

LUISS Guido Carli
School of European Political Economy

**Expectations
and Systemic Risk
in EMU**
Government Bond Spreads

Paolo Canofari
Giancarlo Marini
Giovanni Piersanti

Working Paper
1/2014

LUISS Guido Carli / School of European Political Economy
Working paper n. 01-2014
Publication date: June 2014
Expectations and Systemic Risk in Emu Government Bond Spreads
© 2014 Paolo Canofari, Giancarlo Marini, Giovanni Piersanti
e-mail:
pcanofari@luiss.it
gpiersanti@unite.it
ISBN 978-88-6856-011-9

This working paper is distributed for purposes of comment and discussion only. It may not be reproduced without permission of the copyright holder.

LUISS Academy is an imprint of
LUISS University Press – Pola s.r.l. a socio unico
Viale Pola 12, 00198 Roma
Tel. 06 85225485
e-mail lup@luiss.it
www.luissuniversitypress.it

Editorial Committee:

Leonardo Morlino (chair)
Paolo Boccardelli
Matteo Caroli
Giovanni Fiori
Daniele Gallo
Nicola Lupo
Stefano Manzocchi
Giuseppe Melis
Marcello Messori
Gianfranco Pellegrino
Giovanni Piccirilli
Arlo Poletti
Andrea Prencipe
Pietro Reichlin

EXPECTATIONS AND SYSTEMIC RISK IN EMU GOVERNMENT BOND SPREADS

Paolo Canofari

*University of Rome "Tor Vergata"*¹

Giancarlo Marini

*University of Rome "Tor Vergata"*²

Giovanni Piersanti

*University of Rome "Tor Vergata" – University of Teramo*³

July 2013

Abstract

This paper explores the determinants of 10-years sovereign bond spreads over the German Bund benchmark in the Euro Zone from 2000 to 2013, relying on cross-country quarterly data panel analysis. The paper focal point is the role of contagion and euro break-up risks in widening the sovereign bond yield differentials among EU member countries.

Using a novel synthetic index capable of monitoring the sustainability of currency unions, the paper finds that market expectations of a euro's break up and contagion from Greece were fundamentals drivers of sovereign risk premia in peripheral countries.

JEL codes: C32, C33, E42, E44, E62, F31, F33, F41, G01, G12, H63.

Keywords: Monetary unions, speculative attacks, self-fulfilling expectations, multiple equilibria, shadow exchange rate, financial crisis, contagion, spreads, sovereign default risk, euro break up risk.

¹ Post-Doc presso la School of European Political Economy della Luiss Guido Carli di Roma.

² Professore Ordinario di Economia Politica presso il Dipartimento di Economia, Diritto e Istituzioni dell'Università degli Studi di Roma Tor Vergata.

³ Professore Ordinario di Economia Politica presso la Facoltà di Scienze Politiche dell'Università degli Studi di Teramo.

1 Introduction¹

The view that recent developments in the European government bond market can largely be ascribed to the perceived risk of a possible euro breakdown is gaining popularity in both the academic and policy circles. The reason is easy to understand: the spread reached levels that are well above those that could be justified on the basis of macroeconomic fundamentals, leading theorists to revise their view on the underlying causes of debt crisis in the Euro Zone (EZ).

Arghyrou and Tsoukalas (2011), for example, used insight from the literature on currency crises to model EMU participation as a commitment to a ‘hard’ system of fixed exchange rates, making sovereign spreads to reflect both currency risk and default risk. De Grauwe (2011) proposed a theory of the fragility of a monetary union to show that the government bond markets in the euro area are inevitably exposed to self-fulfilling liquidity and solvency crises due to absence of a ‘lender of last resort’ guarantee by the monetary

¹For helpful comments and discussions, we thank Barbara Annicchiarico, Alberto Bagnai, Manuel Buchholz, Giovanni Di Bartolomeo, Laurence Harris, Alessandro Piergallini, Pasquale Scaramozzino, Partha Sen and seminar participants at the XXV Villa Mondragone International Economic Seminar on June 25-26, 2013, the Workshop on "The Future of Euro and Europe" organized by the University of Rome La Sapienza, Faculty of Economics, on July 2-3, 2013, the International Conference on "Interlinkages and Systemic Risk" organized by Università Politecnica delle Marche-Ancona, on July 4-5, 2013, the 54th Annual Conference of Italian Economic Association on October 24-26, 2013.

authority. Bolton and Jaenne (2011) advanced a model of contagion through the banking system in financially, but not fiscally, integrated unions.

In this paper we analyze the role of contagion risks and expectations of a euro break-up in the dynamics of sovereign spreads over the period 2000-2013 in a number of euro-area countries. Our paper contributes to the literature in two ways. We make use of an index of shadow exchange market pressure derived in an earlier work (Canofari, Marini and Piersanti (CMP), 2012) to measure investors' concerns about EMU sustainability and contagion effects among euro-area countries. We test the power of this index *vis-à-vis* a broad set of fundamentals found in the extant literature on EZ crisis.

The issue of whether a systemic risk is at play in the current wide dispersion of interest rates within the EMU showed up only very recently in the literature. To the best of our knowledge, the first to deal with this issue is Eichler (2011). Using data from American Depositary Receipts (ADR) stock market and analyzing their determinants, this paper finds some evidence that investors added an exchange risk premium to ADR returns to account for the risk that some vulnerable countries might leave the union and reintroduce a new devalued national currency following the outbreak of the crisis. Other papers dealing explicitly with the risk of a break-up of the euro and its systemic consequences are Hui and Chung (2011), Di Cesare *et al.* (2012), Klose and Weigert (2012), Favero (2013). Hui and Chung use information on the dollar-euro currency option prices to estimate the euro's crash probability during the sovereign debt crisis of 2009-2010; Di Cesare *et al.* find that since July 2011 the risk of a euro break-up, approximated by the Google-based indicator for this keyword, has been a major driver of the

instability of euro-area government bond markets; Klose and Weigert show that interest rates spreads in the euro area are correlated with expectations of a union breakdown derived from the virtual trading platform INTRADE. Favero (2013) finds that expectations of exchange rate devaluation, captured by the global European spreads, gained traction during the crises.

Except for Favero (2013), all these papers looked at the break-up issue from a union-aggregate perspective, as their proxies for crash expectations are from the EUR risk premium - that is, from markets expectations on the stability of euro *vis-à-vis* the other major currencies - or from internet virtual expectations. By contrast, we focus on the incentive to leave the euro and hence to break up the union at the country level.

Using the concept of shadow exchange rate and a cost-benefit analysis, our paper adds to this strand of literature by providing a sustainability index for currency unions that can be used to derive model-based expectations of exit and of exchange rate change for each member countries, thus allowing the systemic risk to be theory driven and consistently estimated².

The paper is organized as follows. Section 2 reviews the main events surrounding the EZ crisis and the most recent literature. Section 3 presents the empirical tests derived from a model of shadow exchange market pressure in currency unions. Section 4 describes findings. Section 5 concludes.

²Favero (2013), by contrast, models the euro break-up risk via the global euro area spreads capturing the dependence of each country's spread on all the other countries' spreads and fiscal fundamentals.

2 Facts and literature review

The 10-year government bonds returns for "non-core countries" have seen a rapid and persistent increase of spreads level and volatility in the period following the financial crisis. The paths of these yields and differentials against the German Bund benchmark since 2000 are shown in Figures 1 and 2. Between 2000 and 2008 such returns and differentials were virtually zero. After the 2008 crisis government bond yields and spreads heightened considerably. In particular, countries such as Greece, Ireland and Portugal experienced the largest increase in their bond spreads, followed by Italy and Spain (Table A1).

After the financial crisis of 2008-09 there is a dramatic worsening of public finances, spillover effects across countries and markets, and economic recession that follow with the upsurge in the interest rates, as shown in Appendix A (Tables A2-A4). Since 2008, economic growth plummeted whereas government deficits- and debt-to-GDP ratios rose to record levels in all countries in spite of severe austerity measures taken by the European authorities and national governments.³

Tensions emerged in bond markets and sovereign spreads widened in September 2008 in the wake of Lehman Brothers collapse and the announcement of the bank rescue packages by Irish authorities. Tensions subsided and

³These include among other things: loan agreements and financial support to distressed countries, the creation of the European Financial Stability Facility (EFSF) and the European Stability Mechanism (ESM), a more active policy of supporting the price of government debt securities through market purchases by ECB, strong austerity measures implemented in the affected countries by national policymakers.

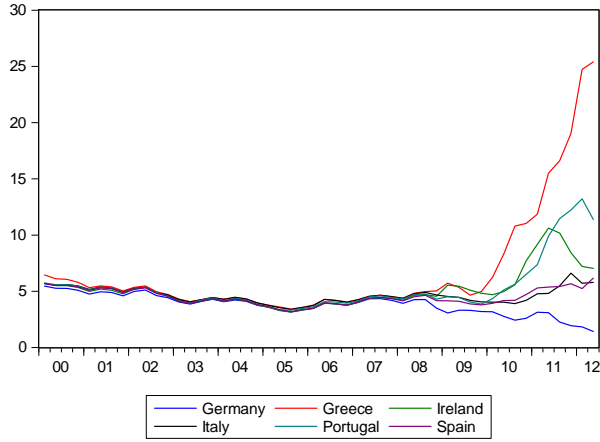


Figure 1: Ten-year government bond yields (quarterly averages; percentages)

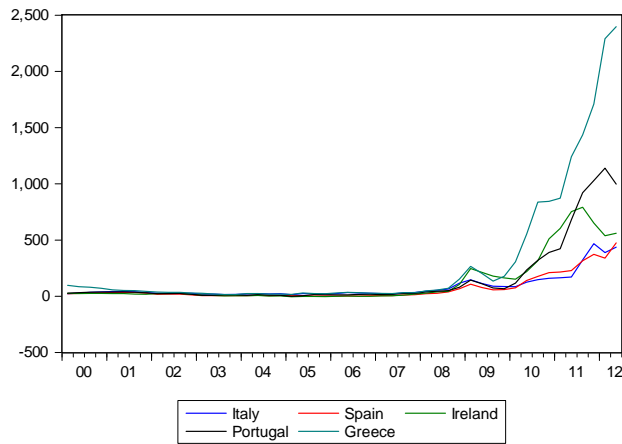


Figure 2: Ten-year government bond spreads vis-à-vis the German Bund (basis points)

spreads started to decrease in the course of 2009 after the announcement of strong budgetary austerity measures by the Irish government on February 2009. However, in November 2009 investors' concern quickly turned to sovereign default risk when the new Greek government revealed a revised budget deficit of 12.7% of GDP for 2009, which was twice as large as previously estimated. Since then, yield spreads started to rise considerably, triggering a debt crisis in most countries and seriously challenging the EMU survival.

Existing studies on the determinants of government bond spreads inside the euro area have identified a number of explanatory factors. Contributions by Barrios *et al.* (2009), Haugh, Ollivaud and Turner (2009), Manganelli and Wolswijk (2009), Sgherry and Zoli (2009), Gerlach, Schulz and Wolff (2010), von Hagen, Schuknecht and Wolswijk (2011), for example, highlighted the role of the global or common risk aversion, i.e. the attitude toward risk of international investors. This effect, typically measured by some index of equity market volatility (e.g., the CBOE Volatility Index (VIX)) or the US corporate bond spread, was found mostly important during the financial turbulence that followed the Lehman demise, when global risk repricing and flight to more liquid and safe government bond markets favoured the German Bund thus widening risk premium differentials inside the EMU.

Other studies pointed out the role of country-specific risk factors capturing the country's creditworthiness or default risk (the so-called 'credit risk'). Papers by Barrios *et al.* (2009), Haugh, Ollivaud and Turner (2009), Attinasi, Checherita and Nickel (2010), Amisano and Tristani (2011), Ejsing, Lemke and Margaritov (2011), Bernoth, von Hagen and Schuknecht (2012), Borgy *et al.* (2012), Favero and Missale (2012), Aizenman, Hutchison and Jinjarak

(2013), for example, found that the deterioration in public finances - measured by the debt (deficit)-to-GDP ratio or by a country's fiscal space - and other macroeconomic and financial fundamentals (e.g., GDP growth, current account deficit, fragility of domestic financial system) played a significant role in the crisis. This effect was prominent after the rise of the Greek fiscal crisis and Germany's perceived reluctance to bailout Greece, when investors started differentiating between countries' fiscal solvency and macroeconomic fundamentals.

Several papers also underlined the role of liquidity risk premium. Gomez-Puig (2006), Barrios *et al.* (2009), Beber, Brandt and Kavajecz (2009), Haugh, Ollivaud and Turner (2009), Manganelli and Wolswijk (2009), Favero, Pagano and von Thadden (2010), for example, found that the liquidity effect (proxied by the share of a country's debt in total EMU sovereign debt or bid-ask spreads) was mostly relevant after the introduction of the euro and during the period of high interest rates and stringent financial conditions.

To summarize, the main insight we gain from this literature is that, at least at low-frequency data, observed spread dynamics is driven by three main factors: global risk aversion, country-specific risk and liquidity risk.⁴

These variables, however, cannot explain a significant portion of sovereign spreads movements occurred after 2010 (see, e.g., Ardagna *et al.*, 2012; IMF, 2012; Di Cesare *et al.*, 2012; Aizenman, Hutchison and Jinjarak, 2013; De Grauwe and Ji, 2013). Caceres, Guzzo and Segoviano (2010), Arezki, Cande-

⁴Using high-frequency data, several papers have also shown the role of macroeconomic news and rating announcements (see, e.g., Alfonso, Furceri and Gomez, 2011; Arezki, Candelon and Sy, 2011; Arru *et al.*, 2012; De Santis, 2012; Gärtner and Griesbach, 2012).

lon and Sy (2011), Amisano and Tristani (2011), Gómez-Puig and Sosvilla-Rivero (2011), De Santis (2012), Metiu (2012), Giordano *et al.* (2013), for example, found clear evidence of spillover effects and financial contagion from Greece, Ireland, Portugal and Spain to a large number of EMU countries. Others argued that the unexplained part of spreads dynamics could reflect a new, systemic risk emerged since 2010: the risk of a euro break-up, that is, the risk that one or more countries might exit from the EMU and introduce new national currencies (see, e.g., Eichler, 2011; Hui and Chung, 2011; Di Cesare *et al.*, 2012; Woo and Vamvakidis, 2012; Klose and Weigert, 2012; Favero, 2013).

To test for the presence of such risks in the interest spreads of non-core countries, we make use of a novel synthetic index capable of measuring the incentive to stay in or exit from a monetary union for each member country. We review the theoretical foundations of our testing strategy and its empirical implementation in the next two sections.

3 Theoretical framework

Our testing strategy builds around a model of voluntary exit and contagion in monetary unions developed in an earlier paper (CMP, 2012). For convenience, we summarize the basic structure and solutions in Appendix C. The model thinks of currency union as a (hard) system of fixed exchange rate where the probability of exiting is non zero. Exit follows from an optimal choice by the policymaker and occurs when the difference between the costs and benefits of staying in a monetary union exceeds a critical value.

Contagion follows from a broad set of channels transmitting ‘monsoonal and spillover’ effects, and ‘pure contagion’ across member countries. A key insight to be gained from this model is that the sustainability of a currency union can be assessed by a synthetic index capable of monitoring the costs and benefits of staying in for each member country. This results from the following two equations, obtained as a solution of an asymmetric three-country monetary union model consisting of a “core” or leader country and two “non-core” or “periphery” economies (A and B):⁵

$$s_t^i - \bar{s}^i = -\frac{\gamma_i}{\gamma_i^2 + \theta^i} \left(y_t^{i,F} - \bar{y}^i \right), \quad (1)$$

$$\frac{\partial \pi_t^i}{\partial \pi_t^j} = G(\bar{u}_{t+1}^i | s_{t+1}^j = s_t^j) - G(\bar{u}_{t+1}^i | s_{t+1}^j = s_t^j + \xi^j) > 0, \quad i, j \in \{A, B\} \quad i \neq j, \quad (2)$$

where all variables are country-specific, measured in logs and

s = nominal (shadow) exchange rate

\bar{s} = entry currency parity

γ = elasticity of (aggregate) demand to the real exchange rate

θ = inflation aversion coefficient

y^F = real output required to stay in the union

\bar{y} = output target

π_t = expected exit probability

\bar{u} = threshold value of random (demand) shock

ξ = devaluation size conditional on exit from the union.

Equation (1) gives country i optimal regime-switching condition measuring the welfare losses arising from alternative policy regimes. It expresses

⁵See Appendix C.

the policymaker's switching rule as a linear relationship between the shadow devaluation rate ($s_t^i - \bar{s}^i$) and the output gap ($y_t^{i,F} - \bar{y}^i$) required to remain in the monetary union.⁶ Condition (1) can also be written as

$$s_t^i - \bar{s}^i \geq \bar{C}^i,$$

where \bar{C}^i denotes the critical devaluation rate such that the welfare losses arising from staying in or opting out of the union are exactly the same.⁷ This equation states that the policymaker will optimally choose to exit and devalue when the shadow exchange rate exceeds the entry parity by the critical value \bar{C}^i , that is, when a random shock greater than a critical value occurs.⁸

Equation (2) highlights that private agents' expectations in different countries are not independent in the model. It computes the effect on the expected exit probability for country i of a change in the perceived probability of exit in country j ($j \neq i$). This equation implies that a rise in π_t^j can push the exit probability in country i high enough that an opting out choice can hardly be avoided, thus modelling a powerful mechanism by which financial instability

⁶See, also, Cavallari and Corsetti (2000), Berger and Wagner (2005). In our model, we think of the shadow exchange rate as the floating rate that would prevail at any date t in country i conditional on exit from the monetary union. The key role this variable plays in the theory of exchange rate crises can be found in Piersanti (2012).

⁷Formally,

$$s_t^i - \bar{s}^i = \bar{C}^i \implies \mathcal{L}_t^{i,F} - \mathcal{L}_t^{i,D} = 0,$$

where $\mathcal{L}_t^{i,F}$ and $\mathcal{L}_t^{i,D}$ are the losses country i runs to when choosing whether to stay in or exit from the currency union, respectively.

⁸See Appendix C.

can become so widespread that a crisis reaches systemic dimensions. Fear of a crisis and exit in one country can spread to other countries, making the union crash more likely to occur.

Equations (1) and (2) are key to our empirical investigation as they enable us to distinguish the euro break-up risk and contagion risk from the other risk factors emphasized in the extant literature. We proceed to discuss their empirical implementation below.

4 Empirical modelling and results

In CMP (2012) we used equation (1) to derive an index of sustainability of currency unions that can evaluate the vulnerability of member countries to speculative attacks and crisis. The index is intended to act as an effective early warning signal of countries under ‘stress’ and hence of the potential of a crisis when a threshold value is crossed. Observing that equation (1) gives the expected shadow devaluation rate for country i conditional on exit from the monetary union, the view we take in this study is to use it as the theoretical relationship of the way market’s concern about the risk of a euro break-up could be measured. After all, the evidence that the divergence of sovereign bond returns from their ‘fair value’ (i.e., the value consistent with country-specific macroeconomic and financial fundamentals) “is negative for some core countries and positive for non-core countries” is likely to be ascribed to “the expectation that a break-up of the euro would entail an appreciation of the new national currencies for the former countries and a depreciation for

the latter, compared with the parities enshrined in the single currency.”⁹

We also use equation (2) as the theoretical relationship for estimating contagion effects, since it models how changes in exit expectations for one country can spread to other countries so propagating instability and systemic risk in currency unions. Details on the empirical implementation of these variables are given further on.

The baseline model specification we used in the empirical investigation is as follows

$$I_{it} = \mathbf{b}'\mathbf{X}_t + \varepsilon_{it} , \quad (3)$$

where I_{it} is the spread between the 10-year government bond yield in country i and the German Bund benchmark in period t , ε_{it} a standard error term, and \mathbf{X}_t a vector of explanatory variables. The set of variables in \mathbf{X}_t includes: global risk aversion, measured by the spread between the yields on US corporate bonds and US treasury bills or the Chicago Board Options Exchange (CBOE) Volatility Index (VIX); sovereign solvency risk, measured by a country’s fiscal space or government debt and budget balance to GDP ratios;¹⁰ liquidity risk, captured by the ratio of a country’s outstanding general government debt to euro-area-wide total; and variables proxing market

⁹Di Cesare *et al.* (2012), p. 5. See also Eichler (2011), Klose and Weigert (2012), Favero (2013).

¹⁰Our measure of fiscal space is from Aizenman and Jinjark (2010). They propose the concept of *de facto* fiscal space, defined as the ratio between the outstanding public debt and the *de facto* tax base, where the latter measures the realized tax collection, averaged across several years to smooth for business cycle. It is argued that this is a better measure of debt sustainability than the debt-to-GDP ratio. See, also, Aizenman, Hutchison and Jinjark (2013) and De Grauwe and Ji (2013).

confidence about EMU survival and contagion effects as shown below. We expect a positive sign for global risk aversion, solvency risk and market's concern about a euro break-up and negative sign for liquidity risk.

In the sequel we follow a two-stage investigation strategy. In the first stage we take no account of contagion effects and focus on the relevance of euro break-up expectations *vis-á-vis* macroeconomic fundamentals. In the second stage we focus on contagion effects in an empirical model that strictly follows from equation (2).

The euro break-up risk and the macro indicators. As stressed in section 3, our indicator of the euro break-up risk follows directly from equation (1), which is shown to include: the nominal fixed parity (\bar{s}), the elasticity of aggregate demand to the real exchange rate (γ), the output gap ($y_t^F - \bar{y}$), and the inflation aversion coefficient (θ). Hence, we need estimates of γ and of $y_t^F - \bar{y}$, and to set values for \bar{s} and θ in order to compute the shadow devaluation rate for each country capturing market expectations of a euro collapse.

We relied on estimates provided by CMP (2012) for EZ countries over the period 1980Q1-2010Q3 for γ and θ . We used the Hodrick-Prescott filter to obtain estimates of potential output and of output gap for each country. We made use of Euro official fixed conversion rates to set values for \bar{s}^i . We finally computed the expected (shadow) devaluation rate for each country ($sr^i \equiv \hat{s}^i - \bar{s}^i$) as

$$\hat{s}_t^i = \bar{s}^i - a_i \Delta \hat{y}_t^i, \quad a_i \equiv \frac{\hat{\gamma}_i}{\hat{\gamma}_i^2 + \hat{\theta}}, \quad \Delta \hat{y}_t^i \equiv y_t^i - \bar{y},$$

where hat variables are estimates and $y_t^i - \bar{y}$ is the output gap. The paths of

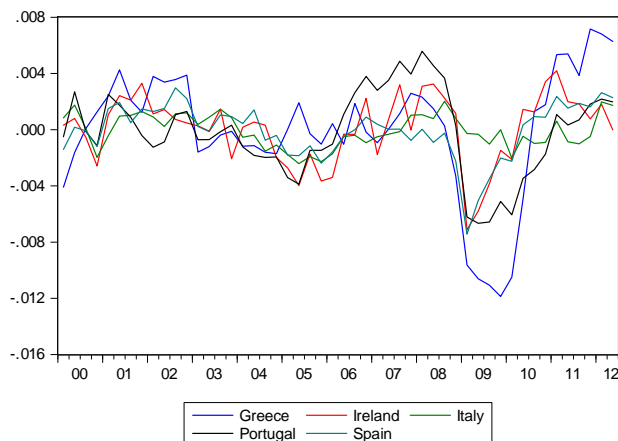


Figure 3: Shadow Spreads

the shadow devaluation rate differentials against the German rate ($dsr^i \equiv sr^i - sr^{GER}$) since 2000 are shown in Figure 3. During the crisis period an impressive similarity with the dynamics of sovereign bond spreads emerges: since 2009 both the devaluation rate differentials and the interest rate spreads in non-core countries move upward, with Greece, Ireland and Portugal showing the largest increase.

Tables A5 and A6 present some preliminary Panel Least Squares estimates of equation (3) for the period 2000Q1-2012Q2 and the two sub-periods labelled as pre-crisis period (2000Q1-2007Q4) and crisis period (2008Q1-2012Q2).¹¹ We used the sample period 2000Q1-2012Q2 for estimation and the period 2012Q3-2013Q1 for out-of-sample testing.

¹¹In the literature, the onset of the crisis is generally accepted to be towards the end of 2007.

Table A5 shows that interest rate spreads react to both market confidence about euro survival and macroeconomic fundamentals. However, the (very) low DW statistics indicates that we cannot dismiss the hypothesis of spurious regressions, as the results in Tab. A6 plainly reveal.¹² The high degree of persistency in sovereign spreads data, therefore, prompt us to check first for the order of integration and then for a long-run or cointegrating equation among the variables of interest.

We assessed the stationarity and cointegration properties of the data set through a battery of panel unit root and cointegration tests that we show in tables A7 and A8. The tests statistics and their p values sharply indicate that yield spreads, fiscal space, liquidity, global uncertainty and shadow devaluation rate are $I(1)$ and that we cannot reject the hypothesis that these variables are cointegrated. Causality tests using VEC modelling also show that we cannot reject the hypothesis that interest spreads are Granger-caused by shadow rates (see, Tab. A9).

The estimated long-run or cointegrated relationships are shown in Table I below.¹³

¹²To save space, in tables A5-A6 we report only the results when the differentials between the shadow devaluation rate ($d sr$) and the fiscal space ($d f s$) in country i and the benchmark country, and the US corporate bond spread ($c b s$) are included in the set of regressors. An absolutely similar picture emerges, however, when the debt- or the budget deficit-to-GDP ratio for each country, and the CBOE Volatility Index appear in the regressor vector \mathbf{X}_t . Results are available upon request.

¹³Similar results are obtained when the CBOE Volatility Index is in the set of regressors in lieu of the US corporate bond spread index. They are available upon request.

Table I Long-run equilibrium relationship				
Sample period: 2000Q1 2012Q2				
$is_t = 14.120dsr_t - 0.001dfs_t + 0.061liq_t - 0.001cbs_t$				
(7.045) (0.107) (0.883) (0.268)				
Pre-crisis period: 2000Q1 2007Q4				
$is_t = 0.123dsr_t + 0.001dfs_t + 0.003liq_t + 0.001cbs_t$				
(1.562) (3.531) (1.884) (11.410)				
Crisis period: 2008Q1 2012Q2				
$is_t = 12.350dsr_t + 0.030dfs_t - 0.195liq_t + 0.029cbs_t$				
(7.873) (3.891) (2.175) (5.394)				
Note: A complete description of variables is in Appendix A, Table A5. <i>t</i> -tests in parentheses				

Two relevant points follow from this model estimation. The first is that a long-run solution between bond yield spreads and the variables appearing in the vector of regressors \mathbf{X}_t manifestly exists. The second is that this relationship is not stable but split in two distinct sub-periods: the period preceding the global financial crisis (2000-2007), when all the explanatory variables played a marginal or no role; the period following the crisis (2008-2012), when the chosen variables acquired a prominent relevance.¹⁴ In particular, we find that before the crisis markets did not perceived any visible risk in the peripheral countries' sovereign debt, as the significant but low value of

¹⁴The discontinuity in the role of various determinants of spreads is also found, for example, in Barrios et al. (2009), Gómez-Puig and Sosvilla-Rivero (2011), Arghyrou and Kontonikas (2012), Aßmann and Boysen-Hogrefe (2012), De Grauwe and Ji (2013), Favero (2013), Giordano *et al.* (2013).

coefficient on the fiscal space variable highlights. As a result, markets priced the default risk in non-core countries in the same way as the risk of core countries, which means that they looked at the EMU as a fully credible monetary union where the probability to exit is zero. The (perceived) low level of credit risk and of global uncertainty and the disappearance of the exchange rate risk since the inception of euro then explain the stability of long-term government bond yields differentials at very low levels in this phase.

By contrast, after the crisis we find that the abnormal increase in the spreads of the peripheral countries can be traced back to the marked shift in both the pricing and the amount of the perceived risk associated with investment in EMU government bonds. Investors' confidence in the irreversibility of the euro loosened and markets started looking at the EMU as a system of fixed exchange rates involving the risk of exchange rate realignments. Specifically, the increase in global risk aversion after the US subprime crises and the perceived reluctance of EU governments to bail out countries facing a sovereign debt crisis led markets to reprice the international risk factor and macroeconomic fundamentals on a country-by-country basis, as the high statistical significance and size of coefficients associated with the country's fiscal space (*dfs*), liquidity premium (*liq*), and global uncertainty (*cbs*) openly show. Yet, the most striking result to emerge from these estimates is the notable relevance of markets expectations of countries' exit from the European Monetary Union and hence of expectations of a euro break-up (*dsr*). It visibly discloses that not only country-specific and international risk factors but also the perceived reluctance of EU governments to fix the monetary union in a political union were critical determinants of the "deep

out-of-the-money euro put option prices, which embedded information on the euro crash risk during the sovereign debt crisis” (Hui and Chung, 2011).¹⁵

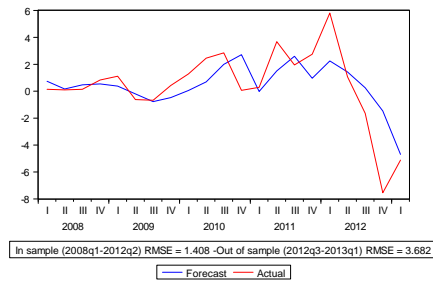
Simple tests of the forecasting performance of the estimated VEC model are shown in Fig. 4. The Figure reports for each country static simulations of the model during the financial crisis period. We used the period 2008Q1-2012Q2 for estimation, we then conducted out-of-sample simulations over the period 2012Q3-2013Q1¹⁶. Overall, we can observe that the model has a significant ability to correctly forecast the dynamics of spreads (i.e., the change in the interest differentials) in all the countries. Of relevance is its (out-of-sample) ability to correctly forecast the resolution phase of the crisis which started in August 2012 after the launch of the OMT by ECB.

¹⁵On this point see also Eichler (2011), Financial Times (2012), Di Cesare *et al.* (2012), Draghi (2012), Woo and Vamvakidis (2012), Klose and Weigert (2012), Favero (2013).

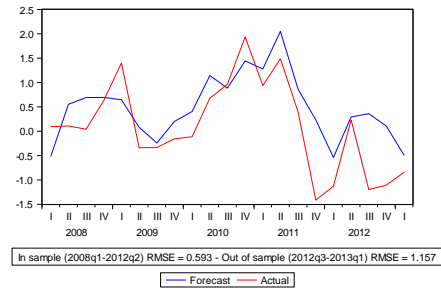
¹⁶The estimated VEC equation is shown in Table A12.

Figure 4: Changes in Interest Spreads ($\Delta is_t = is_t - is_{t-1}$)

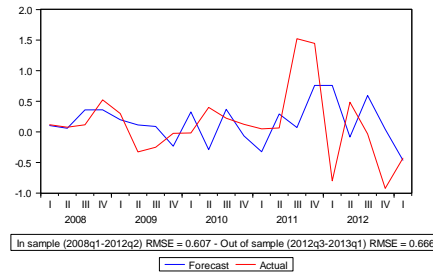
Average RMSE: in sample 0.77; out of sample 1.49



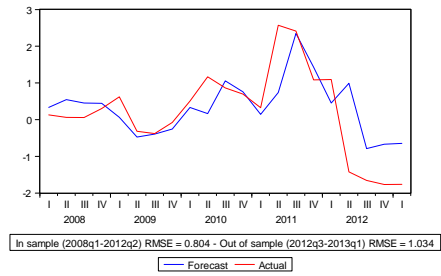
Greece



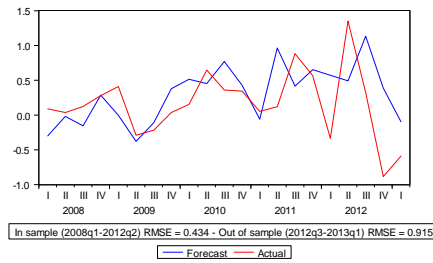
Ireland



Italy



Portugal



Spain

To better understand the role played by each factor during the crisis, we also computed the relative contribution of each regressor to the changes in sovereign yield spreads (see Table II). As in Beber, Brandt and Kavajecz (2009) and Attinasi, Checherita and Nickel (2010), these figures were computed as the ratio between the absolute value of the contribution of each variable, measured as the product between the average value of that variable across time and its estimated coefficient, and the sum of the absolute value of the contributions of all (statistically significant) variables in the model. For example, the relative contribution of the dsr variable (C_{dsr}) is computed as

$$C_{dsr} = \frac{|\hat{\beta}_1 (\overline{dsr}_t)|}{|\hat{\beta}_1 (\overline{dsr}_t)| + |\hat{\beta}_2 (\overline{dfs}_t)| + |\hat{\beta}_3 (\overline{liq}_t)| + |\hat{\beta}_4 (\overline{cbs}_t)|},$$

where $\hat{\beta}_i$ ($i = 1, 2, 3, 4$) is the coefficient estimate from table I (e.g., 12.350 for dsr) and (\bar{x}_t) is the average value over time of the (generic) regressor x .

A run-through of table II shows that, for the whole panel and all countries, global risk aversion made up the majority of the sovereign yield spread during the financial turbulence period of 2009-2012, with fiscal position, liquidity and expectations of a EMU break-up playing a substantially smaller role. Yet, a different picture emerges when we split the euro-area debt crisis in the three phases marked by (i) the explosion of the Greek debt crisis (2009Q1-2010Q4); (ii) tensions on government bond markets of Spain and Italy (2011Q1-2012Q2); (iii) the launch of government bond-buying programme (OMT) by ECB (2012Q3-2013Q1). We find that:

- the relative contribution of the euro break-up risk changed over time in each country consistently with the change in financial stress;

- during the most acute phases, both risk aversion and expectations of countries exit from the monetary union played the major role, with the latter being the most relevant in the case of Greece¹⁷.

Hence, the perceived risk of a break-up of the euro area by private agents do appear to have been a key driver of spreads during the phase of exceptionally high volatility in financial markets.

¹⁷These results replicate those found in the literature using other indicators of the break-up risk (see, e.g., Di Cesare *et al.*, 2012; Klose and Weigert, 2012; Favero, 2013). In particular, it is striking to see the similarity with the results derived from the on line betting platform INTRADE, which (much like our indicator) captures the perceived risk of a country's withdrawal from the currency union by market participants (See Chart 19612 in Klose and Weigert, 2012).

Table II Relative contributions of explanatory variables (%)								
Country	2009Q1 2012Q2				2009Q1 2010Q4			
	<i>dsr</i>	<i>dfs</i>	<i>liq</i>	<i>cbs</i>	<i>dsr</i>	<i>dfs</i>	<i>liq</i>	<i>cbs</i>
Italy	1.73	5.88	17.52	74.86	3.68	20.44	31.40	44.48
Spain	8.98	20.29	3.39	67.34	21.46	8.70	12.65	57.19
Ireland	20.95	16.88	3.47	58.70	29.94	5.83	2.79	61.44
Portugal	8.43	42.06	5.17	44.33	44.48	9.24	2.46	43.82
Greece	7.45	41.43	5.89	45.23	42.36	26.14	3.37	28.13
Panel Average	7.25	21.94	13.19	57.61	31.07	13.83	10.29	44.81
Country	2011Q1 2012Q2				2012Q3 2013Q1			
	<i>dsr</i>	<i>dfs</i>	<i>liq</i>	<i>cbs</i>	<i>dsr</i>	<i>dfs</i>	<i>liq</i>	<i>cbs</i>
Italy	7.86	18.85	29.01	44.28	13.01	19.64	26.62	40.73
Spain	30.54	1.12	13.73	54.60	20.75	11.84	14.95	52.46
Ireland	17.35	29.25	2.88	50.51	7.21	42.50	3.02	47.27
Portugal	27.00	19.98	1.96	51.06	22.77	26.29	3.19	47.75
Greece	43.65	26.32	3.04	26.99	29.30	30.84	3.58	36.28
Panel Average	27.21	20.40	9.72	42.66	15.28	33.72	9.66	41.34

Contagion and systemic risk. We now turn to the critical issue of contagion effects across EMU countries. Specifically, we focus on a key question raised by our theoretical model: to what extent the dramatic increase in the spreads is an instance of propagation of a systemic risk following increasing doubts about the irreversibility of the euro and fears of a Greek exit from the monetary union by markets participants.

In order to inquire into this matter, we focused on equation (2) which

models how expectations of a crisis and exit in one country can spread to other countries and become so widespread that a systemic crisis can hardly be avoided. We brought to the data a simple empirical specification of (2) such as:

$$\widetilde{dsr}_t = a_0 + a_1 dsr_t^{GRE},$$

where \widetilde{dsr}_t now excludes the Greek shadow devaluation rate differential (dsr_t^{GRE}) used as regressor to measure contagion. Estimation results over the period 2008Q1-2012Q2, obtained using cointegration technics to identify the plausible long-run relationship, are as follows (unit root and cointegration tests are in Appendix A, Table A10):

$$\begin{aligned} \widetilde{dsr}_t &= 0.001 + 0.198 dsr_t^{GRE} \\ &(0.006) \quad (2.295) \end{aligned}$$

The estimates show that contagion from the Greek financial crisis and expected exit from the euro area do appear to have occurred in the other countries since the coefficient associated with the Greek shadow devaluation rate is positive and significant. The relative impact of dsr_t^{GRE} on the variation in the shadow devaluation rates of the other peripheral EU countries is far from being negligible, ranging from a worthy 34% over the period 2009-2012 to an impressive 61% or even 78% over the periods 2009-2010 and 2011-2012, respectively.

The strong interdependence between European countries led us to search also for a long-run equilibrium relationship between each non-core country and the other four countries. But the results of cointegration tests (not reported here to save space and available upon request) rejected a long-run solution between them.

To further assess the capability of the shadow exchange rate index to capture the systemic risk or systemic element of the crisis we applied the principal component analysis. The evidence reported in Table 11 shows that the correlation among the expected devaluation rates is high, and that the first principal component explains 78% of the total variation, while the second accounts for 16% of the total. The first two components thus account for 94% of the total variation. This confirms the results of the regression analysis presented above and suggests that the index is measuring the system risk which was behind the redenomination risk discussed by the ECB-President Mario Draghi.

Hence, our paper provides strong empirical support to the view that the increasing loss of confidence in the stability of the euro area and expectations of a EMU break-up have been key drivers of sovereign spreads dynamics in the euro zone.

These findings are strongly consistent with the main implication of our theoretical model, which predicts that in a monetary union financial instability can be transmitted through changes in exit expectations and devaluations of its member countries, thus foreshadowing the occurrence of a union break-up eventually.

5 Conclusion

This paper has focused on the role the perceived risk of a euro break-up and its systemic consequences played in widening government bond yield differentials across EZ countries. To investigate this issue, we used a simple model

of voluntary exit and contagion effects in monetary unions that combines the best features of both first and second generation approaches to currency crises. The model allows to extract a sustainability index for currency unions that we used as a proxy for market expectations of a euro break-up in the empirical analysis of spreads dynamics in non-core EZ countries.

Using quarterly data and panel estimation techniques to model the spreads of 10-year sovereign bond yields over the German Bund benchmark in the Euro Zone over the period 2000Q1-2012Q2, we found that even controlling for country-specific and global risk factors, fears of a reversibility of the euro and contagion from Greece were fundamentals drivers of sovereign risk premia in non-core countries.

These findings have important policy implications. If price dynamics in government bond market is largely driven by market sentiment then some form of ECB intervention or mutual guarantee over public debt (e.g., Eurobonds) with the explicit goal of correcting mispricing by markets can be economically justified (see, for a discussion, Favero and Missale, 2012).

References

- Aßmann, C. and J. Boysen-Hogrefe (2012). “Determinants of Government Bond Spreads in the Euro Area: In Good Times as in Bad.” *Empirica*, 39 (August), 341-356.
- Aizenman, J. and Y. Jinjara (2010). “De facto Fiscal Space and Fiscal Stimulus: Definition and Assessment”. NBER Working Paper. No. 16539, November.
- Aizenman, J., M.M. Hutchinson and Y. Jinjara (2013). “What is the Risk of European Sovereign Debt Defaults? Fiscal Space, CDS Spreads and Mar-

- ket Mispricing of Risk.” *Journal of International Money and Finance*, 34 (April), 37-59.
- Afonso, A., D. Furceri and P. Gomes (2011). “Sovereign Credit Ratings and Financial Markets Linkages: Application to European Data.” ECB Working Paper Series, No. 1347, June.
- Amisano, G. and O. Tristani (2011). “The Euro Area Sovereign Crisis: Monitoring Spillovers and Contagion.” *ECB Research Bulletin*, No. 14 (Autumn), pp. 2-4.
- Ardagna S., C. Burgi, G. Cole and F. U. Garzarelli (2012). “Euro Area Debt: The Path to Redemption”. *Goldman Sachs Global Market ECS Research – Fixed Income Monthly*, March.
- Arezki, R., B. Candelon and A.N.R. Sy (2011). “Sovereign Rating News and Financial Markets Spillovers: Evidence from the European Debt Crisis.” IMF Working Paper Series, No.11/68, March.
- Argyrou, M.G. and J. D. Tsoukalas (2011). "The Greek Debt Crisis: Likely Causes, Mechanics and Outcomes". *The World Economy*, 34 (February), 173-191.
- Argyrou, M.G. and A. Kntonikas (2012). “The EMU Sovereign-Debt Crisis: Fundamentals, Expectations and Contagion.” *Journal of International Financial Markets, Institutions and Money*, 22 (October), pp. 658-677.
- Arru, D., D. Iacovoni, L. Monteforte and F. Pericoli (2012). “EMU Sovereign Spreads and Macroeconomic News”. MPRA Paper No. 37200, March.
- Attinasi, M.G., C. Checherita and C. Nickel (2010). “What Explains the Surge in Euro Area Sovereign Spreads During The Financial Crisis of 2007-09?” *Public Finance and Management*, 10 (October), 595-645. .
- Barrios, S., P. Iversen, M. Lewandowska and R. Setzer (2009). “Determinants of Intra-Euro Area Government Bond Spreads During the Financial Crisis.” European Commission Economic Papers, No. 388, November.
- Beber, A., M. Brandt and K. Kavajecz (2009). “Flight-to-Quality or Flight-to-Liquidity? Evidence from the Euro-Area Bond Market.” *Review of Financial Studies*, 22 (March), 925–57.

- Berger, W. and H. Wagner (2005). “Interdependent Expectations and the Spread of Currency Crises.” *IMF Staff Papers*, 52 (April), pp. 41-54.
- Bernoth K., J. von Hagen and L. Schuknecht (2012). “Sovereign Risk Premiums in the European Government Bond Market.” *Journal of International Money and Finance*, 31 (September), pp. 975–995.
- Bolton P. and O. Jeanne (2011). “Sovereign Default Risk and Bank Fragility in Financially Integrated Economies.” *IMF Economic Review*, 59 (June). pp. 162-94.
- Borgy V., T. Laubach, J.-S. Mésonnier and J.-P. Renne (2012). “Fiscal Sustainability, Default Risk and Euro Area Sovereign Bond Spreads.” Banque de France Documents de Travail, No. 350, July.
- Buiter, W.H., G. Corsetti and P.A. Pesenti (2001). *Financial Markets and European Monetary Cooperation: The Lessons of the 1992-93 Exchange Rate Mechanism Crisis*. Cambridge University Press, Cambridge U.K.
- Caceres C., V. Guzzo and M. Segoviano (2010). “Sovereign Spreads: Global Risk Aversion, Contagion or Fundamentals?” IMF Working Papers, No. 10/120, May.
- Canofari, P., G. Marini and G. Piersanti (2012). “The Sustainability of Monetary Unions. Can the Euro Survive?” CEIS Tor Vergata Research Paper Series, No. 226, March.
- Cavallari, L. and G. Corsetti (2000). “Shadow Rates and Multiple Equilibria in the Theory of Currency Crises”. *Journal of International Economics*, 51 (August), 275-86.
- De Grauwe P. (2011). “The Governance of a Fragile Eurozone.” CEPS Working Document, No. 346, May.
- De Grauwe P. and Y. Ji (2013). “Self-Fulfilling Crises in the Eurozone: An Empirical Test.” *Journal of International Money and Finance*, 34 (April), 15-36.
- De Santis, R.A. (2012). “The Euro Area Sovereign Debt Crisis: Safe Haven, Credit Rating Agencies and the Spread of the Fever from Greece, Ireland and Portugal.” ECB Working Paper Series, No. 1419, February.

- Di Cesare, A., G. Grande, M. Manna and M. Taboga (2012). “Recent Estimates of Sovereign Risk Premia for Euro-Area Countries.” Banca d’Italia Occasional Papers, No. 128, September.
- Draghi, M. (2012). Speech at the Global Investment Conference in London 26 July 2012, published as *BIS central bankers’ speeches* (available at <http://www.bis.org/review/r120727d.pdf>).
- Eichler, S. (2011). “What Can Currency Crisis Models Tell Us About the Risk of Withdrawal from the EMU? Evidence from ADR Data.” *Journal of Common Market Studies*, 49 (July), 719–739
- Ejsing, J., W. Lemke and E. Margaritov (2011). “Sovereign Bond Spreads and Fiscal Fundamentals – A Real-Time, Mixed-Frequency Approach.” Mimeo, European Central Bank, February.
- Favero C. A. (2013), “Modelling and Forecasting Government Bond Spreads in the Euro Area: A GVAR Model”, *Journal of Econometrics*, 177 (December), 243-56.
- Favero C. A., M. Pagano and E.-L. von Thadden (2010). “How Does Liquidity Affect Government Bond Yields?” *Journal of Financial and Quantitative Analysis*, 45 (February), 107-134.
- Favero, C.A., and A. Missale. (2012). “Sovereign Spreads in the Eurozone: Which Prospects for a Eurobond?” *Economic Policy*, 27 (April), 231–273.
- Financial Times (2012), “Central Bankers Brace for Euro Break-Up”, June 14.
- Gärtner, M. and B. Griesbach (2012). “Rating Agencies, Self-Fulfilling Prophecy and Multiple Equilibria? An Empirical Model of the European Sovereign Debt Crisis 2009-2011”. University of St. Gallen Discussion Paper, Department of Economics, No. 2012-15, June.
- Gerlach, S., A. Schulz and G. Wolff (2010), “Banking and Sovereign Risk in the Euro Area.” CEPR Discussion Paper, No. 7833, May.
- Giordano R., M. Pericoli and P. Tommasino (2013), “Pure or Wake-up-Call Contagion? Another Look at the EMU Sovereign Debt Crisis”, *International Finance*, 16 (Summer), 131–160.

- Gómez-Puig, M. (2006). “Size Matters for Liquidity: Evidence from EMU Sovereign Yield Spreads.” *Economics Letters*, 90 (February), 156-162.
- Gomez-Puig M. and S. Sosvilla-Rivero (2011), “Causality and Contagion in Peripheral EMU Public Debt Markets: A Dynamic Approach,” ICEI Working Paper, No. 08/11.
- Haugh, D., P. Ollivaud and D. Turner (2009), “What Drives Sovereign Risk Premiums? An Analysis of Recent Evidence from the Euro-Area,” OECD Economics Department Working Papers, No. 718, July.
- Hui, C.-H. and T.-K. Chung (2011), “Crash Risk of the Euro in the Sovereign Debt Crisis of 2009–2010”, *Journal of Banking & Finance*, 35 (November), pp. 2945–2955.
- International Monetary Fund (2012). *IMF Fiscal Monitor Update. Nurturing Credibility While Managing Risks to Growth*. Fiscal Affairs Department, July.
- Jeanne, O. (1997). “Are Currency Crises Self-Fulfilling? A Test.” *Journal of International Economics*, 43 (November), 263-86.
- Jeanne, O. and P. R. Masson (2000). “Currency Crises, Sunspots and Markov-Switching Regimes.” *Journal of International Economics*, 50 (April), 327-50.
- Klose, J., and B. Weigert (2012). “Determinants of Sovereign Yield Spreads During the Euro-Crisis – Fundamental Factors versus Systemic Risk.” German Council of Economic Experts, Working Paper, No. 07, November.
- Manganelli, S. and G. Wolswijk (2009). “What Drives Spreads in the Euro Area Government Bond Market?” *Economic Policy*, 24 (April), pp. 191-240.
- Masson, P.R. (1999). “Contagion: Macroeconomic Models with Multiple Equilibria.” *Journal of International Money and Finance*, 18 (August), pp. 587-602.
- Metiu, N. (2012). “Sovereign Risk Contagion in the Eurozone.” *Economics Letters*, 117 (October), pp. 35-38.

- Obstfeld, M. (1996). “Models of Currency Crises with Self-Fulfilling Features.” *European Economic Review*, 40 (April), pp.1037-1047.
- Piersanti G. (2012). *The Macroeconomic Theory of Exchange Rate Crises*. Oxford University Press, Oxford.
- Sgherri, S. and E. Zoli (2009). “Euro Area Sovereign Risk During the Crisis.” IMF Working Paper No. 09/222, October.
- Velasco, Andrés (1996). “Fixed Exchange Rates: Credibility, Flexibility and Multiplicity.” *European Economic Review*, 40 (April), 1023-35.
- Von Hagen, J., L. Schuknecht and G. Wolswijk (2011). “Government Bond Risk Premiums in the EU Revisited: the Impact of the Financial Crisis.” *European Journal of Political Economy*, 27 (March), pp. 36-43.
- Woo, D. and A. Vamvakidis (2012). “Game Theory and Euro Breakup Risk Premium”. Bank of America Merrill Lynch Research Report, July.

Appendix A - Tables

Table A1 Long-term sovereign yield spreads: descriptive statistic (2008-2012)								
Country	2008Q2 - 2012Q2				2011Q2 - 2012Q2			
	mean	max	min	st.dv.	mean	max	min	st.dv.
Portugal	401.31	1139.00	45.00	393.69	953.33	1139.00	680.00	171.69
Ireland	357.90	791.67	390.00	252.13	658.60	791.67	537.67	112.60
Italy	184.63	468.00	52.73	132.80	357.40	468.00	171.00	117.64
Greece	796.84	2398.00	56.33	770.10	1814.73	2398.00	1240.00	512.88
Spain	175.53	474.67	26.00	133.86	346.33	474.67	228.00	89.62

Yield spreads are expressed in basis points. Source: See Appendix B

Table A2		Real GDP growth				
Country	2007	2008	2009	2010	2011	2012*
Portugal	2.365	-0.009	-2.908	1.401	-1.669	-3.005
Ireland	5.445	-2.109	-5.456	-0.766	1.431	0.353
Italy	1.683	-1.156	-5.494	1.804	0.400	-2.100
Greece	2.996	-0.157	-3.250	-3.517	-6.906	-6.000
Spain	3.479	0.893	-3.742	-0.322	0.400	-1.400
Germany	3.388	0.802	-5.073	4.024	3.100	0.900

*Forecast. Source: World Economic Outlook

Table A3		Government Budget Deficit/GDP ratio					
Country	2000	2007	2008	2009	2010	2011	2012*
Portugal	-3.313	-3.212	-3.697	-10.169	-9.843	-4.239	-4.990
Ireland	4.687	0.062	-7.340	-13.931	-30.946	-12.752	-8.301
Italy	-0.911	-1.590	-2.673	-5.368	-4.475	-3.822	-2.725
Greece	-3.734	-6.801	-9.912	-15.561	-10.496	-9.113	-7.519
Spain	-0.997	1.904	-4.152	-11.193	-9.365	-8.931	-6.993
Germany	1.323	0.237	-0.057	-3.212	-4.144	-0.781	-0.389

*Forecast. Source: World Economic Outlook

Table A4		Government Debt/GDP ratio					
Country	2000	2007	2008	2009	2010	2011	2012*
Portugal	48.359	68.262	71.582	83.051	93.320	107.818	119.066
Ireland	37.493	24.988	44.489	64.859	92.175	106.460	117.743
Italy	108.475	103.082	105.749	115.992	118.605	120.102	126.332
Greece	103.441	107.448	112.622	128.952	144.550	165.412	170.731
Spain	59.379	36.301	40.172	53.917	61.316	69.117	90.693
Germany	60.182	65.355	66.911	74.719	82.394	80.555	83.038

*Forecast. Source: World Economic Outlook

Table A5	Panel Least Squares estimates: 10-year government bond yield spreads over Germany (<i>is</i>)			
Sample period: 2000Q1 2012Q2				
$is_t = 3.081 + 3.235dsr_t + 0.045dfs_t - 0.726liq_t + 0.007cbs_t$				
(1.967) (5.961) (7.532) (3.158) (1.981)				
$\bar{R}^2 = 0.402; SE = 2.504; DW = 0.181; FE = 0.000$				
Pre-crisis period: 2000Q1 2007Q4				
$is_t = 1.019 + 0.049dsr_t + 0.003dfs_t - 0.156liq_t + 0.001cbs_t$				
(4.823) (0.988) (5.493) (4.701) (3.335)				
$\bar{R}^2 = 0.590; SE = 0.104; DW = 0.241; FE = 0.000$				
Crisis period: 2008Q1 2012Q2				
$is_t = 3.880 + 5.756dsr_t + 0.052dfs_t - 1.377liq_t + 0.030cbs_t$				
(1.191) (8.167) (5.500) (3.154) (2.770)				
$\bar{R}^2 = 0.670; SE = 2.742; DW = 0.517; FE = 0.044$				
<p>Note: All the data are expressed in percentages. The panel members include Greece, Ireland, Italy, Portugal and Spain. <i>dsr</i> = Shadow devaluation rate differential over Germany; <i>dfs</i> = Fiscal space differential over Germany; <i>liq</i> = Ratio of government debt to euro-area-wide total; <i>cbs</i> = US corporate bond spread; \bar{R}^2 = Adjusted R^2; <i>SE</i> = Standard error of regression; <i>DW</i> = Durbin Watson statistic; <i>FE</i> = Redundant fixed effects test (<i>p</i>-value); <i>t</i> statistics in parentheses. A complete description of data sources is in Appendix B.</p>				

Table A6 Panel Least Squares estimates: 10-year government bond yield spreads over Germany (is)
<p style="text-align: center;">Sample period: 2000Q1 2012Q2</p> $is_t = -0.254 + 1.132is_{t-1} + 0.065dsr_t - 0.002dfs_t + 0.031liq_t + 0.001cbs_t$ <p style="text-align: center;">(0.684)(64.643) (0.473) (1.350) (0.569) (1.245)</p> $\bar{R}^2 = 0.968; SE = 0.584; DW = 1.526; FE = 0.400$
<p style="text-align: center;">Pre-crisis period: 2000Q1 2007Q4</p> $is_t = 0.145 + 0.842is_{t-1} + 0.037dsr_t + 0.001dfs_t - 0.017liq_t - 0.000cbs_t$ <p style="text-align: center;">(1.572) (23.431) (1.734) (2.041) (1.179) (1.910)</p> $\bar{R}^2 = 0.926; SE = 0.042; DW = 1.735; FE = 0.353$
<p style="text-align: center;">Crisis period: 2008Q1 2012Q2</p> $is_t = 0.412 + 1.045is_{t-1} + 0.632dsr_t - 0.000dfs_t - 0.100liq_t + 0.003cbs_t$ <p style="text-align: center;">(0.367) (24.753) (1.990) (0.074) (0.638) (0.893)</p> $\bar{R}^2 = 0.962; SE = 0.937; DW = 1.661; FE = 0.275$

Table A7 Panel Unit Root Tests (p -value)						
Sample period: 2000Q1 2012Q2						
Level				1st difference		
	LLC	F-ADF	F-PP	LLC	F-ADF	F-PP
<i>is</i>	1.000	1.000	1.000	0.000	0.003	0.000
<i>dsr</i>	0.975	0.203	0.258	0.000	0.000	0.000
<i>dfs</i>	1.000	0.998	0.437	0.004	0.002	0.000
<i>liq</i>	0.945	0.992	0.918	0.005	0.016	0.000
<i>cbs</i>	0.918	0.923	0.905	0.000	0.000	0.000

Note: Null hypothesis= unit root. LLC= Levin, Lin, and Chu test (common unit root process); F-ADF and F-PP= Fisher-ADF and Fisher-PP tests (individual unit root process). The test on the level includes individual fixed effects (intercepts and trends); the test on 1st difference includes no deterministic component. Maximum number of lags fixed at 3.

Table A8 Panel cointegration tests (p -value)					
Sample period: 2000Q1 2012Q2					
No. CE	None	At most 1	At most 2	At most 3	At most 4
J-F test	0.000	0.000	0.013	0.274	0.125
Kao test	0.001				

Note: None, At most 1, 2, 3 and 4 denote the number of cointegrated equations (No. CE) under the J-F test. J-F test= Johansen-Fisher cointegration test. Null hypothesis for Kao cointegration test= No cointegration. Maximum number of lags fixed at 3.

Table A9 Causality tests	
Sample period: 2000Q1 2012Q2	
Null Hypothesis	<i>p</i> -value
<i>d</i> <i>sr</i> does not Granger cause <i>i</i> <i>s</i>	0.0002
<i>i</i> <i>s</i> does not Granger cause <i>d</i> <i>sr</i>	0.1489

Table A10 Panel Tests (<i>p</i> -value)									
Sample period: 2008Q1 2012Q2									
Unit root							Cointegration		
Level				1st difference			No. CE	None	1
	LLC	F-ADF	F-PP	LLC	F-ADF	F-PP	J-F test	0.028	0.913
$\widetilde{d}sr$	0.821	0.933	0.959	0.000	0.002	0.000	Kao test	0.003	
$d sr^{GRE}$	0.057	0.702	0.984	0.000	0.021	0.000			

Note: 1= At most 1. Maximum number of lags fixed at 2. For other label names see Tables A7 and A8. Analogous results are obtained if the tests are carried out over the period 2000Q1-2012Q2 .

Table 11 Principal Component Analysis					
Ordinary correlations					
	dsr^{GRE}	dsr^{IR}	dsr^{PT}	dsr^{ES}	dsr^{IT}
dsr^{GRE}	1.000				
dsr^{IR}	0.771	1.000			
dsr^{PT}	0.972	0.798	1.000		
dsr^{ES}	0.858	0.964	0.867	1.000	
dsr^{IT}	0.512	0.298	0.592	0.437	1.000
Components					
No.	Cumulative ratio				
1	0.782				
2	0.942				
3	0.992				
4	0.998				
5	1.000				

Table 12 VEC estimates: Sample 2008Q1 2012Q2										
Eq.: $\Delta is_{it} = \beta_1 \Delta is_{it-1} + \beta_2 \Delta is_{it-2} + \beta_3 \Delta dsr_{it-1} + \beta_4 \Delta dsr_{it-2} + \beta_5 \Delta dfs_{it-1}$ $+ \beta_6 \Delta dfs_{it-2} + \beta_7 \Delta liq_{it-1} + \beta_8 \Delta liq_{it-2} + \beta_9 \Delta cbs_{it-1} + \beta_{10} \Delta cbs_{it-2} + \beta_{11} ec_{it-1}$										
β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}	β_{11}
0.617	-0.055	1.005	0.381	0.027	-0.003	-0.237	.482	-0.300	-0.002	-0.049
(5.124)	(0.408)	(2.038)	(0.858)	(2.971)	(0.238)	(0.424)	(0.872)	(0.663)	(0.388)	(1.750)
$\bar{R}^2 = 0.341$ $SE = 0.855$										
$ec_{it-1} \equiv is_{it-1} - 12.350 dsr_{it-1} - 0.030 dfs_{it-1} + 0.195 liq_{it-1} - 0.029 cbs_{it-1}$										
<i>t</i> statistics in parentheses										

Appendix B – Data Sources

Variable's name: 10-yr government bond yields

- Description: Current yield on 10-year government bonds
- Source: IMF: International Financial Statistics
- Frequency: Quarterly
- Period: 2000Q1-2013Q1

Variable's name: 10-year government bond yield spread (*is*)

- Description: Differential in the current government bond yield vis-à-vis the German Bund
- Source: IMF: International Financial statistics and own calculations
- Frequency: Quarterly
- Period: 2000Q1-2013Q1

Variable's name: Real GDP

- Description: Real GDP expressed in national currency units; seasonally adjusted
- Source: OECD: Main Economic Indicators
- Frequency: Quarterly
- Period: 2000Q1-2013Q3

Variable's name: Real GDP growth

- Description: Percentage change of real GDP
- Source: IMF: World Economic Outlook
- Frequency: Annual
- Period: 2007-2012

Variable's name: Budget deficit/GDP ratio

- Description: General government primary net lending/borrowing to GDP ratio
- Source: IMF: World Economic Outlook
- Frequency: Annual
- Period: 2000-2012

Variable's name: Debt/GDP ratio

- Description: General government gross debt to GDP ratio
- Source: IMF: World Economic Outlook
- Frequency: Annual
- Period: 2000-2012

Variable's name: Tax revenues

- Description: Total general government revenues

- Source: Eurostat
- Frequency: Annual
- Period: 1996-2012

Variable's name: De facto fiscal space

- Description: Ratio of government consolidated gross debt to (four years) average tax revenues
- Source: Eurostat and own calculations
- Frequency: Quarterly
- Period: 2000Q1-2013Q1

Variable's name: Fiscal space differential (*dfs*)

- Description: Fiscal space differential over Germany
- Source: Eurostat and own calculations
- Frequency: Quarterly
- Period: 2000Q1-2013Q1

Variable's name: Bond market liquidity (*liq*)

- Description: Ratio of a country's outstanding general government debt to euro-area-wide total (EU 27)
- Source: Eurostat and own calculations

- Frequency: Quarterly
- Period: 2000Q1-2013Q1

Variable's name: US corporate bond spread (*cbs*)

- Description: Differential between US AAA Corporate Bond Yields and US 10-year Treasury Constant Maturity Rate
- Source: Federal Reserve Bank of St. Luis, Board of Governors of Federal Reserve System, and own calculations.
- Frequency: Quarterly
- Period: 2000Q1-2013Q1

Appendix C – A Simple Model of Exit and Contagion in Monetary Unions

Our model uses a multi-country setting consisting of a three-country monetary union and the rest of the world. The union is taken to be asymmetric and partitioned in two ‘periphery’ economies or ‘non-core’ countries (*A* and *B*) - with identical structural parameters, to simplify modelling - and a ‘core’ or leader country. Under fixed price and a zero inflation rate, the macroeco-

nomic structure can be summarized by the following set of equations:¹⁸

$$\mathcal{L}_t^i = (y_t^i - \bar{y}^i)^2 + \theta^i (s_t^i - \bar{s}^i)^2 + \delta \mathbb{C}^i \quad (\text{C.1})$$

$$y_t^i = \gamma_i (s_t^i - \bar{s}^i) + y_t^{i,F} \quad (\text{C.2})$$

$$y_t^{i,F} \equiv D + \gamma_i (\bar{s}^i - \phi s_t^j - \alpha s^W) - u_t^i \quad i, j \in \{A, B\} \quad i \neq j, \quad (\text{C.3})$$

where all variables are measured in logs and \mathcal{L} = welfare loss, \mathbb{C} = opting out cost, y = real output, \bar{y} = output target, s = nominal (shadow) exchange rate, \bar{s} = entry currency parity, s^W = world exchange rate, D = autonomous component of aggregate demand, u = random shock.

Equation (C.1) is a standard social loss function with an additional linear term (\mathbb{C}) measuring the cost of opting out of the union, where $\delta = 1$ if $\Delta s_t^i \equiv s_t^i - \bar{s}^i \neq 0$, and $\delta = 0$ if $\Delta s_t^i = 0$. Equation (C.2) gives equilibrium output in the goods market of country i , where $(s^i - \phi s_t^j - \alpha s^W)$ is the real exchange rate defined as a trade-weighted variable with weight ϕ for country j , η for the core or leader country, and $\alpha = 1 - \phi - \eta$ for the rest of the world. Equation (C.3) gives the output for country i required to stay in the monetary union, where u_t^i is an i.i.d. random (demand) shock characterized by a continuous, bell-shaped and symmetric (around zero) probability density function.

¹⁸Similar theoretical structures are also found, e.g., in Masson (1999), Buiter, Corsetti, and Pesenti (2001), Berger and Wagner (2005).

Model solution yields the optimal switching conditions

$$s_t^i - \bar{s}^i = -\frac{\gamma_i}{\gamma_i^2 + \theta^i} \left(y_t^{i,F} - \bar{y}^i \right), \quad (\text{C.4})$$

$$\bar{u}_t^i = \frac{(\gamma_i^2 + \theta^i) \bar{\mathbb{C}}^i}{\gamma_i} + D + \gamma_i (\bar{s}^i - \phi s_t^j - \alpha s^W) - \bar{y}^i, \quad i, j \in \{A, B\} \quad i \neq j. \quad (\text{C.5})$$

(C.4) is equation (1) in the text. (C.5) computes the threshold value of the shock (\bar{u}_t^i) at which the policymaker is indifferent between opting out and remaining in the union, where $\bar{\mathbb{C}}^i \equiv \sqrt{\frac{\mathbb{C}^i}{\gamma_i^2 + \theta^i}}$ is the critical devaluation rate such that the welfare losses arising from alternative regimes are exactly the same. It states that if $u_t^i \leq \bar{u}_t^i$ it is optimal for country i to stay in; on the contrary, if $u_t^i > \bar{u}_t^i$ it is optimal to exit and implement an independent monetary policy, carrying out a devaluation of size $s_t^i - \bar{s}^i$.

Under rational expectations, equilibrium requires

$$\pi_t^i = \text{Pr}_t [u_{t+1}^i > \bar{u}_{t+1}^i] = \text{Pr}_t [(s_{t+1}^i - \bar{s}^i) > \bar{\mathbb{C}}^i],$$

or

$$\pi_t^i = 1 - G(\bar{u}_{t+1}^i | s_{t+1}^i = \bar{s}^i + \xi^i) \equiv \Phi(\pi_t^i; f_t), \quad (\text{C.6})$$

where π_t^i is the exit probability for country i formed at time t for period $t+1$, $G(\cdot)$ is the cumulative distribution function of u_t^i , ξ^i the expected devaluation rate following the opting out decision, and f_t the state of fundamentals at time t .

The mutual interdependence of private agents' expectations in different countries implies that we can express π_t^i as

$$\begin{aligned} \pi_t^i &= \pi_t^j [1 - G(\bar{u}_{t+1}^i | s_{t+1}^j = s_t^j + \xi^j)] \\ &+ (1 - \pi_t^j) [1 - G(\bar{u}_{t+1}^i | s_{t+1}^j = s_t^j)] \equiv \Psi(\pi_t^i, \pi_t^j; f_t) \quad , \quad (\text{C.7}) \end{aligned}$$

where π_t^j is the expected probability of exit in country j , and ξ^j the size of country j 's devaluation conditional on exit from the currency union. Equation (C.7) shows that private agents compute π_t^i as a weighted average of two conditional probabilities: the probability that country j exits and devalues and the probability that j continues to remain in the union next period. As both sides of (C.7) are increasing with π_t^i multiple equilibria can arise as in the second generation models by Obstfeld (1996), Velasco (1996), Jeanne (1997), Jeanne and Masson (2000).

Equation (C.7) shows the three main channels for contagion of the shocks. ‘Monsoonal effects’ result from changes in s^W , or D ; ‘spillover effects’ from changes in π_t^j ; ‘pure contagion’ from self-fulfilling expectations of an exit of country i . The possibility of contagion is also related to changes in exit expectations for country j . This follows from

$$\frac{\partial \pi_t^i}{\partial \pi_t^j} = G(\bar{u}_{t+1}^i | s_{t+1}^j = s_t^j) - G(\bar{u}_{t+1}^i | s_{t+1}^j = s_t^j + \xi^j) > 0 \quad , \quad (\text{C.8})$$

which is equation (2) in the text. It implies that a rise in π_t^j can push the exit probability in country i high enough that an opting out choice can hardly be avoided. Fear of a crisis and exit in one country can spread in the other country, making the opting out choice more likely to occur.