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THE PRICING OF SOVEREIGN RISK AND CONTAGION DURING THE EUROPEAN SOVEREIGN DEBT CRISIS

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Abstract

The paper analyses the drivers of sovereign risk for 31 advanced and emerging economies during the European sovereign debt crisis. It shows that a deterioration in countries' fundamentals and fundamentals contagion – a sharp rise in the sensitivity of financial markets to fundamentals – are the main explanations for the rise in sovereign yield spreads and CDS spreads during the crisis, not only for euro area countries but globally. By contrast, regional spillovers and contagion have been less important, including for euro area countries. The paper also finds evidence for herding contagion – sharp, simultaneous increases in sovereign yields across countries – but this contagion has been concentrated in time and among a few markets. Finally, empirical models with economic fundamentals generally do a poor job in explaining sovereign risk in the pre-crisis period for European economies, suggesting that the market pricing of sovereign risk may not have been fully reflecting fundamentals prior to the crisis.

JEL No: E44, F30, G15, C23, H63

Keywords: Sovereign risk, contagion, sovereign debt crisis, bond spreads, CDS spreads, ratings.

Non-technical summary

The European sovereign debt crisis initially came as a surprise to most observers and policy-makers. Economic growth was generally strong, fiscal deficits limited and public debt levels were rising only modestly in most of Europe prior to the 2007-08 global financial crisis, in particular among those euro area countries that are now engulfed most intensely in the subsequent debt crisis. This has spurred some observers and policy-makers to argue that financial markets have been overreacting and overpricing sovereign risk since the 2007-08 crisis, and that this overreaction is due to contagion, in particular from the most affected countries, such as Greece, to other more innocent or prudent bystanders. Indeed, Constâncio (2012) makes the point that *"Without denying that imprudent fiscal behavior and lack of effort to maintain the competitiveness of countries are deep origins of the European sovereign debt crisis, I will argue that contagion phenomena play a crucial role in exacerbating the problems"*.

To what extent have financial markets been overpricing sovereign risk in the euro area during the European sovereign debt crisis? And what has been the role of contagion for sovereign risk? The paper critically examines these questions for a broad set of 31 advanced economies (AEs) and emerging market economies (EMEs) by empirically modeling the link between three measures of sovereign risk (long-term government spreads, CDS spreads and ratings of sovereigns) and economic fundamentals over the period 2000 to 2011. Although our focus is on the European sovereign debt crisis, our analysis is carried out across 31 advanced and emerging economies to enable us to assess the pricing of sovereign risk in the euro area periphery countries under stress in a coherent framework relative to other economies. While there is a number of ways in which contagion can be defined in the literature, the concept essentially relates to an excess spillover, one which goes beyond what can be explained by economic fundamentals, or one whereby the transmission mechanism changes in crisis compared to tranquil times (see Constâncio (2012) for further details). Taking this into account, contagion is defined as the *change* in the way countries' own fundamentals or other factors are priced during a crisis period, i.e. a change in the reaction of financial markets either in response to observable factors, such as changes in sovereign risk among neighboring countries, or due to unobservables, such as herding behavior of market participants.

Our findings suggest that country-specific fundamentals had less importance for the pricing of sovereign risk in the euro area during the pre-crisis period compared to other economies. The empirical analysis of the paper shows that the price of sovereign risk has been much more sensitive to fundamentals and that fundamentals explain a substantially higher share of the movements and cross-country differences in sovereign risk during the 2008-2011 crisis than in the pre-crisis period. Applying a counterfactual analysis for the crisis period shows that sovereign yields and CDS spreads would have been much more dispersed before 2007, in particular among euro area countries, if markets had priced fundamentals in the pre-crisis period in the same way that they did in 2008-11.

What explains these disparities and shift in the pricing of sovereign debt during the 2008-11 period? There are three different conceptual reasons for such a change. First, market participants may come to price the same fundamentals in a different way over time. While they may have ignored cross-country differences or changes in country-specific fundamentals during some periods, they may react a lot more strongly during a crisis period. This is what the literature has referred to as "wake-up call" contagion or fundamentals contagion (Goldstein 1998, Bekaert et al. 2010). Second, the pricing of

sovereign risk may have been affected by cross-country contagion, i.e. the transmission of a negative sovereign shock in countries such as Greece may have raised the price of sovereign risk in other, related countries. The third conceptual reason for changes in the pricing of sovereign risk relates to herding behavior or panic among investors. We find evidence that regional contagion has not been important during the 2008-11 sovereign debt crisis in Europe. Interestingly, the estimates indicate that the cross-country spillovers of sovereign risk were stronger prior to the crisis than during the crisis. In other words, while financial markets tended to price sovereign risk within a region, in particular within the euro area, in a similar way, irrespective of differences across countries' fundamentals, they started to discriminate on the basis of fundamentals more strongly during the crisis. Moreover, even after accounting for "fundamentals contagion" and "regional contagion", there is a substantial part of the increase in the price of sovereign risk in 2008-11 that remains unexplained and that points to the importance of "pure contagion".

For the last part of the analysis, we try to quantify the importance of each of the three types of contagion for the pricing of sovereign risk during the 2008-11 sovereign debt crisis. A first important finding in this regard is that most of the increase in the price of sovereign risk during the 2008-11 sovereign debt crisis among euro area countries that experienced tensions in the sovereign bond market, and other euro area countries, was due to a deterioration in countries' fundamentals and fundamentals contagion. By contrast, regional contagion and spillovers were relatively unimportant overall while also pure contagion played a small, but limited role. In fact, we find strong evidence for a decoupling among European sovereign debt markets during the crisis, with changes in one country's sovereign debt being transmitted to neighboring countries much less intensely during the crisis than compared to before the crisis. Overall, therefore, the findings suggest that the deterioration of fundamentals and fundamentals contagion are the prime explanations for the sharp rise in sovereign risk during the European sovereign debt crisis.

Our paper was written in the context of addressing the notion among some observers and policy-makers that financial markets have overreacted during the crisis and that sovereign risk is mis-priced or has become "over-priced", especially for the euro area periphery economies, i.e. those economies experiencing sovereign bond market tensions (Greece, Ireland, Portugal, Spain and Italy). It is very hard to evaluate such a normative claim as any statement about a mispricing requires having a precise definition of what an adequate, equilibrium pricing of risk should imply. In fact, the empirical findings suggest that there have been substantial and sustained differences in the pricing of fundamentals for sovereign risk among euro area countries before and during the crisis, suggesting the presence of multiple equilibria in this relationship. At the same time, the question which of these equilibria are sustainable ones and ones that are attainable by policy is a crucial issue from a policy perspective as it determines what policy could or should do to deal with financial markets' pricing of countries' sovereign risk. While we are very cautious in stressing the limits of any normative interpretation, using different benchmarks our analysis suggests that financial markets may not have fully priced in countries' fundamentals and thus may have under-priced sovereign risk in the euro area during the pre-crisis period.

1. Introduction

The European sovereign debt crisis initially came as a surprise to most observers and policy-makers. Economic growth was generally strong, fiscal deficits limited and public debt levels were rising only modestly in most of Europe prior to the 2007-08 global financial crisis, in particular among those euro area countries that are now engulfed most intensely in the subsequent debt crisis. This has spurred some observers and policy-makers to argue that financial markets have been overreacting and overpricing sovereign risk since the 2007-08 crisis, and that this overreaction is due to contagion, in particular from the most affected countries, such as Greece, to other more innocent or prudent bystanders.

The question about the drivers of sovereign risk is important also from a longer-term policy perspective in order to understand how policy can react to the challenges of the sovereign debt crisis and the great global recession in the next decade. As Reinhart and Rogoff (2011a, p.3) argue: "The combination of high and climbing public debts (a rising share of which is held by major central banks) and the protracted process of private deleveraging makes it likely that the ten years from 2008 to 2017 will be aptly described as a decade of debt."

To what extent have financial markets been overpricing sovereign risk in the euro area during the European sovereign debt? And what has been the role of contagion for sovereign risk? The paper critically examines these questions for a broad set of 31 advanced economies (AEs) and emerging market economies (EMEs) by empirically modeling the link between three measures of sovereign risk (long-term government spreads, CDS spreads and ratings of sovereigns) and economic fundamentals over the period 2000 to 2011. Although our focus is on the European sovereign debt crisis, our analysis is carried out across 31 advanced and emerging economies to enable us to assess the pricing of sovereign risk in the euro area periphery countries under stress relative in a coherent framework relative to other economies. While there is a number of ways in which contagion can be defined in the literature (see Constâncio (2012) for further details), the concept essentially relates to an excess spillover, one which goes beyond what can be explained by economic fundamentals (e.g. Eichengreen, Rose, and Wyplosz (1996) and Bekaert, Harvey and Ng (2005)), or one whereby the transmission mechanism changes in crisis compared to tranquil times (e.g. Forbes and Rigobon (2002)). Taking this into account, contagion is defined as the *change* in the way countries' own fundamentals or other factors are priced during a crisis period, i.e. a change in the reaction of financial markets either in response to observable factors, such as changes in sovereign risk among neighboring countries, or due to unobservables, such as herding behavior of market participants.

We motivate the empirical analysis for the determinants of sovereign yields through a standard definition of sovereign risk as reflecting credit risk, liquidity risk and risk appetite. Based on this conceptual framework, the first part of the analysis highlights that if one takes the relationship between fundamentals and sovereign risk during the pre-crisis period 2000-07 as the true relationship, then sovereign risk is indeed substantially overpriced in many Europeans economies, and in particular among the euro area periphery economies, i.e. those economies experiencing sovereign bond market tensions (Greece, Ireland, Portugal, Spain and Italy), but not for many EMEs, especially outside Europe. However, it is striking that those fundamentals that one would expect to be the most important determinants for the price of sovereign risk – the public debt level, fiscal deficit, growth and the current account – explain very little of the pricing of risk in euro

area periphery countries before the crisis, but have much more explanatory power for sovereign risk in other AEs and EMEs. In fact, the most important determinant for the price of sovereign debt in the euro area periphery countries in the pre-crisis period was the price of public debt among other European countries, such as that of Germany. And indeed, the small spreads and very high comovements of sovereign yields within the euro area suggest that other factors than fundamentals may have been the prime determinants of sovereign debt in Europe before the crisis.[1]

This finding thus suggests that country-specific fundamentals had less importance for the pricing of sovereign risk in the euro area during the pre-crisis period compared to other economies. The empirical analysis of the paper shows that the price of sovereign risk has been much more sensitive to fundamentals and that fundamentals explain a substantially higher share of the movements and cross-country differences in sovereign risk during the 2008-2011 crisis than in the pre-crisis period. Applying this counterfactual analysis for the crisis period shows that sovereign yields and CDS spreads would have been much more dispersed before 2007, in particular among euro area countries, if markets had priced fundamentals in the pre-crisis period in the same way that they did in 2008-11. In fact, there is a negative correlation between the "mispricing" of sovereign risk – i.e. the deviation of actual market prices of risk from those implied by empirical models based on fundamentals – during the crisis and in the pre-crisis period. In other words, those countries for which sovereign risk was "underpriced" in the pre-crisis period were also those that became "overpriced" relative to economic fundamentals during the crisis.

The findings raise the question of what constitutes a "fair" pricing of sovereign risk and an over-pricing or under-pricing of such risk.[2] A basic intertemporal budget constraint for a government highlights the importance of expectations for determining the sensitivity of the pricing of sovereign risk – market expectations about the future primary balance, debt level, inflation, as well as about a government's willingness and ability serve debt all influence how markets price existing fundamentals that are relevant for the sustainability of public debt. As such, the empirical findings of the paper suggest that there may be multiple equilibria between the market price of sovereign risk and underlying fundamentals, which depend on existing market expectations.

What explains these disparities and shift in the pricing of sovereign debt during the 2008-11 period? There are three different conceptual reasons for such a change. First, market participants may come to price the same fundamentals in a different way over time. While they may have ignored cross-country differences or changes in country-specific fundamentals during some periods, they may react a lot more strongly during a crisis period. This is what the literature has referred to as "wake-up call" contagion or fundamentals contagion (Goldstein 1998, Bekaert et al. 2010). In fact, the findings indicate that for some countries, such as the euro area periphery economies, there is

[1] Some have speculated that a market perception of an implicit bail-out guarantee, or simply ignorance among financial market participants to country-specific fundamentals may be the main explanations for this comovement. We stress that the paper cannot provide an answer to the precise reasons for this high comovements in the pre-crisis period.

[2] We stress that the terms "overpricing" and "underpricing" as used throughout the paper with regard to sovereign risk should not necessarily be interpreted in a normative sense, because such a normative interpretation would require making a statement about what the "true" pricing of risk should be.

strong evidence in favor of this "wake-up call" contagion, though for other countries there is much less of such evidence.

Second, the pricing of sovereign risk may have been affected by cross-country contagion, i.e. the transmission of a negative sovereign shock in countries such as Greece may have raised the price of sovereign risk in other, related countries. We refer to this as "regional contagion" following the argument of some that such a transmission across countries was particularly important within the euro area in 2008-11. The third conceptual reason for changes in the pricing of sovereign risk relates to herding behavior or panic among investors. The literature refers to this type of contagion often as "pure contagion" or herding contagion. It is the most difficult type of contagion to measure empirically, as it at least partly reflects factors that are unobservable to the economic modeler. Yet it may also be the most difficult one to address for policy-makers as using firewalls, financial support and improving fundamentals may be insufficient to fully address it.

We find evidence that regional contagion has not been important during the 2008-11 sovereign debt crisis in Europe. Interestingly, the estimates indicate that the cross-country spillovers of sovereign risk were stronger prior to the crisis than during the crisis. In other words, while financial markets tended to price sovereign risk within a region, in particular within the euro area, in a similar way, irrespective of differences across countries' fundamentals, they started to discriminate on the basis of fundamentals more strongly during the crisis. Moreover, even after accounting for "fundamentals contagion" and "regional contagion", there is a substantial part of the increase in the price of sovereign risk in 2008-11 that remains unexplained and that points to the importance of "pure contagion".

To get at the role of pure contagion, we analyze the comovements of that part of the price of sovereign risk that cannot be explained by either changes in fundamentals, by fundamentals contagion or by regional contagion. Following the approach of Boyson, Stahel and Stulz (2010), we analyze the clustering in time of large unexplained changes in the pricing of sovereign risk. We find that there is indeed some evidence of such clustering among euro area countries, but that this occurred at the height of the global financial crisis in 2008 and mostly not during 2010 and 2011 with the exception of July-September 2011 when 70% of euro area countries experienced sharp increases in the pricing of their sovereign risk. However, this period was very short, indicating that herding contagion can help explain the overall dynamics of sovereign risk to a very limited extent.

For the last part of the analysis, we try to quantify the importance of each of the three types of contagion for the pricing of sovereign risk during the 2008-11 sovereign debt crisis. A first important finding in this regard is that most of the increase in the price of sovereign risk during the 2008-11 sovereign debt crisis among euro area periphery countries and other euro area countries was due to a deterioration in countries' fundamentals and fundamentals contagion. By contrast, regional contagion and spillovers were relatively unimportant overall while also pure contagion played a small, but limited role. In fact, we find strong evidence for a decoupling among European sovereign debt markets during the crisis, with changes in one country's sovereign debt being transmitted to neighboring countries much less intensely during the crisis than compared to before the crisis. Overall, therefore, the findings suggest that the deterioration of fundamentals and fundamentals contagion are the prime explanations for the sharp rise in sovereign risk during the European sovereign debt crisis.

The paper is organized as follows. Section 2 discusses the related academic literature on modeling the pricing of sovereign risk. Section 3 describes the methodology to measure the impact of fundamentals, regional risk and contagion on the price of sovereign risk, while section 4 describes the data and presents a number of stylized facts about the evolution of sovereign risk during the crisis. Section 5 outlines the main empirical results and various extensions. Finally, Section 6 summarizes the findings and discusses implications for the policy discussion.

2. Related literature

A range of previous papers has analyzed the determinants of the pricing of sovereign risk. Early studies tended to focus on government bond yield spreads as the reference measure for sovereign risk, and also on explaining sovereign risk in emerging economies, e.g. Ferrucci (2003). More recent work also included examining sovereign CDS spreads and sovereign ratings. An early study of the factors driving government bond spreads was carried out by Edwards (1984), who found that domestic macroeconomic fundamentals were important determinants, including factors such as the public debt, foreign reserves, the current account balance and inflation. More recently, Aizenman, Hutchinson and Jinjarak (2011), focusing on pricing sovereign risk for 60 economies based on CDS spreads, find evidence of mis-pricing in the euro area periphery relative to a set of macroeconomic fundamentals comprised of public debt, fiscal balance, trade openness, external debt, inflation and the TED spread (see also Amato, 2005; Packer and Zhu, 2005; Cecchetti et al, 2010).

One of the first empirical studies on the determinants of sovereign credit ratings was carried out by Cantor and Packer (1996), who focused on an examination of both the criteria underlying ratings and their impact on sovereign borrowing costs. They found that ratings can be explained by per capita income, GDP growth, inflation, external debt, the level of economic development, and the default history. Amadou (2001) focused on bond spreads and sovereign credit ratings in emerging economies, highlighting differences between the market and rating agency perception of the price of sovereign risk. Afonso et al. (2007) assess the determinants of sovereign debt credit ratings using a panel estimation and probit model over the period 1995 to 2005. They find that the sovereign credit rating is a function of GDP per capita, GDP growth, government debt, government effectiveness indicators, external debt, external reserves, and default history.[3] Doetz and Fischer (2010) focus on euro area countries, explaining how the volatility in sovereign bond spreads is indicative of a rise in market perception of default probability. Manganelli and Wolswijk (2007) assess the determinants of euro area sovereign spreads after the introduction of the euro. The paper was written in the context of historically low spreads in the euro area since 1999 despite adverse fiscal situations and developments in many countries. The underlying market perception was that financial integration in the euro area eliminated markets' willingness / ability to discriminate between the creditworthiness of different national fiscal policies. A particular focus is on whether market discipline is advanced or

[3] Afonso et al (2007) also highlight the difficulty in modeling sovereign spreads. Firstly, as the ratings are ordinal qualitative measures, a linearity is assumed between rating levels. While a probit modeling technique would appear to be the most appropriate model given the nature of the rating measure, a very large sample would be needed for asymptotic robustness. To attain sufficient power, they argue that a panel model with country-specific effects is the best approach.

obstructed by financial integration and by fiscal rules such as those contained in the Stability and Growth Pact. Using a fixed-effects panel model, these authors also provide strong empirical evidence that spreads depend on the ratings of the underlying bond and to a large extent are driven by the level of short-term interest rates. Attinasi, Checherita and Nickel (2009) use a dynamic panel approach to explain the determinants of widening sovereign spreads in the euro area over the period 2007 to 2009, finding an important role played by budget deficits and government debt ratios relative to Germany.

As well as understanding the drivers of the price of sovereign risk, some more recent papers have examined the issue of capital flows into government bond markets. For example, in recent years the bond market has experienced much greater inflows of capital, notably from emerging to advanced economies, which has helped to suppress US bond yields (e.g. Hauner and Kumar, 2009). In addition, Baldacci and Kumar (2010) make the point that the greater integration of government bond markets globally has enabled a more efficient pricing of sovereign risk and better facilitated price discovery. A further strand of the literature examines whether the sovereign risk of particular economic regions is perceived differently by the market. Hauner et al (2010) assess whether rating agencies and investors perceived the sovereign risk of the new EU Member States to be different to that of other emerging markets. They found that higher policy credibility owing to EU membership helped led to a lower perceived sovereign risk of the new EU Member States compared to other emerging economies. As regards the issue of the crisis, there is an emerging academic literature. For example, Schuknecht, Von Hagen and Wolswijk (2010) make the interesting point that while bond yield spreads in the euro area before and during the crisis can be largely explained by fundamentals, the market has penalized fiscal imbalances much more harshly in the period after the collapse of Lehman Brothers.

More recent research has focused on contagion effects linked to the European sovereign debt crisis. While some of this research has examined spillovers and contagion between sovereigns and banks (e.g. Alter and Beyer (2013), Gross and Kok (2013)), other papers have examined the determinants of sovereign spreads. For example, D'Agostino and Ehrmann (2013) model the determinants of sovereign spreads using a time-varying stochastic volatility model for the G7 economies. While a strong role is found for economic fundamentals, these authors also note that risk appears to have been mis-priced for the G7 economies both before and during the European sovereign debt crisis. Other recent work on contagion has stressed the importance of time variation. For example, Favero and Missale (2012) make the point that fiscal fundamentals have a greater role to play in driving the price of sovereign risk in periods of high global risk aversion. Another strand of this growing literature focuses on the role played by sovereign credit ratings announcements. De Santis (2012), for example, finds contagious effects in the euro area linked to ratings. In particular, he finds that the rating downgrade in Greece contributed to a widening in sovereign spreads in other euro area countries with weaker economic fundamentals, i.e. Ireland, Portugal, Italy, Spain, Belgium and France.

The European sovereign debt crisis that began to intensify during 2010 has called into question the extent to which the price of sovereign risk reflects macroeconomic fundamentals. Where the price of sovereign risk cannot be explained by fundamentals, this would suggest that the risk is driven by other factors, such as financial market sentiment or contagion. Our analysis builds on the previous literature by providing an assessment of the extent to which sovereign risk may be mis-priced, looking in particular at emerging and advanced economies in both non-crisis and crisis regimes. In addition,

we assess whether sovereign risk mis-pricing spills over to other regions in crisis compared to non-crisis times.

3. Methodology

The starting point to motivate the empirical analysis for the determinants of sovereign yields is a standard definition of sovereign risk as reflecting credit risk, liquidity risk and risk appetite:

$$r_t = (1-P(X_t))(1-\mu_t)+\Omega_t+\Phi_t \quad (1)$$

where r_t is the sovereign yield of a particular country relative to a risk-free asset, $1\text{-}P(X_t)$ the probability of default, $(1\text{-}\mu_t)$ the loss given default, Ω_t a risk premium and Φ_t the liquidity premium. This raises the question about which fundamentals determine these three terms, and thus influence the price of sovereign risk. To gauge this, it is useful to think of a basic intertemporal budget constraint for a government:

$$\sum_{j=0}^{\infty} E_t\left[\frac{\tau_{t+j}-g_{t+j}+s_{t+j}+T_{t+j}}{(1+r)^j}\right] \geq \frac{M_{t-1}+D_{t-1}}{P_t} \quad (2)$$

where the numerator on the left-hand-side is the primary government balance (τ tax revenue, s seignorage, T transfers, g primary expenditures), M the money stock, D the public debt level, and P the price level. The important point here, to which we will return further below, is that expectations may play a central role in determining fiscal sustainability, thus giving rise to multiple equilibria in the relationship between fundamentals and the price of sovereign risk r.

Based on this conceptual framework, we examine the determinants of the pricing of sovereign risk both in non-crisis and crisis states for a range of advanced and emerging economies, using a standard panel model with country fixed effects (building on a common approach in the literature, e.g. Edwards 1984, Hauner et al 2010). In its most simple form, the approach is based on the following models:

$$s_{i,t} = \alpha_0 + \alpha_i + \beta_1 X_{i,t} + \gamma_1 S_{j,t} + \varepsilon_{i,t} \quad (3)$$

We extend this benchmark specification to allow for a shift in the parameters over time, and in particular during crisis times, in the following way:

$$s_{i,t} = \alpha_0 + \alpha_i + \beta_1 X_{i,t} + \gamma_1 S_{j,t} + (\delta_0 + \delta_i + \beta_2 X_{i,t} + \gamma_2 S_{j,t})D_t^C + \varepsilon_{i,t} \quad (4)$$

where $s_{i,t}$ represents the price of sovereign risk (which can either be government bond spreads relative to a benchmark rate, CDS spreads relative to a benchmark, or sovereign credit risk ratings), $X_{i,t}$ represents a set of economic fundamentals, and D^C is a crisis dummy taking the value of one in the period after the collapse of Lehman Brothers in September 2008.[4] $S_{j,t}$ is the regional price of sovereign risk for the region in which

[4] We choose this starting date for the crisis, though one could also take a later date, such at the end of 2009 when tensions in European sovereign debt markets intensified. In the empirical analysis, however, it turns out that the empirical estimates are quite robust to changing the precise starting point.

country i is located and excludes country i itself. In the benchmark specification, this regional risk is simply an unweighted average of the price of sovereign risk in other regional economies, while in the extensions the model also allows for a transmission across different prices of sovereign risk (e.g. from ratings to bond yields), either domestically or regionally.

α_i and δ_i are country-specific fixed effects, and as common intercepts are included as well, these are country-specific deviations from the common intercepts. Note that equation (3) is a representation of sovereign risk for a particular time period, while equation (4) extends this framework to allow for a change in the pricing of fundamentals and of regional risk during the crisis period. The estimation is done via OLS with robust standard errors, and at monthly data frequency.

As is common in the literature, contagion is defined as the *change* in the way countries' own fundamentals or regional risk are priced during a particular period, i.e. a change in the reaction of financial markets either in response to observable factors, such as changes in sovereign risk among neighboring countries, or due to unobservables, such as herding behavior of market participants.

Conceptually, there are five sources for changes in the pricing of sovereign risk. The first one is a change in fundamentals $X_{i,t}$ or a change in the regional risk $S_{j,t}$, e.g. with a deterioration of the quality of fundamentals or a rise in regional risk driving up the price of sovereign risk. In our terminology, none of these two factors is referred to as contagion as the pricing of the factors is unchanged from the pre-crisis period.

A second source is a change in the way financial markets price a particular fundamental during the crisis, as markets may, for example, become more sensitive to the same fundamental during the crisis (as measured by parameters β_2). This is what the literature has referred to as "wake-up call" contagion or fundamentals contagion. A third source is related to the pricing of regional risk $S_{j,t}$ (indicated by parameters γ_2), with a change in this pricing what we refer to as "regional contagion", i.e. an intensification in the cross-country transmission of sovereign risk.

A fourth reason for changes in the pricing of sovereign risk is the country-specific fixed effects during the crisis δ_i. It is hard to gauge what these country-specific effects measure. It may be that they reflect a change in unobservable fundamentals during the crisis, or alternatively a change in the sensitivity with which unobservable factors are priced. In the former case, we would not refer to this phenomenon as contagion, while the latter would indeed imply contagion. Nevertheless, since these terms are constant over time (allowing for a discrete change during the crisis) none of these two descriptions may be entirely plausible, and a better way to describe them is merely as country risk premia.

The fifth source for changes in the pricing of sovereign risk is a shift in the residual $\varepsilon_{i,t}$. While the residuals in equations (3) and (4) are unsystematic components of the pricing of risk, they may nevertheless provide an indication of herding contagion across countries at certain points in time. Following the approach of Boyson, Stahel and Stulz (2010), we analyze the clustering across countries of large unexplained changes in the pricing of sovereign risk. Herding contagion is present if there are large positive residuals simultaneously, at the same point in time, in several countries. More precisely, we look at the distribution of the residuals of equation (4), and extract those that lie in the top 10^{th}

percentile of each country's distribution. If the residuals were uncorrelated across countries, then in each period *t* about 10% of the residuals of all countries should be in their respective top decile. However, if we find a substantial clustering in the number of countries with large unexplained increases in the pricing of sovereign risk, it is indicative of what we refer to as "pure contagion" or herding contagion.

There are a number of points that need emphasising. A first one is that the choice of the empirical model for the pricing of sovereign risk is far from uncontroversial as there is a multitude of potential fundamentals that may influence the sustainability of debt and thus the price of sovereign risk. As we will explain in the next section, our aim is to stay as close as possible to the literature in the specification of the empirical model, though we conduct a number of robustness tests with additional determinants.

A second point relates to the spillover of changes in prices of sovereign risk. The framework of equations (3) and (4) allows only for the transmission within the same region and within the same asset class (e.g. within the government bond market, or within the CDS market), while a transmission may also occur across market segments and across regions. In extensions to the benchmark specification below, we are particularly interested in cross-market spillovers, such as, for example, whether changes in sovereign ratings are particularly important in driving bond yield spreads or CDS prices, both within countries and across countries.

A third point refers to the question of whether the price of sovereign risk is truly exogenous to the fundamentals included in the model. In particular during the European sovereign debt crisis, it has been obvious that a rise in sovereign spreads has adversely affected confidence and thus may have also exerted an effect on fundamentals. While it is likely that such a transmission has been present, it does not seem plausible that such effects materialise immediately, within the same month.

Finally, it is likely that there is heterogeneity in the way financial markets price fundamentals across countries. To test for such heterogeneity, after estimating the benchmark models (3) and (4), we also provide estimates for various country groups and subsamples in order to gauge the extent and potential pattern of such heterogeneity.

4. Data and stylized facts

This section discusses the choice of data and presents some stylized facts on the evolution of sovereign risk over the past decade.

A first crucial issue is the definition of sovereign risk. Our approach is to take a financial market perspective and analyze how financial markets price sovereign risk. More specifically, we analyze three separate financial prices of sovereign risk – the government bond yield spreads (relative to 3-month money market rates), sovereign CDS spreads, and Standard & Poors sovereign credit ratings. As is common in the literature, sovereign ratings are transformed linearly into a numerical format, ranging from 1 (AAA) to 20 (default). All of these series are obtained from Bloomberg. Each of the three measures of sovereign risk has its shortcomings. For instance, sovereign yield and CDS spreads may

be influenced by risk premia and liquidity premia,[5] while ratings have a discrete nature, and rating changes may frequently be anticipated by market participants. While we mostly focus on sovereign yield spreads as our preferred measure, we also check for robustness of the findings using the other two measures.

In line with the literature on the determinants of sovereign spreads and ratings (see also discussion above), the country-specific macroeconomic variables are the public debt/GDP ratio, fiscal balance/GDP ratio, real GDP growth, and the current account balance/GDP ratio, while we also include the VIX index to reflect a common global risk factor (as in Hauner et al 2010). Given the lack of availability of some of these variables at a monthly frequency, we follow the literature in this regards using standard interpolation (e.g. Hauner et al, 2010; Dell'Ariccia et al, 2006; Ferrucci, 2003). Data for country-specific fundamentals stems from the IMF's IFS, while the VIX series is taken from Bloomberg. Tables 1 and 2 provide summary statistics for the countries covered, and for the variables of the empirical analysis.

Tables 1 – 2

A crucial choice is the country sample. Our approach is to include as many financially open countries as possible, based on data availability, including emerging markets. Our benchmark sample is for 31 advanced and emerging economies for the period from 1999 until 2011. In order to check for heterogeneity across countries, all of our estimations are conducted both for the whole country sample as well as for sub-samples, distinguishing in particular between euro area countries, EMEs, and other advanced economies (AEs). EMEs in our analysis include Brazil, Bulgaria, Chile, China, Colombia, Hungary, Malaysia, Mexico, Peru, Philippines, Poland, Russia, South Africa, and Turkey. The advanced economies are comprised of the following euro area advanced economies: Belgium, Finland, France, Germany, Netherlands, Greece, Italy, Portugal, Spain, and Ireland; and the following non-euro area advanced economies: Australia, Denmark, New Zealand, Sweden, Switzerland, the United Kingdom, and the United States.

Figures 1 – 2, Table 3

Turning to some key stylized facts, Figure 1 and Table 3 show how the sovereign debt crisis has impacted upon the price of sovereign risk across a range of advanced and emerging economies. The largest rise in the price of sovereign risk is evident in the case of the euro area programme countries, i.e. Greece, Ireland and Portugal. The impact of the sovereign debt crisis appears to have had a much more muted effect in Latin America and Asia, with the price of sovereign risk in fact declining in some countries. Emerging European countries, on the other hand, have experienced some negative reactions, notably in the cases of Hungary and Poland. The other advanced euro area countries have also experienced a rise in the price of sovereign risk as measured by bond spreads and CDS spreads.

Changes in the price of sovereign risk mask the fact that levels of risk may remain fundamentally different across countries. Figures 2 plot the *levels* in sovereign yield

[5] Moreover, sovereign CDS data for a broad cross-section of countries is available only from 2004 onwards.

spreads against sovereign ratings (Figures 2.A – B) and of CDS spreads against sovereign ratings (Figures 2.C – D) before the crisis (in September 2008) and at the end of the sample period in September 2011. Recall that a higher number for sovereign ratings indicates higher risk, i.e. a worse rating. There are two points to note. First, there is a clear relationship between the rating and the market price of sovereign risk, whether measured by government bond yields or by CDS spreads.

A second, and highly intriguing finding is that the pricing of risk for euro area/EMU countries seems to be very different to that of non-EMU countries. In essence, there is no systematic difference in the pricing-rating relationship between EMU countries and non-EMU countries for those with low sovereign risk. However, there is a substantial difference between those EMU countries and non-EMU countries (the latter being EMEs) with high sovereign risk. Before the crisis, differences in yields and CDS spreads across EMU countries were very small, while differences in sovereign ratings were larger – resulting in relatively flat regression lines in Figures 2.A and C for EMU countries. By contrast, during the sovereign debt crisis this relationship shifted substantially. Most importantly, the link between the market price of sovereign risk and ratings became much steeper for EMU countries during the crisis.

How should one interpret this shift in the link between the market price of sovereign risk and sovereign ratings during the crisis? It is hard to provide a definite answer to this question. In principle, there should, at all times, be a fairly close link between the market price of risk and the rating. Of course the two do not proxy the same thing. For instance, yield spreads and CDS spreads are subject to risk and liquidity premia, and may also be affected by adverse market contagion from other countries, factors which presumably do not affect the ratings of sovereigns. However, if the ratings correctly reflect a country's fundamentals, then the steeper sovereign price-rating link for EMU countries compared to non-EMU countries suggests that markets "overprice" the sovereign risk of EMU countries. By contrast, if market prices are "correct" in pricing fundamentals, then this steeper relationship implies that sovereign ratings tend to be too favorable during the crisis for EMU countries relative to non-EMU countries. Such an implication stands in sharp contrast to the widely heard allegations by some policy-makers that rating agencies have exacerbated the European sovereign debt crisis, as the latter interpretation would imply that rating agencies have been too timid in downgrading some EMU countries during the crisis.

The analysis of the pricing of sovereign risk, and the drivers of this pricing and the potential role of contagion is the objective of the remainder of the paper.

5. Empirical results

This section presents and discusses the empirical results. It starts by outlining the empirical results of the benchmark model for the pricing of sovereign risks, then turns to different proxies for the "mis-pricing" of sovereign risk, and concludes by analyzing various potential sources of contagion.

5.1 The benchmark model

As a starting point, we derive a comprehensive yet simple model for the pricing of sovereign risk, which follows standard approaches in the literature, and includes five

fundamental determinants of sovereign risk: public debt to GDP ratio, fiscal balance to GDP ratio, real GDP growth, the current account balance relative to GDP, and finally, as a common determinants, the degree of risk in global financial markets, as proxied by the VIX index. Using this benchmark specification, we estimate model (4) in order to gauge how well this model explains sovereign risk, and equally importantly, whether there is evidence for fundamentals contagion or regional contagion. Tables 4 – 5 provide the estimates for equation (4), showing β_1 and γ_1 for the pre-crisis period and the total effects ($\beta_2 + \gamma_2$) for the crisis period, as well splitting the sample for various country groups.[6]

Tables 4 – 5

The tables yield, overall, a plausible and intuitive link between fundamentals and sovereign risk – with higher public debt, lower growth, a worsening in the fiscal balance and the current account in previous years all being associated with higher sovereign risk in financial markets. Moreover, there are plausible cross-country differences in this link between fundamentals and sovereign risk. For instance, when focusing on yield spreads, EMEs are much more sensitive to public debt, growth and fiscal balances in the relatively more tranquil pre-crisis period than other country groups. This is consistent with the argument that EMEs in the past were forced to run tighter (and often highly pro-cyclical) fiscal policies because of the much higher sensitivity of financial markets to changes in fiscal conditions in EMEs than in advanced economies.

A second compelling finding relates to changes over time in the relationship between fundamentals and the price of sovereign risk. It is the pricing of sovereign risk of the euro area periphery economies which has been most sensitive to fundamentals during the sovereign debt crisis, while for EMEs there has generally been little change in this relationship. This evidence indicates the presence of "wake-up call" or fundamentals contagion during the crisis, in particular for the euro area periphery countries. Note that although most of the coefficients have the expected signs, they are sometimes not statistically significant, in part due to the relatively small number of countries.

A third key finding is that regional contagion during the crisis has been unimportant, in particular for European countries. The estimates show that the cross-country transmission of sovereign risk within the euro area has decreased significantly during the crisis (implying a negative γ_2). Note that this does not imply that there has been no regional spillovers of sovereign risk during the crisis – in fact there has been as indicated by the positive sum of coefficients ($\gamma_1 + \gamma_2$) – but the sensitivity of domestic sovereign debt markets to foreign markets has decreased.

Another interesting finding relates to the pricing of regional risk prior to the crisis. This has nowhere been as high as in the euro area – with a coefficient of close to 1 indicating that changes in sovereign risk in the region was transmitted one-for-one to domestic markets. Looking at the euro area periphery countries during the pre-crisis period indicates that what has been driving the pricing of sovereign risk in these economies prior to 2008 was primarily the sovereign risk elsewhere in the region, while domestic fundamentals played little or no role. This may indeed be suggestive of an underpricing of

[6] For brevity reasons, we report the results for bond spreads and CDS spreads. The results for ratings, which are qualitatively very similar to those of the other two measures of sovereign risk, are available from the authors upon request.

fundamentals in sovereign debt markets, an issue to which we address in more detail in the next section.

Fourth, comparing the empirical estimates across the three types of sovereign risk – bond spreads, CDS spreads and sovereign ratings – yields qualitatively very similar results. We noted above the shortcomings of the analysis for ratings, given the discrete nature of the ratings as well as the few changes in ratings, in particular for other advanced economies, and hence that these findings needs to be interpreted cautiously. It is important to stress, nonetheless, that across the three types of sovereign debt markets, a similar story prevails as regards the determinants of the price of sovereign risk prior and during the crisis.

Table 6

Finally, we extend model (4) to allow for spillovers and contagion not only within the same region but also specifically from the euro area periphery countries, and we also allow for spillovers and contagion across market segments. For instance, some observers have argued that the rating downgrades of some European countries have been important in driving up sovereign yield spreads and CDS spreads.

Table 6 shows the estimates for this extended model for sovereign bond yield spreads, highlighting two main points. The first point is that there seems to have been little cross-market spillovers or contagion. In particular ratings downgrades (indicated by a rise in the rating scale in the data for the estimates) are not associated with a rise in yield spreads, thus not lending support to the claim that ratings changes systematically triggered a rise in yield spreads. The second point is that there does not seem to have been any spillover or contagion from changes in sovereign risk in euro area periphery countries to other regions. None of the contagion coefficients for the euro area periphery economies for the crisis period is statistically significant in the estimation.

5.2 Detecting potential mis-pricing of sovereign risk

We now turn to the question to what extent one can derive normative implications from the empirical estimates presented above. It is important to note that the presence of contagion, as identified in the previous sub-section, does not necessarily imply a mis-pricing or over-pricing of sovereign risk for euro area periphery economies (or any other) countries. It merely indicates that there has been a shift in the pricing of fundamentals or regional risk between the pre-crisis period and the crisis period. It might well be that sovereign risk was under-priced prior to the crisis. If one takes the entire country sample as the benchmark to which to compare the pricing of sovereign risk, Tables 4-6 suggest that during the pre-crisis period sovereign risk in euro area periphery countries may indeed have been under-priced because financial markets did not seem to consider any of the fundamentals, bar the fiscal balance, for the pricing of sovereign risk in euro area periphery countries. By contrast, markets priced fundamentals more strongly for euro area periphery countries than this benchmark during the crisis.

In order to get at a normative notion of the pricing of sovereign risk, it is useful to conduct a counter-factual analysis and ask how sovereign risk would have been priced during the crisis if the pre-crisis model was the correct one, i.e. the one that reflects an accurate relationship between fundamentals and sovereign risk. We then compare this prediction with one that takes the crisis model as the true one to see what it would have implied for the pricing of sovereign risk in the pre-crisis period for different countries.

Figure 3

Figure 3 shows the estimates from this counterfactual exercise for bond yield spreads.[7] From the pre-crisis estimation of equation (3) for the all-country sample and including own fundamentals only, we extract the predicted values for the crisis period based on the pre-crisis parameters. Similarly, from the crisis estimation of equation (3), we take the predicted values for the pre-crisis period. The figures plot against both the actual price of sovereign risk for pre-crisis and crisis periods.

Two main findings stand out. First, when using the pre-crisis model as benchmark, then the actual price of sovereign risk of euro area periphery countries is substantially over-priced, i.e. actual yields in euro area periphery countries are much higher than those implied by the pre-crisis relationship between fundamentals and risk. This is consistent with the findings of the previous section, which showed that markets became much more sensitive to fundamentals. By contrast, for the core euro area countries, such as Germany, France and the Netherlands, sovereign risk according to this benchmark has been under-priced significantly during the crisis, i.e. actual yields have remained substantially below those implied by the pre-crisis model. This is not, or much less often the case for countries outside the euro area, for most of which actual spreads and predicted spreads are quite close also during the crisis.

The second finding is that the picture reverses if one takes the crisis model of equation (3) and derives implied spreads for the pre-crisis period. This analysis shows that spreads would have been higher, in particular for Greece and to some extent for other euro area countries such as Italy and Belgium, in the pre-crisis period than they actually were.[8] By contrast, those of the core euro area countries would have been much lower. It is worth noting that there exists some heterogeneity across the euro area periphery countries as regards the predicted spreads based on the pre-crisis and crisis models, which may be related to whether crises were driven by government budget deficits or the private sector (Stein, 2011). While the pattern is very similar for Greece, Portugal and to a lesser extent Italy (i.e. negative prediction errors in the pre-crisis period and positive prediction errors in the crisis period), the pattern is somewhat different for Spain and very different in the case of Ireland.[9] As regards Ireland, counterfactual spreads would have actually been lower before the crisis, given that the country actually had low levels of public debt and

[7] Corresponding figures for CDS spreads and ratings are not shown for brevity reasons. They yield qualitatively very similar findings, and are available upon request. Also for reasons relating to space, we have shown only the results for the euro area periphery countries plus a selection of non-periphery euro area countries. The results for all other countries in the sample are available from the authors upon request.

[8] The findings in relation to Greece are consistent with those of Gibson et al (2012), who make the point that before the crisis, interest rate spreads were much lower than justified by fundamentals owing to the role played by Greece's euro area membership on biasing investor expectations. After the crisis, interest rate spreads have been higher than those predicted by fundamentals due to a lack of belief by the market that sustainable fiscal consolidations measures and structural reforms had been implemented.

[9] In Greece, Italy, and Portugal, structural government balances were around twice as high as the euro area average in the period 1998-2007, while they were notably lower in Ireland and Spain. Thus the cross-country heterogeneity observed in the evolution of the predicted spreads based on the pre-crisis and crisis models may be related to the origin of the crisis. While government budgetary policy and large structural deficits were underlying factors for Greece, Italy and Portugal, the crisis in Ireland and Spain was closely linked to the private banking sector,

high growth rates. Moreover, large liabilities due to the financial sector in Ireland have been an important factor during the crisis. There is one *additional* element that may be important for explaining the *levels* of sovereign risk, and this is the country-specific premia as measured by the country-fixed effects α_i for the pre-crisis period and δ_i for the crisis period. As these are constants they cannot account for any of the time variations within each sub-period, but they may explain, for example why a country has a relatively high price of its sovereign debt while its observable fundamentals may be comparatively strong, and vice versa. As discussed in detail above, it is hard to give an economic interpretation to these fixed effects, and they likely, at last in part, reflect country-specific risk premia that financial markets demand to hold a particular country's public debt.

Figure 4

Understanding how these country-specific premia have evolved during the crisis may thus provide important information about cross-country changes in the pricing of sovereign risk. Figure 4 plot the pre-crisis premia α_i against the crisis premia δ_i from the estimation of the full model (4) for all countries for bond spreads and CDS spreads. Our prior is that there should be a positive relationship between pre-crisis fixed effects and crisis fixed effects if the evolution of the price of sovereign risk in the empirical model is primarily explained by fundamentals and regional spillovers.

Figure 4 shows that there is no such systematic relationship for EMU countries.[10] In fact, all EMU countries, including the stressed countries (i.e. euro area countries experiencing sovereign bond market tensions), had very similar country fixed effects during the pre-crisis period, but very different premia during the crisis, suggesting that markets did not discriminate much across euro area countries. What is striking is that the country fixed effects are much more negative for stressed countries, which implies that the observable fundamentals of the stressed countries in the model during the crisis indicate that sovereign spreads should have been even higher for these countries (if markets had priced fundamentals in the same way across all countries). It is consistent with the finding of the previous section that in fact the sensitivity of financial markets to fundamentals in euro area periphery countries became particularly high during the crisis.[11]

Focusing on the pre-crisis period, conducting a counter-factual analysis only for the pre-crisis period, estimating (3) for the pre-crisis period over the entire country sample and including only fundamentals into the model, is informative about the premia during the pre-crisis period. Our analysis shows that the highest negative country premia during the pre-crisis period existed for countries, such as Italy and Greece. This means that these countries should have had much higher sovereign spreads before the crisis, based on their fundamentals alone, than they actually did. And this premium is substantial at above 400

[10] This is consistent with the results based on sovereign credit ratings, which are not shown for space reasons.

[11] Of course, there may be complementary interpretations of these country fixed effects, especially for euro area countries. The negative effects for euro area periphery countries may have partly resulted also from financial support through EU-IMF programmes.

basis points, which would have brought spreads for these two countries to similar levels as in the pre-EMU period of the 1990s. By contrast, fixed effects for most EMEs were positive and substantial, implying that those governments had to pay positive premia to investors for purchasing their sovereign debt.

5.3 Herding contagion

One of the potential shortcomings of models, such as equation (4), for identifying contagion is that they assume that contagion is present persistently over the crisis period, i.e. parameters are allowed to change with the crisis, but not in individual periods within the crisis episode. However, there may be contagion during individual weeks or months of a crisis, but not necessarily during the entire crisis period. As such, equation (4) measures an average form of contagion during the crisis period.

A second potential shortcoming of such models is that contagion is defined on the basis of changing relationships of *observable* fundamentals. The advantage of such an approach is that one can actually give contagion a meaningful interpretation, and in turn derive policy recommendations. However, any empirical model may exclude relevant variables. In fact, behavioral explanations of financial market reactions, such as those often linked to herding behavior, is difficult to capture with observable fundamentals.

A complementary approach to equations (3) and (4) to address both caveats and to get at the role of herding contagion during the European sovereign debt crisis is to look at the cross-country correlation of the unexplained components of sovereign risk. More precisely, we employ the approach of Boyson, Stahel and Stulz (2010) and examine the distribution of the residuals from equation (4) across countries at each point in time. In particular, we investigate the presence of tail clustering at the tenth percentile of the distribution, focusing on differences between the non-crisis and crisis periods, and between the euro area and other regions.

Figure 5

Figure 5 below presents the results of this analysis for the tenth percentile of the residual distribution for all 31 countries, for the euro area, and for emerging economies. The figures plot the percentage share of countries for which the model indicates that the residual is in its top 10^{th} percentile in a particular month. If residuals were uncorrelated across countries, then there should be no systematic clustering and about 10% of all countries should have residuals in their top 10^{th} percentile every month. By contrast, a large share of countries experiencing such a sharp increase in sovereign risk that cannot be explained by the model's fundamentals and regional spillovers, indicates the presence of what we refer to as herding or pure contagion. As we noted before, the caveat of such an exercise is that we don't precisely know what the underlying factor is that explains such clustering and simultaneously sharp increase in sovereign risk.

Figure 5 provides compelling evidence in favour of herding contagion, but that it played at most a minor role during the European sovereign debt crisis. In particular, such herding contagion is concentrated in time – for euro area countries it rises sharply in 2008, for a number of months, i.e. well before the start of the European debt crisis, and again in July-September 2011. The latter is a period when Italy was under substantial pressure by financial markets. In each of these episodes, the clustering rises sharply for a few months, but then again falls significantly. Moreover, we find a similar rise across EME yield spreads, though the clustering for these occurred mainly in 2009. Hence, although this

evidence suggests the presence of herding contagion, it also stresses clearly that such contagion has been temporary and relatively short-lived and did not dominate the European crisis period.

5.4 Economic significance

We have shown so far that fundamentals contagion, regional contagion as well as herding contagion have all played a role during the European sovereign debt crisis, and in particular for euro area countries. But how important have these different elements been? Are euro area periphery countries, or at least some of them, innocent bystanders who mostly suffered from adverse contagion from other euro area countries, while fundamentals contagion played only a minor role? Or is it the reverse, in that a deterioration in fundamentals and a higher sensitivity of markets to such a deterioration explains the largest share of the sharp increase in the price of sovereign risk in the euro area?

To get at these questions, we estimate equation (4) and then extract the different elements of equation (4) for the last month before the crisis (September 2008, indicated by a superscript 08) and the last month of the crisis in the sample (September 2011, indicated by a superscript 11). We then derive the total *change* in sovereign risk over the entire crisis period as:

$$\begin{aligned} \Delta s_i^{crisis} &= \left(s_i^{11} - s_i^{08}\right) = \hat{\delta}_i + \hat{\beta}_1\, \Delta X_i + \hat{\gamma}_1\, \Delta S_j + \hat{\beta}_2\, X_i^{11} + \hat{\gamma}_2\, S_j^{11} + \hat{\eta}_i \\ &= \hat{\delta}_i + \hat{\beta}_1\, \Delta X_i + \hat{\gamma}_1\, \Delta S_j + \hat{\beta}_2\, \Delta X_i + \hat{\beta}_2\, X_i^{08} + \hat{\gamma}_2\, \Delta S_j + \hat{\gamma}_2\, S_j^{08} + \hat{\eta}_i \end{aligned} \tag{5}$$

with the terms being defined as follows:

$\hat{\delta}_i$ the country-fixed effect

$\hat{\beta}_1\, \Delta X_i$ the change in a country's fundamentals at pre-crisis pricing

$\hat{\beta}_2\, \Delta X_i$ fundamentals contagion: the change in a country's fundamentals with change of pricing in crisis

$\hat{\beta}_2\, X_i^{08}$ fundamentals contagion: the level of a country's pre-crisis fundamentals with change of pricing in crisis

$\hat{\gamma}_1\, \Delta S_j$ the change in regional sovereign risk at pre-crisis pricing

$\hat{\gamma}_2\, \Delta S_j$ regional contagion: the change in regional sovereign risk with change of pricing in crisis

$\hat{\gamma}_2\, S_j^{08}$ regional contagion: the level of regional sovereign risk with change of pricing in crisis

$\hat{\eta}_i$ unexplained change in price of sovereign risk during crisis

The added advantage of looking at the changes is that it allows for gauging whether it is the change in fundamentals or regional risk over the crisis period and to what extent it is the pricing of these two types of risk that influences sovereign risk. Figure 6 show the different components for the September 2011 levels of sovereign yield spreads, CDS spreads and ratings, as well as for the different contributions to the changes over the crisis period.

Figure 6

Focusing first on the euro area periphery countries shows that most of the spreads are explained by fundamentals, and not by regional spillovers or regional contagion. The dominance of fundamentals for the explanation of sovereign yield spreads is strongest for Greece, but it also holds for all of the euro area periphery countries. Moreover, an important finding is that regional contagion during the crisis has been relatively unimportant. The negative coefficient for γ_2 implies that there has only been a modest adverse total spillover of regional risk during the crisis ($\gamma_1 + \gamma_2$), generally about 100-200 basis points for the euro area periphery countries. Looking at the changes in spreads leads to the same conclusions, given that, as we have seen above, macroeconomic fundamentals explained very little of the price of sovereign risk in euro area periphery countries prior to the crisis. The main point of the estimates for the changes in spreads is that the rise in sovereign spreads in euro area periphery economies has been due to two factors: (i) a higher sensitivity of financial markets to existing fundamentals (β_2), and (ii) a deterioration in fundamentals (ΔX_i).

Turning to other, non- euro area periphery countries yields the same conclusions: it is mainly the strength of countries' fundamentals that explain the level of spreads at the end of 2011 as well as the change in overall spreads during the crisis. An important finding is that for all regions, markets have become more sensitive to existing fundamentals, and as fundamentals have deteriorated in almost all economies globally during the crisis, fundamentals have worked to push up sovereign yields everywhere, not just in euro area periphery economies. Hence fundamentals contagion has played a role, and an economically meaningful one, for most countries, not just for euro area periphery countries.

By contrast, regional contagion through the spillover of sovereign risk in the region has not played a significant role during the crisis. In fact, the strength of the spillover of sovereign risk has mostly weakened somewhat during the crisis, as indicated by a negative γ_2 coefficient. Nevertheless, total regional spillovers during the crisis ($[\gamma_1 + \gamma_2]*S_j$) has not been negligible, accounting for an increase in spreads of about 100 basis points for most EMEs, of about 50 basis points for core euro area countries, and 20-30 basis points for other AEs.

A final point relates to the country fixed effects. Although α_i and δ_i are individual mostly quite sizeable, they in many cases partly offset each other with the sum of both for the crisis ($\alpha_i + \delta_i$) being more modest in magnitude. Interestingly, the crisis-specific fixed effects are mostly negative for AEs, and are especially large for the US and Germany while fundamentals alone for these two countries would indicate that sovereign yields should have risen much more during the crisis than they actually did. This is consistent

with a flight-to-safety explanation, in which in particular sovereign bonds of the US and Germany benefit from safe haven flows.

6. Conclusions

Europe's ongoing sovereign debt crisis has raised calls for more global and concerted policy intervention to stop, in particular, the crisis from spreading contagiously across countries and regions. The paper has analyzed whether contagion has indeed been present during the crisis, distinguishing between three types of contagion – fundamentals contagion due to a higher sensitivity of financial markets to existing fundamentals, regional contagion from an intensification of spillovers of sovereign risk across countries, and herding contagion due to a temporary overreaction of financial markets that is clustered across countries. The focus of the analysis has been not only on euro area countries, but also on other advanced and emerging economies globally, covering 31 countries in total over the period 1999-2011, in order to have alternative benchmarks for comparison.

A key finding of the analysis is that there has indeed been fundamentals contagion, or "wake-up call" contagion, as financial markets have become more sensitive to countries' economic fundamentals during the crisis compared to the pre-crisis period. And this increase in sensitivity has been particularly pronounced for the high yield economies in the European periphery. By contrast, regional spillovers of sovereign risk has not increased systematically during the crisis, but in fact decreased in particular in the euro area. This does not mean that there has been no cross-country spillovers of sovereign risk during the crisis – in fact regional spillovers may explain as much as 100-200 basis points of the rise in sovereign yield spreads among euro area periphery countries – but it implies that markets have started to discriminate more on the basis of countries' fundamentals during the crisis than before, in particular within the euro area.

In terms of overall economic significance, the analysis of the paper shows that most of the level of sovereign risk and the rise during the crisis period is explained by countries' own economic fundamentals, and its underlying fundamentals contagion, while regional contagion explains a much more modest magnitude of sovereign risk. This applies equally to all regions, including for the euro area.

The analysis of the paper also detects evidence that is consistent with the presence of herding contagion in sovereign debt markets during the crisis. However, we find that such herding contagion is concentrated in time and geographically. For EMEs, simultaneous sharp rises in sovereign risk were concentrated in 2009. For euro area countries, sharp increases in sovereign risk occurred in 2008 and in August-September 2011, though these periods were short-lived and can account for only a small extent of the dynamics of sovereign debt prices during the European crisis.

There has been the notion among some observers and policy-makers that financial markets have overreacted during the crisis and that sovereign risk is mis-priced or has become "over-priced", especially for the euro area periphery economies. It is very hard to evaluate such a normative claim as any statement about a mispricing requires having a precise definition of what an adequate, equilibrium pricing of risk should imply. In fact, the empirical findings suggest that there have been substantial and sustained differences in the pricing of fundamentals for sovereign risk among euro area countries before and during the crisis, suggesting the presence of multiple equilibria in this relationship.

At the same time, the question which of these equilibria are sustainable ones and ones that are attainable by policy is a crucial issue from a policy perspective as it determines what policy could or should do to deal with financial markets' pricing of countries' sovereign risk. While we are very cautious in stressing the limits of any normative interpretation, using different benchmarks our analysis suggests that financial markets may not have fully priced in countries' fundamentals and thus may have under-priced sovereign risk in the euro area during the pre-crisis period.

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Table 1

Euro Area economies	Other Advanced economies	Emerging market economies	
		Latin America	***Other EMEs***
Belgium	Australia	Brazil	Bulgaria
Finland	Denmark	Chile	Hungary
France	New Zealand	Colombia	Poland
Germany	Sweden	Mexico	Russia
Netherlands	Switzerland	Peru	South Africa
Greece	United Kingdom		Turkey
Italy	United States		China
Portugal			Malaysia
Spain			Philippines
Ireland			

Table 2: Descriptive statistics

	Pre-crisis				Crisis			
	avg	max	min	std dev	avg	max	min	std dev
Bond spreads								
- Euro area	71.92	243.80	-137.70	83.05	3186.60	-148.00	330.33	3186.60
- Other AEs	-0.58	353.70	-295.70	122.34	143.01	345.10	-267.20	117.03
- EMEs	201.38	984.34	41.85	147.37	263.23	1366.32	37.21	159.26
CDS spreads								
- Euro area	7.91	84.56	1.00	9.71	187.77	2989.93	7.50	299.27
- Other AEs	9.32	88.12	1.43	11.85	57.06	206.28	10.00	30.67
- EMEs	119.53	838.90	4.50	129.99	191.41	783.38	53.00	117.06
Sovereign ratings								
- Euro area	2.63	7.00	1.00	1.82	3.96	20.00	1.00	3.43
- Other AEs	1.14	2.00	1.00	0.35	1.15	3.00	1.00	0.37
- EMEs	9.39	14.00	5.00	2.49	8.80	13.00	4.00	2.33
Public debt/GDP								
- Euro area	65.30	111.70	21.75	25.75	85.27	170.97	34.81	28.22
- Other AEs	41.66	73.40	9.36	19.12	49.81	103.70	12.40	23.42
- EMEs	37.76	73.08	4.01	18.26	38.02	80.74	5.40	20.24
Real GDP growth								
- Euro area	2.68	6.57	-3.87	1.62	-0.91	5.55	-9.14	3.32
- Other AEs	2.70	4.73	-1.50	1.22	0.49	7.16	-6.30	3.23
- EMEs	6.02	14.64	0.12	2.43	2.92	10.62	-8.83	4.67
Δ Current account/GDP								
- Euro area	-0.70	4.42	-6.93	1.90	0.64	6.91	-8.25	2.44
- Other AEs	-0.42	3.85	-17.92	2.34	1.02	16.87	-15.42	3.44
- EMEs	-0.31	6.79	-12.25	2.68	0.56	21.18	-11.77	4.13
Δ Budget balance/GDP								
- Euro area	-0.07	3.00	-7.65	1.77	-1.36	30.14	-20.53	5.56
- Other AEs	0.27	4.09	-4.24	1.54	-1.38	3.51	-7.23	2.61
- EMEs	0.75	6.30	-4.58	1.54	-0.86	7.54	-12.08	3.09
Δ VIX index	0.41	13.94	-15.57	5.96	-0.07	39.37	-41.86	18.08
Regional bond spreads								
- Euro area	71.92	234.05	-106.20	82.52	355.27	1422.73	-119.03	253.18
- Other AEs	-0.58	196.84	-198.47	80.14	143.01	255.35	-192.60	89.36
- EMEs	201.81	338.25	122.77	55.02	267.28	517.30	157.26	75.64
Regional CDS spreads								
- Euro area	7.91	45.80	1.58	8.27	187.77	1296.39	9.26	227.61
- Other AEs	9.32	35.68	1.93	5.77	57.06	164.00	15.55	25.91
- EMEs	120.09	301.39	35.82	56.78	196.34	607.90	112.72	93.24
Regional ratings								
- Euro area	2.63	5.00	1.25	1.18	3.96	11.50	1.25	2.71
- Other AEs	1.15	1.17	1.00	0.06	1.15	1.33	1.00	0.07
- EMEs	9.40	10.67	8.38	0.46	8.80	9.23	8.38	0.19

Source: Bloomberg

Table 3: Changes in the price of sovereign risk during the crisis

	Bond spreads			**CDS**			**Ratings**		
	Sep '08	Sep '11	***bpsΔ***	Sep '08	Sep '11	***bpsΔ***	Sep '08	Sep '11	***notchΔ***
Brazil	332.6	277.3	***-55.3***	129.9	142.3	***12.4***	10.0	9.0	***-1.0***
Chile	223.2	181.0	***-42.1***	61.5	92.6	***31.1***	5.0	5.0	***0.0***
Colombia	497.6	191.0	***-306.6***	160.1	141.1	***-19.0***	10.0	10.0	***0.0***
Mexico	274.8	266.8	***-8.0***	117.8	140.5	***22.7***	8.0	9.0	***1.0***
Peru	309.9	279.4	***-30.5***	133.5	147.2	***13.7***	10.0	10.0	***0.0***
Bulgaria	301.5	351.5	***50.0***	185.0	274.0	***89.0***	9.0	9.0	***0.0***
Hungary	725.3	555.4	***-169.8***	124.3	411.0	***286.7***	9.0	11.0	***2.0***
Poland	168.8	309.0	***140.2***	68.0	217.8	***149.8***	6.0	6.0	***0.0***
Russia	299.1	340.4	***41.3***	133.0	185.8	***52.8***	8.0	8.0	***0.0***
South Africa	197.4	248.7	***51.3***	173.5	148.5	***-25.0***	8.0	8.0	***0.0***
Turkey	290.4	354.1	***63.7***	266.2	223.6	***-42.6***	13.0	12.0	***-1.0***
China	227.8	277.8	***50.0***	66.0	107.0	***41.0***	5.0	4.0	***-1.0***
Malaysia	194.2	233.1	***38.9***	132.3	115.7	***-16.6***	8.0	9.0	***1.0***
Philippines	324.0	288.9	***-35.1***	243.8	158.1	***-85.7***	13.0	12.0	***-1.0***
Greece	11.4	3186.6	***3175.2***	50.7	2989.9	***2939.2***	7.0	20.0	***13.0***
Ireland	-59.3	760.0	***819.3***	29.8	822.5	***792.7***	2.0	8.0	***6.0***
Italy	-26.1	551.8	***577.9***	40.1	378.7	***338.6***	5.0	6.0	***1.0***
Portugal	-70.3	1192.5	***1262.8***	37.7	994.4	***956.7***	5.0	12.0	***7.0***
Spain	-83.1	475.1	***558.2***	37.5	372.1	***334.6***	3.0	4.0	***1.0***
Belgium	-73.3	350.5	***423.8***	20.5	242.5	***222.0***	3.0	3.0	***0.0***
Finland	-111.6	129.0	***240.6***	9.3	67.5	***58.3***	1.0	1.0	***0.0***
France	-111.2	181.2	***292.4***	11.1	160.0	***148.9***	2.0	2.0	***0.0***
Germany	-148.0	65.3	***213.3***	7.5	75.3	***67.8***	1.0	1.0	***0.0***
Netherlands	-105.3	108.2	***213.5***	9.2	78.9	***69.7***	1.0	1.0	***0.0***
Australia	-161.5	-57.3	***104.2***	19.5	66.8	***47.3***	1.0	1.0	***0.0***
Denmark	-256.8	64.0	***320.7***	10.3	98.8	***88.5***	1.0	1.0	***0.0***
New Zealand	-221.6	59.9	***281.5***	22.7	78.0	***55.3***	2.0	3.0	***1.0***
Sweden	-184.5	-84.9	***99.6***	10.0	53.2	***43.2***	1.0	1.0	***0.0***
Switzerland	-13.1	14.6	***27.7***	19.5	57.6	***38.1***	1.0	1.0	***0.0***
UK	-202.7	130.3	***333.0***	17.7	75.3	***57.6***	1.0	1.0	***0.0***
US	-128.5	157.8	***286.3***	16.3	51.3	***35.0***	1.0	1.0	***0.0***

Notes: The table shows the level of the three proxies of sovereign risk immediately before and at the end of the crisis, as well as the total change over the crisis period.

Table 4 Determinants of bond yield spreads

	All	All EA	EA periphery	Other EA	Other AE	EME
Pre-crisis						
Public debt/GDP	3.03***	0.28***	0.08	0.39***	1.39***	8.24***
Real GDP growth	-1.24**	0.34	0.25	-0.19	8.45***	-3.92***
Δ Current account/GDP	0.24	0.25	0.44	-0.24	-0.22	1.92
Δ Fiscal balance/GDP	-0.02	-2.20***	-0.63*	-0.36	12.31	-46.08**
ΔVIX	-0.00	-0.01	0.04	-0.01	-0.25	0.19
Regional bond spreads (i≠*j*)	0.81***	0.98***	1.01***	0.99***	0.81***	0.58***
Crisis						
Public debt/GDP	5.62***	13.01***	17.84***	0.45	7.24***	7.25***
Real GDP growth	-5.16***	-17.51***	-28.38***	-1.74***	5.24**	-1.67**
Δ Current account/GDP	-0.75	-6.02	-7.75	-3.78**	-3.61**	-4.01**
Δ Fiscal balance/GDP	-2.48*	1.71	-5.78	-3.90	-12.96**	0.17
ΔVIX	-0.00	-2.49***	-1.72	-0.13	-1.11	1.96**
Regional bond spreads (i≠*j*)	0.65***	0.31***	0.20	0.99***	0.77***	0.77
Adjusted R-squared	0.86	0.93	0.91	0.99	0.83	0.76
No. of countries	*31*	*10*	*5*	*5*	*7*	*14*
No. of observations	*4278*	*1490*	*690*	*745*	*966*	*2086*

Notes: Table 4 shows the estimates from equation (4)

$$s_{i,t} = \alpha_0 + \alpha_i + \beta_1 X_{i,t} + \gamma_1 S_{j,t} + \left(\delta_0 + \delta_i + \beta_2 X_{i,t} + \gamma_2 S_{j,t}\right) D_t^C + \varepsilon_{i,t} \quad (4)$$

where $s_{i,t}$ represents government bond spreads, $X_{i,t}$ represents a set of macroeconomic fundamentals, D^C is a crisis dummy taking the value of one in the period after the collapse of Lehman Brothers in September 2008, and $S_{j,t}$ is the regional price of sovereign risk for the region in which country i is located and excludes country i itself. α_i and δ_i are country-specific fixed effects, and as common intercepts are included as well, these are country-specific deviations from the common intercepts. Note that the table shows β_1 and γ_1 for the pre-crisis period and the <u>total</u> effects ($\beta_2 + \gamma_2$) for the crisis period. ***, **, * indicate statistical significance at the 99%, 95% and 90% levels, respectively.

Table 5: Determinants of CDS spreads

	All	All EA	EA periphery	Other EA	Other AE	EME
Pre-crisis						
Public debt/GDP	0.82***	-0.04	0.02	-0.15*	-0.03	9.25***
Real GDP growth	-0.91**	-0.83**	0.44	-0.45**	-1.07**	-6.58***
Δ Current account/GDP	-0.22	4.02	0.77	0.06	-0.27**	-6.05***
Δ Fiscal balance/GDP	0.36	0.55	0.20	-0.08	-0.49	-25.46**
Δ VIX	-0.00	-0.00	0.03	-0.00	-0.00	0.00
Regional CDS spreads (i≠*j*)	0.51***	0.70***	0.94***	0.31**	0.26**	0.34***
Crisis						
Public debt/GDP	1.95***	6.67***	10.42***	0.48**	0.73**	2.29**
Real GDP growth	-2.83***	-7.33***	-38.34***	-1.33***	-1.06	-2.36***
Δ Current account/GDP	-0.42	-0.65	6.65	-4.54	0.03	-0.53
Δ Fiscal balance/GDP	-2.58	-4.33	-0.74	-1.66	0.92	4.57
Δ VIX	-0.10	-0.00	-0.38	0.00	-0.00	0.00
Regional CDS spreads (i≠*j*)	0.76***	0.44***	0.33***	0.65***	0.96***	0.88***
Adjusted R-squared	0.87	0.82	0.88	0.87	0.89	0.85
No. of countries	*31*	*10*	*5*	*5*	*7*	*14*
No. of observations	*2852*	*920*	*460*	*460*	*644*	*1288*

Notes: Table 5 shows the estimates from equation (4)

$$s_{i,t} = \alpha_0 + \alpha_i + \beta_1 X_{i,t} + \gamma_1 S_{j,t} + \left(\delta_0 + \delta_i + \beta_2 X_{i,t} + \gamma_2 S_{j,t}\right) D_t^C + \varepsilon_{i,t} \quad (4)$$

where $s_{i,t}$ represents CDS spreads, $X_{i,t}$ represents a set of macroeconomic fundamentals, D^C is a crisis dummy taking the value of one in the period after the collapse of Lehman Brothers in September 2008, and $S_{j,t}$ is the regional price of sovereign risk for the region in which country i is located and excludes country i itself. α_i and δ_i are country-specific fixed effects, and as common intercepts are included as well, these are country-specific deviations from the common intercepts.

Note that the table shows β_1 and γ_1 for the pre-crisis period and the <u>total</u> effects ($\beta_2 + \gamma_2$) for the crisis period. ***, **, * indicate statistical significance at the 99%, 95% and 90% levels, respectively.

Table 6: Determinants of bond yield spreads – with own-contagion and cross-contagion

	All	All EA	EA periphery	Other EA	Other AE	EME
Pre-crisis						
Public debt/GDP	2.15***	-0.02	0.57***	-0.26	3.00***	4.39***
Real GDP growth	-0.32	1.43**	0.16	0.02	18.31***	-15.59***
Δ Current account/GDP	0.02	-0.25	0.12	-0.73	-3.68**	1.01
Δ Fiscal balance/GDP	0.16	-2.13***	0.57	-0.74	-1.37	-23.45
ΔVIX	-0.34	0.05	-0.02	0.03	0.14	0.94
Regional CDS spreads (i≠*j*)	-0.22***	-0.16**	-0.12*	0.02	-0.48*	0.14*
Regional bond spreads (i≠*j*)	0.85***	1.01***	1.01***	0.87***	-0.16	0.18**
Regional ratings (i≠*j*)	-3.26	2.68	0.20	-1.84	10.59	1.48
EA periphery bond spreads				0.13*	0.97***	0.06
EA periphery CDS spreads				0.01	0.34	0.48
EA periphery ratings				-1.28	18.00	41.62***
Crisis						
Public debt/GDP	6.46***	12.96***	18.66***	0.24	9.52***	6.25***
Real GDP growth	-5.58***	-16.34***	-29.88***	-0.63	6.21**	0.03
Δ Current account/GDP	-1.89**	-5.73	-10.16	-2.57***	-3.27**	-6.03***
Δ Fiscal balance/GDP	-3.84	0.85	-6.45	-0.56	-9.23**	1.70
ΔVIX	-0.29	-1.41**	-1.62	-0.07	-0.59	2.15***
Regional CDS spreads (i≠*j*)	-0.00	-0.04	0.07	-0.24**	0.36*	0.22***
Regional bond spreads (i≠*j*)	0.80***	0.49***	0.21*	1.00***	0.75***	0.47***
Regional ratings (i≠*j*)	-61.68***	-24.61**	-11.42	-354.09	202.67**	47.99
EA periphery bond spreads				0.03	0.01	-0.05
EA periphery CDS spreads				0.01	-0.08	0.00
EA periphery ratings				-3.57	-10.65	5.99
Adjusted R-squared	0.88	0.93	0.90	0.98	0.91	0.77
No. of countries	*31*	*10*	*5*	*5*	*7*	*14*
No. of observations	*2852*	*920*	*460*	*460*	*644*	*1288*

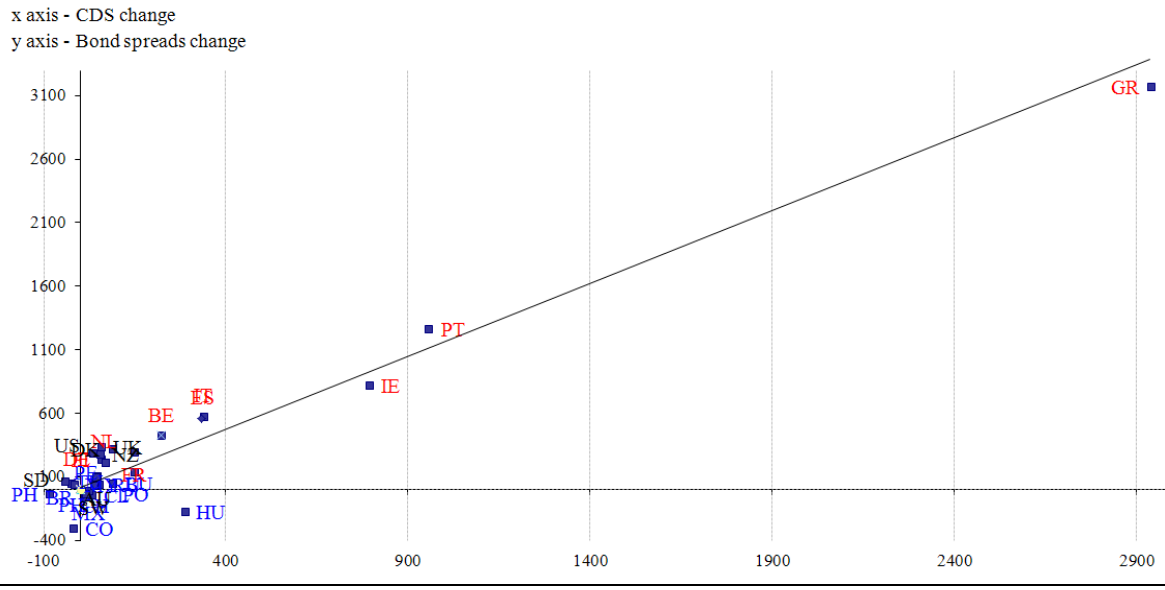
Notes: The table shows the estimates for an extended version of equation (4) for bond spreads.

$$s_{i,t} = \alpha_0 + \alpha_i + \beta_1 X_{i,t} + \gamma_1 \sum_k S_{j,k,t} + \left(\delta_0 + \delta_i + \beta_2 X_{i,t} + \gamma_2 \sum_k S_{j,k,t} \right) D_t^C + \varepsilon_{i,t} \quad (4')$$

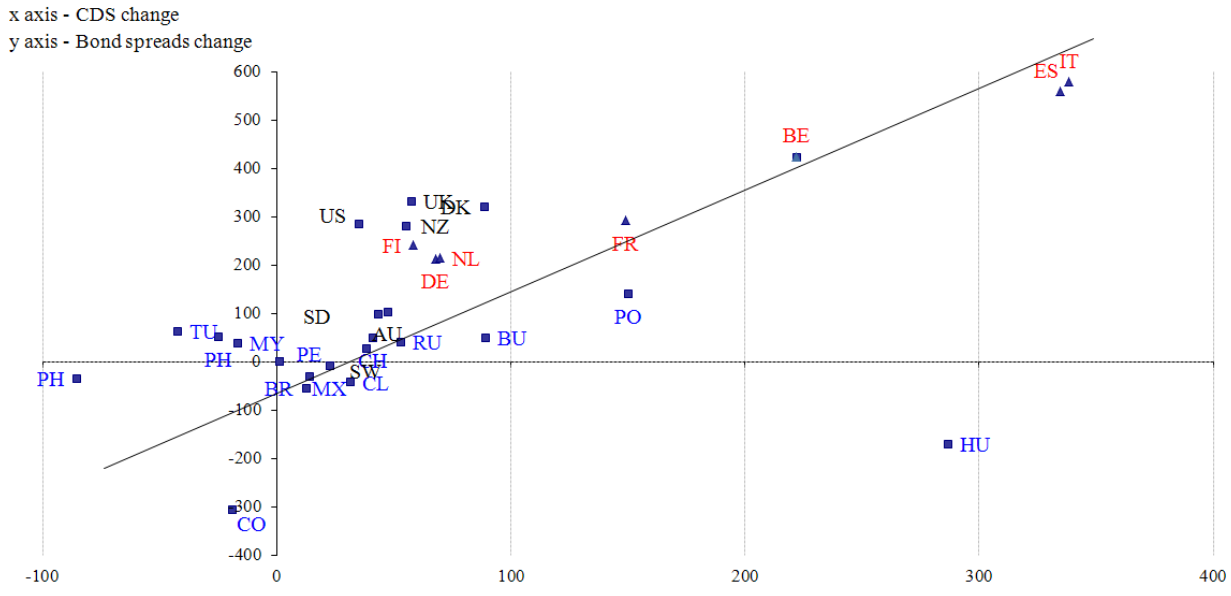
where $S_{i,k,t}$ represents government bond spreads, $X_{i,t}$ represents a set of macroeconomic fundamentals, D^C is a crisis dummy taking the value of one in the period after the collapse of Lehman Brothers in September 2008. α_i and δ_i are country-specific fixed effects, and as common intercepts are included as well, these are country-specific deviations from the common intercepts. Note that the table shows β_1 and γ_1 for the pre-crisis period and the total effects ($\beta_2 + \gamma_2$) for the crisis period. ***, **, * indicate statistical significance at the 99%, 95% and 90% levels, respectively. The estimation where $S_{i,k,t}$ represents, in turn, CDS spreads and sovereign credit ratings are qualitatively very similar and are available from the authors upon request.

Figure 1: Changes in sovereign bond spreads and CDS spreads during the crisis

1.A: All countries



1.B: All countries excluding Greece, Ireland and Portugal



Notes: The figures shows the change in sovereign bond spreads and CDS spreads – in basis points – between September 2008 and September 2011. Figure 1.B excludes the programme countries Greece, Ireland and Portugal in order to better show the differences among other countries.

Figure 2: Market pricing of sovereign risk versus sovereign ratings in EMU and non-EMU countries

Figure 2.A: Sovereign bond spreads and sovereign ratings before the crisis

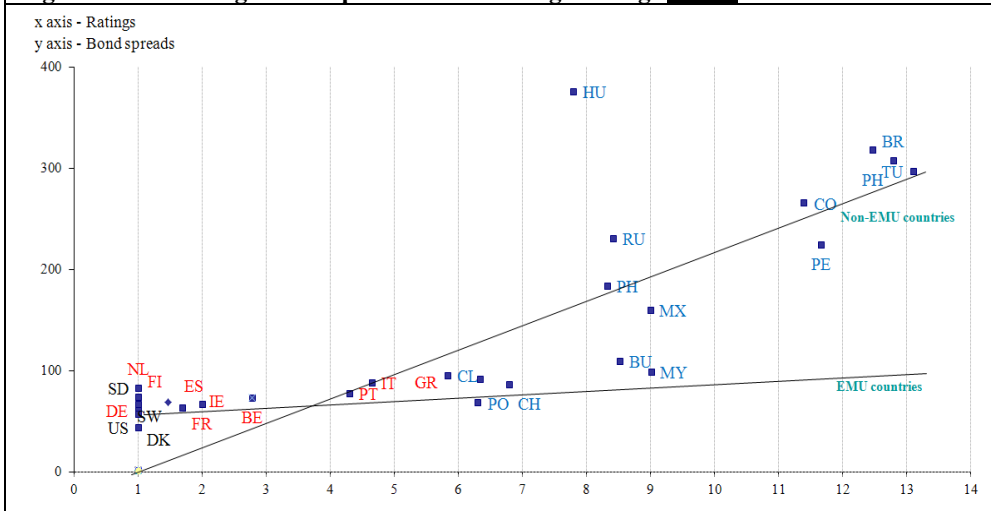


Figure 2.B: Sovereign bond spreads and sovereign during the crisis

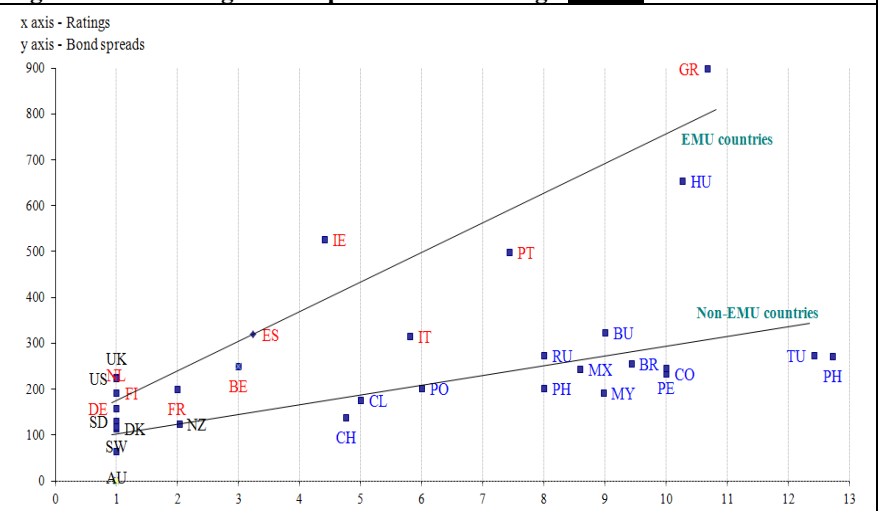


Figure 2.C: CDS spreads and sovereign ratings before the crisis

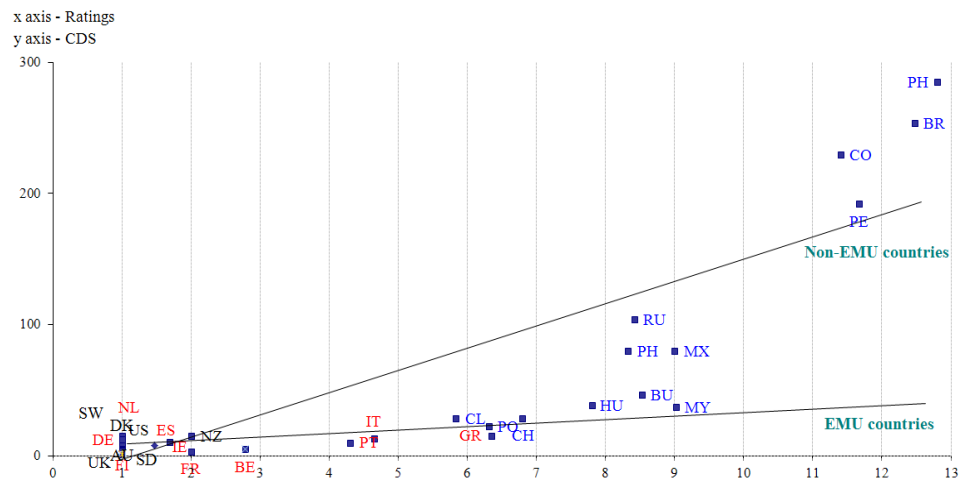
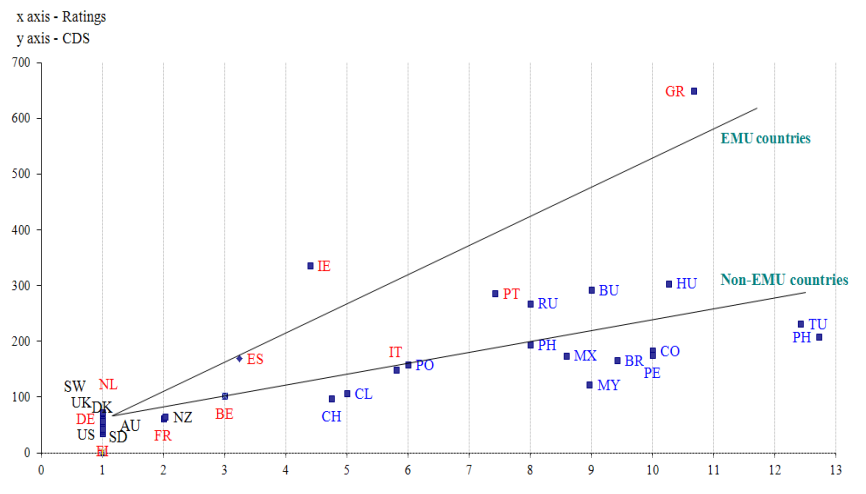
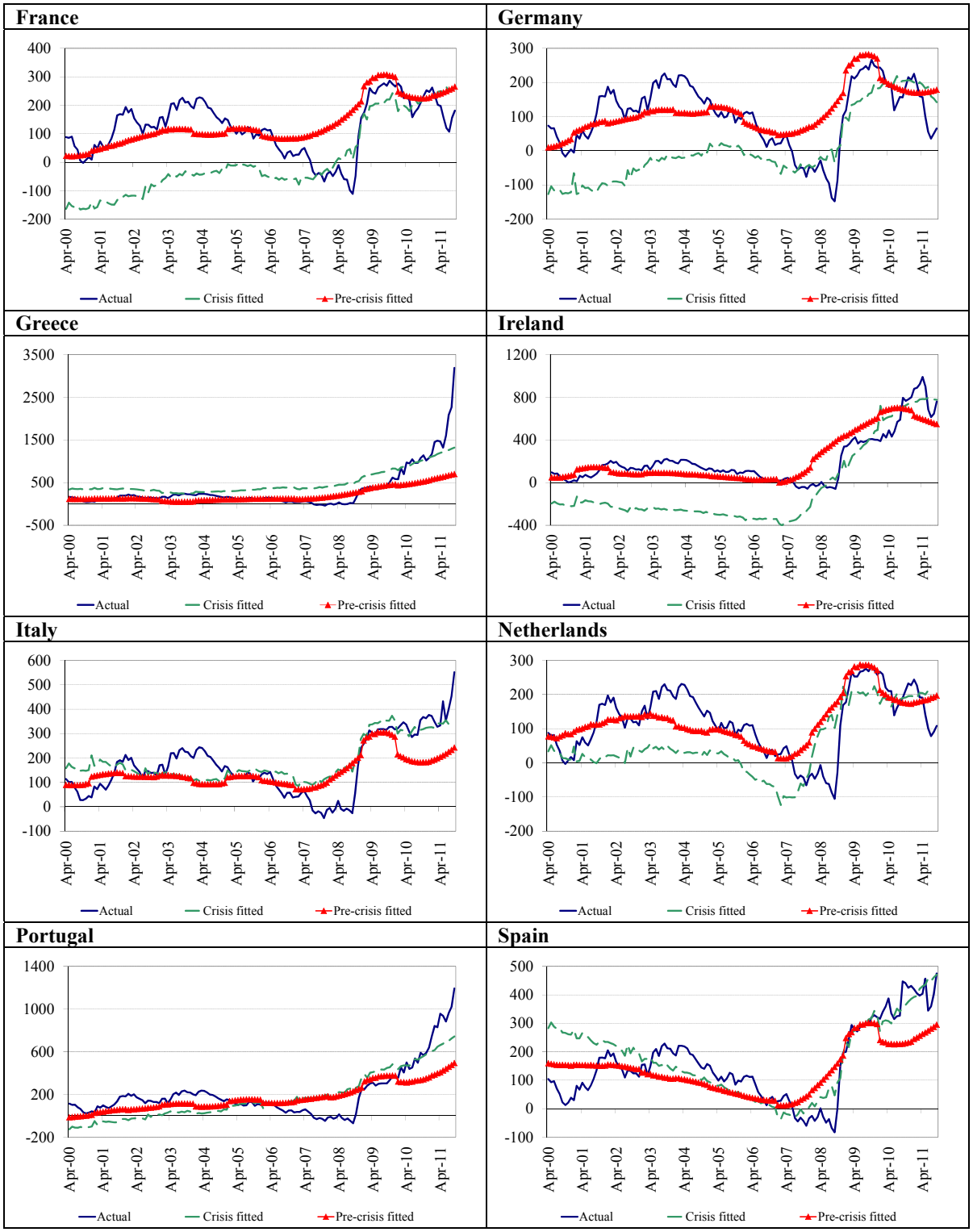


Figure 2.D: CDS spreads and sovereign ratings during the crisis



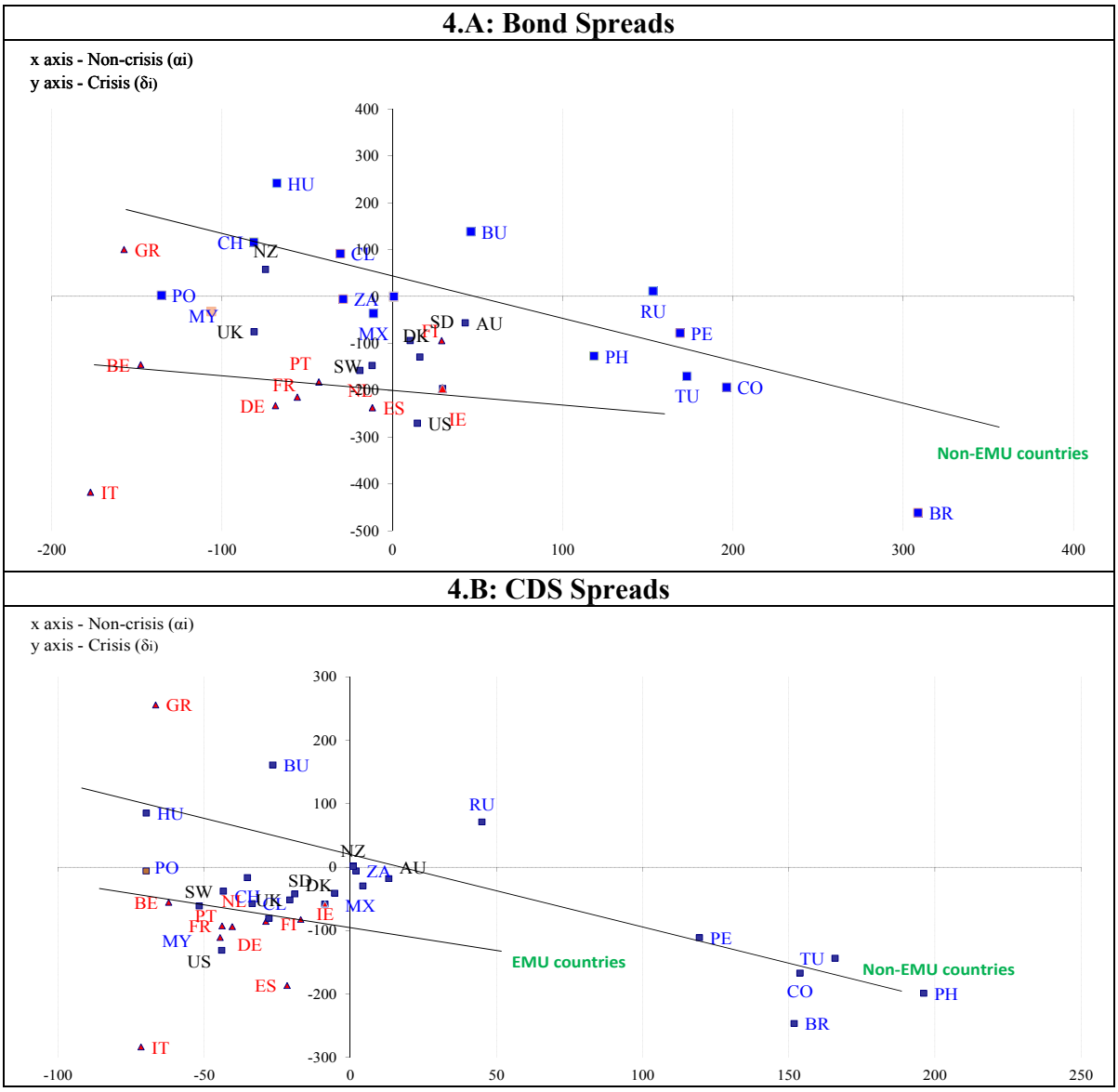
Notes: The Figure shows the levels of yields, CDS and ratings before the crisis (September 2008) and at the end of the sample (September 2011).

Figure 3: Counterfactual analysis – Sovereign bond spreads



Notes: The figures show the fitted values when estimating equation (3), for the all-country sample and including own fundamentals only, for the crisis period based on the pre-crisis parameters, and similarly for the pre-crisis period based on the crisis model. For space reasons, we present the results only for the stressed euro area countries plus a selection of other euro area countries.

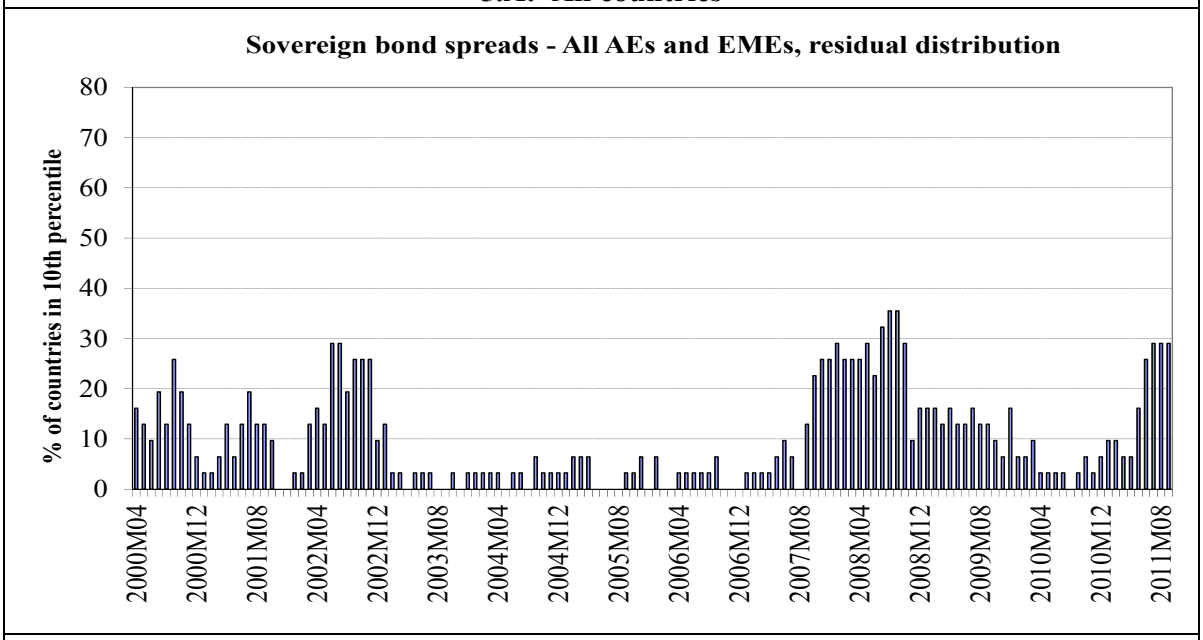
Figure 4: Fixed effects in the pre-crisis (α_i) and crisis (δ_i)



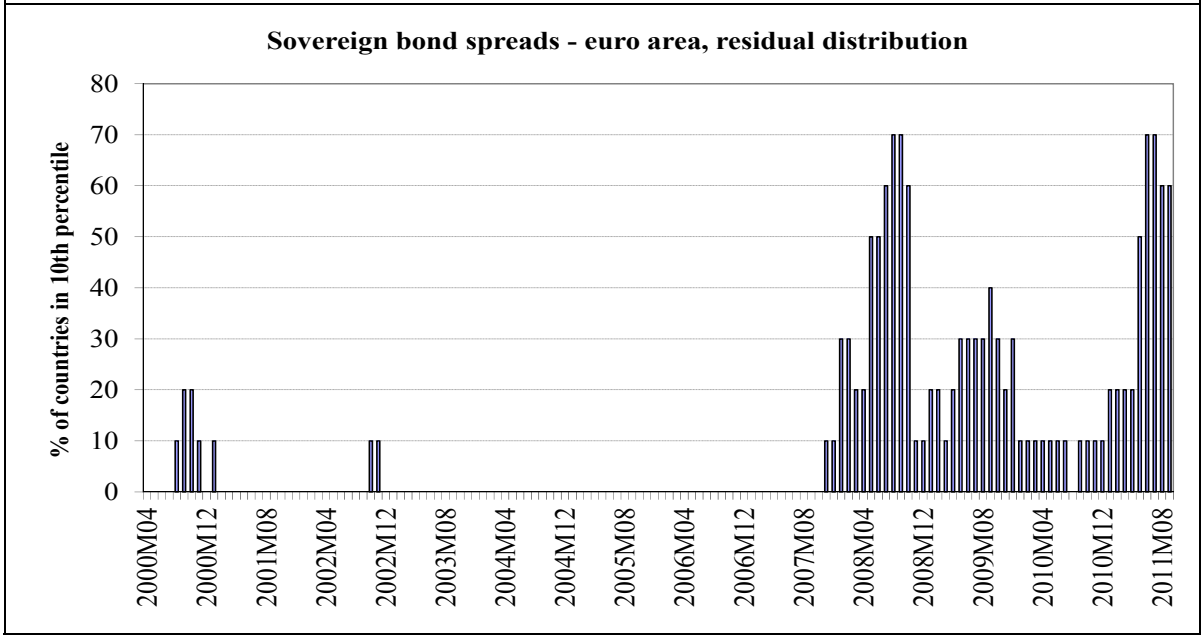
Note: Figures 4A-4B plot the pre-crisis premia α_i against the crisis premia δ_i from the estimation of the full model (4) for all countries for bond spreads and CDS spreads.

Figure 5: Herding contagion – residual distribution for bond spreads

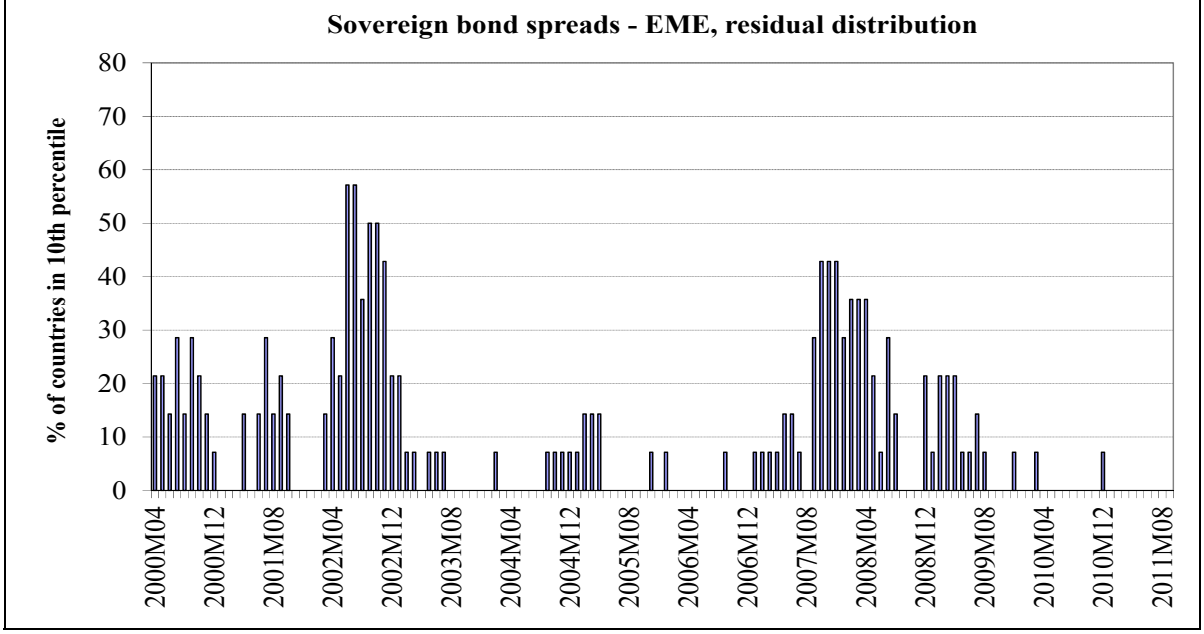
5.A: All countries



5.B: Euro area countries



5.C: EMEs



Notes: The figures plot the percentage share of countries for which model (4) (with regional contagion) indicates that the residual is in its top 10th percentile in a particular month. If residuals were uncorrelated across countries, then there should be no systematic clustering and about 10% of all countries should have residuals in their top 10th percentile every month.

Figure 6: Decomposition of sovereign risk – bond spreads

Notes: Figures 6.A to 6.C plot the decomposition of the price of sovereign risk based on its level as at September 2011, as well as on the change in the level from September 2008 to September 2011 The factors depicted in the *levels* charts are explained as follows:

b1X11 – macroeconomic fundamentals at September 2011
b2X11 - change in the pricing of fundamentals
g1S11 - regional contagion/spillovers
g2S11 - change in pricing of regional contagion/spillovers
fixed effect – total country-specific fixed effect in pre-crisis and crisis
resid – difference between actual and fitted value

The factors depicted in the *changes* charts are explained as follows:
b1ΔX - change in fundamentals
b2X08 - change in pricing of level of fundamentals
g1ΔS - change in regional contagion/spillovers
g2S08 - change in pricing of the level of regional contagion/spillovers
b2ΔX - change in pricing of change in fundamentals
g2ΔS - change in pricing of change in regional contagion/spillovers
d11 - change in fixed effect in the crisis versus the pre-crisis period