2005). Empirical modelling of contagion: a review of methodologies. *Quantitative Finance*, 5(1):9–24.

Elliott, G., Rothenberg, T. J., and Stock, J. H. (1996). Efficient tests for an autoregressive unit root. *Econometrica*, 64(4):813–836.

Faini, R. (2006). Fiscal policy and interest rates in Europe. *Economic Policy*, 21(47):443–489.

Favero, C., Pagano, M., and von Thadden, E.-L. (2010). How does liquidity affect government bond yields? *Journal of Financial and Quantitative Analysis*, 45:107–134.

Forbes, K. (2012). The Big C: Identifying and mitigating contagion. Technical report, MIT Sloan School Working Paper 4970-12.

Forbes, K. and Rigobon, R. (2002). No Contagion, Only Interdependence: Measuring Stock Market Comovements. *The Journal of Finance*, 5:2223–2261.

Giordano, R., Pericoli, M., and Tommasino, P. (2013). Pure or wake-up-call contagion? Another look at the EMU sovereign debt crisis. *International Finance*, 16(2):131–160.

Goldstein, M. (1998). The Asian financial crisis: causes, cures, and systemic implications. *Policy Analyses in International Economics*, 55.

Gómez-Puig, M. and Sosvilla-Rivero, S. (2014). Causality and contagion in EMU sovereign debt markets. *International Review of Economics & Finance*, 33:12–27.

González-Hermosillo, B. and Johnson, C. (2014). Transmission of financial stress in Europe: The pivotal role of Italy and Spain, but not Greece. IMF Working Paper Series, No. 76.

Gündüz, Y. and Kaya, O. (2014). Impacts of the financial crisis on eurozone sovereign CDS spreads. *Journal of International Money and Finance*, 49(B):425–442.

King, M. and Wadhwani, S. (1990). Transmission of volatility between stock markets. *Review of Financial Studies*, 3(1):5–33.

Longstaff, F., Pan, J., Pedersen, L., and Singleton, K. J. (2011). How sovereign is sovereign credit risk? *American Economic Journal: Macroeconomics*, 3(2):75–103.

Ludwig, A. (2014). A unified approach to investigate pure and wake-up-call contagion: evidence from the eurozone's first financial crisis. *Journal of International Money and Finance*, 48(A):125–146.

Manganelli, S. and Wolswijk, G. (2009). What drives spreads in the euro area government bond market? *Economic Policy*, 24(58):191–240.

Martin, V., Hurn, S., and Harris, D. (2012). *Econometric modelling with time series: specification, estimation and testing*. Cambridge University Press.

Masson, P. (1999). *The Asian Financial Crisis: Causes, Contagion and Consequences*, chapter contagion: monsoonal effects, spillovers, and jumps between multiple equilibria. Cambridge University Press, Cambridge, UK.

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

Ng, S. and Perron, P. (2001). Lag length selection and the construction of unit root tests with good size and power. *Econometrica*, 69(6):1519–1554.

Pericoli, M. and Sbracia, M. (2003). A Primer on Financial Contagion. *Journal of Economic Surveys*, 17(4):571–608.

Perron, P. (1989). The great crash, the oil price shock, and the unit root hypothesis. *Econometrica*, 57:1361–1401.

Perron, P. and Ng, S. (1996). Useful modifications to some unit root tests with dependent errors and their local asymptotic properties. *The Review of Economic Studies*, 63(3):435–463.

Pesaran, M. and Pick, A. (2007). Econometric issues in the analysis of contagion. *Journal of Economic Dynamics and Control*, 31(4):1245–1277.

Phillips, P. (1988). Regression theory for near-integrated time series. *Econometrica*, 56(5):1021–1043.

Samitas, A. and Tsakalos, I. (2013). How can a small country affect the European economy? The Greek contagion phenomenon. *Journal of International Financial Markets, Institutions and Money*, 25:18–32.

Sargan, J. (1958). The estimation of economic relationships using instrumental variables. *Econometrica*, 26:393–415.

Sibbertsen, P., Wegener, C., and Basse, T. (2014). Testing for a break in the persistence in yield spreads of EMU government bonds. *Journal of Banking & Finance*, 41:109–118.

Stock, J. and Watson, M. (1988). Testing for common trends. *Journal of the American Statistical Association*, 83(404):1097–1107.

Vasicek, O. (1977). An equilibrium characterization of the term structure. *Journal of Financial Economics*, 5(2):177–188.

Wu, Y. and Zhang, H. (1996). Mean reversion in interest rates: New evidence from a panel of OECD countries. *Journal of Money, Credit and Banking*, 28:604–621.

Zivot, E. and Andrews, D. (1992). Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. *Journal of Business & Economic Statistics*, 10(3):251–270.