Sovereign debt spreads in EMU: The time-varying role of fundamentals and market distrust[☆]

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Abstract

This paper provides further analysis on the determinants of sovereign debt spreads for peripheral Eurozone countries since the start of EMU, paying special attention to episodes that characterized the global financial crisis aftermath starting in 2007. More specifically, the purpose of our research is to disentangle the role of fundamental variables and market perception about variations on risk in order to explain the evolution of sovereign spreads in EMU during the recent crisis. Our results, in line with previous literature, show the importance of three groups of observable variables, namely, changes in risk-aversion of creditors, fiscal indebtedness and liquidity variables. In addition, our model includes unobserved components that are estimated through the Kalman filter as time-varying deviation from fixed-mean parameters of spread determinants. This shows the importance of expectations (market sentiments), amplifying (or reducing) the relative importance of the spread determinants over time through the time-varying behavior of the parameters around their steady-state estimates.

JEL Classification: C33, E44, F36

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1. Introduction

The emergence of a sovereign debt crisis in Europe has raised fears about the risks and consequences of sovereign default, giving birth to a burgeoning literature on sovereign markets. From the launching of the euro up to the financial crisis, empirical studies focused mainly on the dynamic evolution of the degree of financial integration in the Eurozone. However, with the sharp increase of sovereign spreads in the euro area following the 2008-09 financial crisis, academic interest has shifted to the identification of drivers affecting the behavior of sovereign bond yield spreads. To ascertain the determinants of the idiosyncratic and systemic components is an empirical question, which thus far has remained unresolved. At the beginning of the European Monetary Union (EMU), academic attention was confined to testing for a co-movement in bond yields for Euro member countries[1]. The idea behind this exercise was that these countries would share a large systemic component, indicating consequently a remarkable degree of financial integration within the euro area. Empirical studies undertaken after 2008, such as Gómez-Puig (2009), Favero and Missale (2012) or Kim et al. (2015), show an increase of the idiosyncratic risk component in spread movements, becoming stronger than the systemic one. Bernoth and Erdogan (2012) find evidence that European sovereign bond spreads incorporate both liquidity and default risk premia, the latter being related to fiscal conditions in euro-area countries. More recently, Georgoutsos and Migiakis (2013) reject the assumption that fiscal variables (or fundamentals in a broader sense) cause movements in sovereign bond spreads, whereas they confirm the significance of the economic sentiment variables. Moreover, as in other types of debt, sovereign bond prices and risk premia depend not only on borrowers' economic conditions, but also on lenders' risk-aversion. Recent approaches, such as Bernoth and Erdogan (2012) or Afonso et al. (2014) suggest a time-varying relationship between spreads and their determinants but do not outline a formal model that supports this evidence.

In this article we seek to offer an exploration of the determinants of sovereign debt spreads for Eurozone peripheral countries. More specifically, the purpose of our research is to disentangle the role of fundamental variables and market perception about variations on risk in order to explain the evolution of sovereign spreads in EMU during the recent crisis. We argue that the literature on credibility and currency crisis is able to provide a good explanation of the behavior of yields for this group of countries. Our theoretical approach is mainly drawn from Arghyrou and Tsoukalas (2011), who provide a simple model for the Greek debt crisis combining the model of self-fulfilling currency crises developed by Obstfeld (1996) and the treatment of the 1998 Asian crisis due to Krugman (1999). The gist of our study is the use of time-varying coefficients estimated through a multivariate Kalman filter, where deviations from steady-state mean of parameters are driven by an unobservable state-variable. Under this time-varying framework, yield spread evolution can be related, either to changes in market perception on government fiscal solvency, mostly due to a rise in unemployment and worsening fundamentals, or in a complementary way, to investors' relative risk-aversion.

Our research contributes to the existing literature in several respects. A distinctive feature of our exercise is that we resort to a combination of three different theoretical approaches to

[1] See, for instance, Codogno et al. (2003) or Gómez-Puig (2006)

build our encompassing empirical framework. First, we consider the models on currency crises providing a framework where investors can anticipate either fiscal unsustainability, worsening fundamentals or moral hazard in financial markets, and hence an increase in sovereign spreads. This increase in sovereign spread can lead to a default on debt or not, depending on the market sentiment. That is to say, a country can find itself in a situation where multiple equilibria are possible. Second, connected to the previous point, we borrow from literature regarding credibility and dynamic inconsistency of policies to explain the evolution of sovereign spreads in the Eurozone context. The assumption is that once EMU was launched, member countries reached a "fully credible commitment". However, this "full credibility" can be eroded if tough (austerity) policies, despite increasing reputation by worsening persistently fundamentals, reach a threshold beyond which credibility falls sharply [2]. Third, and particularly important, our approach relies on an optimum currency areas (OCA) theory, as we assign to cycle asymmetries in the Eurozone a key role governing market distrust for EMU peripheral countries.

A second additional contribution of our research is the econometric methodology employed which, to the best of our knowledge, is novel in the area. Using the Kalman filter, we have estimated in a panel data setting a time-varying multi-parameter model, allowing for the inclusion of observed (control) variables. Although other studies in the literature have also used the Kalman filter, they generally modelize simple transition equations assuming a random walk behavior of unobserved components, and do not make explicit the estimation of their autoregressive component.

Our results suggest a time-varying relationship linking sovereign spreads for peripheral EMU countries to the evolution of global risk aversion, and also to idiosyncratic variables such as the increase of fiscal indebtedness and the worsening of fundamentals. Moreover, cyclical asymmetries, and in particular, output growth misalignment between peripheral and core economies drives the different paths of the particular time-varying market distrust parameters, reflecting the evolution of changing market belief about sovereign risk for those countries.

The rest of the paper is structured as follows. Section 2 reviews literature on sovereign debt determinants in the Eurozone. Section 3 presents the theoretical framework as well as the testing model. Section 4 exposes the empirical approach and the dataset. In section 5 we discuss the results. Finally, Section 6 gathers the main conclusions of the paper.

2. Sovereign spreads in the Eurozone. A concise review of the literature.

Since the launching of the EMU, euro-area bond markets tended to converge towards a single market, comparable in terms of size to the US or the Japanese market. Although, in the-

[2]Drazen and Masson (1994) illustrate the problem of enhancing credibility with a simple story: "One afternoon, a colleague announces that he is serious about losing weight and plans to skip dinner. He adds that he has not eaten for two days. Does this information make it more or less credible that he really will skip dinner? The traditional view on credibility would imply that with each meal he skips, the "tough policy" of skipping the next meal becomes more credible, as each observation of playing tough raises the probability we assign to his being a fanatical dieter. Once we realize that his skipping one meal makes him hungrier at the next mealtime (i.e., that policy has persistent effects), we are led to the opposite conclusion, namely, that it becomes less likely he will stick to his diet the more meals he has skipped".

ory, exchange rate risk was non-existent, a reduced country risk premium was still present. Therefore, spreads did not disappear completely. However, the private sector considered the probability of default to be very low, and sovereign yields remained very similar across euro-area countries until 2007, despite the steady deterioration of macroeconomic fundamentals, and notably, the significant differences in the fiscal positions of individual member countries. However, from that date on, economic policy measures undertaken by the different euro members to face the global financial crisis gave rise to special fiscal packages, guarantees and bailouts for banks which, together with a decline in government revenue, led to widespread increases in government deficits and debt. Until the eruption of the financial crisis, sovereign default in developed countries, such as EMU members, was considered as highly unlikely (see Cottarelli et al., 2010). The key reason for this difference between advanced and emerging economies is attributed to the distinct nature of their debt structure. Emerging and developing countries are usually unable to issue debt in their domestic currency, and therefore, a default is more likely[3].

On the contrary, developed countries usually issue debt in their own currency and the central bank can always act as a lender of last resort. However, this is not exactly the case for EMU member countries. As De Grauwe (2012) has recently pointed out, the fact that Eurozone countries have no direct control over their own currency, makes them in some way, similar to developing countries, augmenting their fragility vis-à-vis financial markets. Consequently, after the outbreak of the financial crisis, investors dramatically changed their perception and attitude towards sovereign credit risk in the Eurozone, increasing pressure on sovereign spreads of peripheral countries whose public finances were deteriorating to levels inconsistent with long-term EMU participation.

In the literature, sovereign risk is commonly measured by the yield spreads between government bonds and a suitable reference asset which is perceived to be risk-free. For the euro area, previous studies have widely employed the German government bond yields as the benchmark asset, since its probability of default is commonly perceived as very low. However, for reasons of construction, this empirical strategy does not allow us to analyse the changes in the sovereign risk of the reference country, as what is actually being measured is in fact a differential risk.

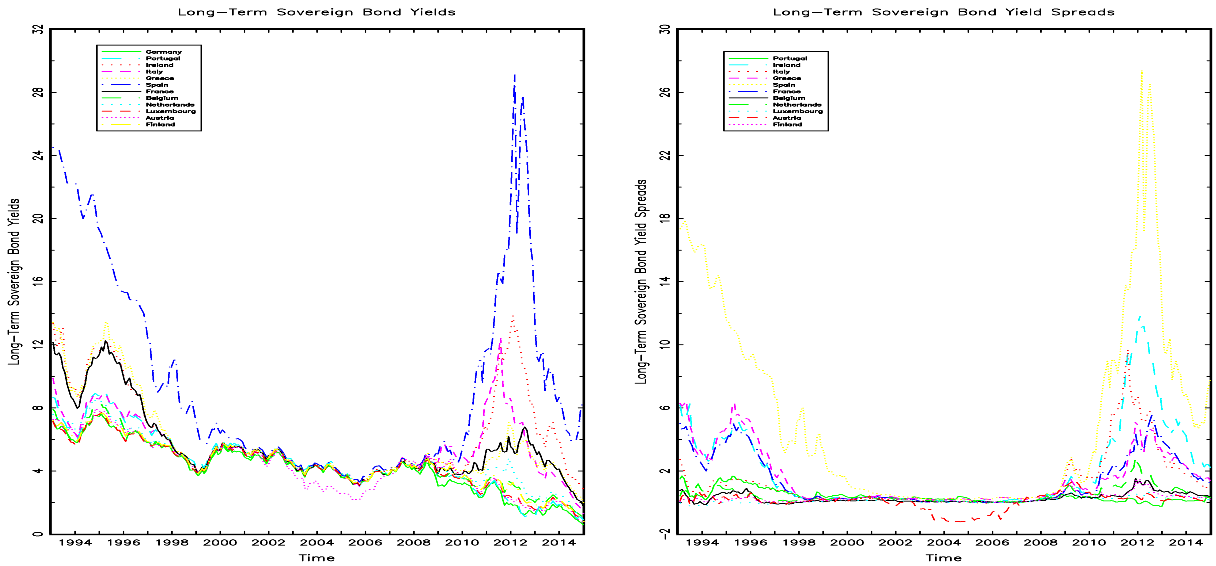
Sovereign credit default swaps (SCDSs) provide an alternative means for estimating individual sovereign risk. A CDS is an OTC[4] contract that provides insurance against a default (or “credit event”) by a particular company or sovereign entity (the “reference entity”). For a sovereign CDS, the “credit event” would be the equivalent of the issuer State defaulting on its payment commitments. In CDS, the buyer (of protection against sovereign risk) makes periodic payments to the seller and in return obtains the right to sell a bond issued by the reference entity for its face value if a credit event occurs. The rate of payments made per year by the buyer is known as the CDS spread.

In theory the N-year CDS spread should be close to the excess of the yield on an N-year bond issued by the reference entity over the risk-free rate, but perhaps the main problem lies in choosing the risk-free rate. Theoretically, the CDS premium (or spread) is roughly equal to

[3]See, for instance, Eichengreen et al. (2003)

[4]Over the Counter.

Figure 1: Long-term Sovereign Spreads, Eurozone selected countries 2000-2013.



the bond spread for the same borrower and maturity. Both spreads are meant to compensate for the investor's loss in the event of the borrower's default. The relation between eurozone SCDS and their relation with underlying sovereign bonds has been studied, among others, by Pan and Singleton (2008), Fontana and Scheicher (2010), Broto et al. (2011), da Silva et al. (2015) and Blommestein et al. (2016).

However, as stated in Coudert and Gex (2010), the government bond market is still much larger, when compared to a sovereign CDS market in infancy, despite its recent astonishing growth. Prior to 2007, it can be argued that SCDS markets were not liquid enough to measure developed economies' sovereign risk adequately. It was only after the outbreak of the crisis when a sharp increase in in trading volumes (which doubled) occurred[5]. As the econometric approach we follow needs a longer sample for the Kalman filter algorithm to converge, we have chosen the 10-year government bond yield spread relative to Germany to construct the spread.

Moreover, Singh et al. (2016) argue that CDS spreads capture only the credit risk, while yield spreads also include inflation expectations, re-denomination risk, demand/supply for lending conditions as well as default risk. And moreover, they better represent the size and liquidity concerns in the government debt market.

Figure 1 plots the evolution of sovereign yield and spreads for the original eleven EMU countries plus Greece, in terms of monthly 10-year government bond yield spread relative to Germany, computed using data from EUROSTAT.

Spreads show a high degree of co-movement, but with different intensities affecting individual countries after the financial crisis. Distinguishing between common and idiosyncratic

[5]Nevertheless, according to IMF, CDS contracts that reference sovereign credits are only a small part of the sovereign debt market ($3 trillion notional sovereign CDS outstanding in end-June 2012, compared with $50 trillion of government debt outstanding at end-2011).

factors governing the evolution of the spread is a difficult task. Moreover, this first distinction can be refined by breaking down the different types of risk: liquidity, credit/default and exchange rate risk. As depicted in Figure 1 and following Afonso et al. (2014) we can differentiate between three distinct periods to explain the determinants of euro-area spreads allowing for time-varying coefficients: first, the period preceding the global credit crunch (1999.01 – 2007.07); second the period during which the global credit crunch had not yet mutated into a sovereign debt crisis (2007.08 – 2009.02); and third, the period during which the global financial crisis mutated into a sovereign debt crisis (2009.03 – 2010.12). During the first period the exchange rate premium disappeared completely from the very moment the euro was launched, and the credit risk diminished progressively as markets perceived sovereign markets as a single one, without paying attention to the no bail-out clause. This situation changed from 2007, where liquidity risk augmented, and especially, from 2009 where a default and even a possible break-up of the EMU was again considered possible. Therefore, as the credit risk and exchange-rate increased, the risk premia also augmented in parallel. This evolution is, however, quite different depending on the country considered. Disentangling the different determinants for each country remains an important empirical challenge.

The empirical literature on spread determinants has typically reported very simple estimated functions on the yield spreads of bonds issued by European countries. In general, sovereign yield spreads may just reflect the premia that investors demand in order to bear the country-specific risks in relation to those of a benchmark country. As in Codogno et al. (2003), the standard definition of sovereign risk includes two main domestic or idiosyncratic components, namely, credit risk and market liquidity for the asset, together with a measure of an international or common risk factor, reflecting investors' changes in risk aversion.

First, the credit risk premium that is demanded by investors depends primarily on the issuer's probability of default. If the risk of a default is high, investors demand a higher yield to compensate. In general, a government's default risk is measured by historical fiscal data such as the debt-to-GDP and the deficit-to-GDP ratios (Hallerberg and Wolff, 2008). In the same vein, Balassone et al. (2004), among others, show that yield spreads against Germany of government bonds issued by the other EU countries in their national currencies between 1980 and 2003 depend positively on the change in the government debt-to-GDP ratio. Likewise, Aizenman et al. (2013) link spreads to the evolution of fiscal variables and other macroeconomic fundamentals.

Second, yield spreads could also be influenced by the so-called liquidity premium, as demanded by investors in compensation for the potential trading costs when selling illiquid securities under bad market conditions, as highlighted in Gómez-Puig (2006) or Favero et al. (2010), among others, suggesting small gains from greater liquidity[6].

The sharp increase in sovereign spreads after the global financial crisis shifted the attention from idiosyncratic factors towards a common factor, which would reflect a change in investors' risk aversion, triggering "herd behavior" as defined previously in (Shiller, 1995). Therefore, variations in the global risk might also have contributed to the widening of the sovereign risk premium differentials (Litterman and Scheinkman, 1991). This common factor, also called

[6]Moreover, academic literature has also showed the influence of other factors. For instance, Bernoth and Wolff (2008) find evidence linking sovereign debt spreads to creative accounting measures.

"global risk-aversion", could be linked to the attitude of investors towards bearing risk. In times of high uncertainty, investors are supposed to be more risk-averse. In practice, shifts in investors' risk appetite are not directly observable and the impact on global risk repricing should affect spreads through its interaction with risk-content of a particular asset which could also be time-varying.

Previous empirical studies consider a typical function where a measure of the sovereign debt yield spreads (y_{it}) is influenced by a vector of explanatory variables (x_{it}) through a fixed-parameters relationship ($\bar{\beta}_i$). But the variability in risk pricing over time suggests the need for time-varying coefficient models as a proper empirical approach. Recent studies, such as Bernoth and Erdogan (2012) or Afonso et al. (2015) also prove the existence of a time-varying relationship between euro area sovereign spreads and their underlying fundamentals, turning from inactive to active since the onset of the global financial crisis and further intensifying during the sovereign debt crisis. In the same vein, De Grauwe and Ji (2013) theorize on how the financial crisis seems to have changed the relationship between fiscal indebtedness and spreads for peripheral EMU countries. For these authors, this fact would confirm fragilities of EMU and how liquidity crises in a monetary union can lead to multiple equilibria, and also the role of expectations in determining if an adverse self-fulfilling equilibrium is reached. The common factor that characterizes the evolution of the expectations is by definition an unobserved variable with a time-varying behavior that can be proxied using a transition equation. This transition equation can be defined either by making some assumptions on a random variable or, as we do in this paper, by adding a signalling variable as a proxy. Even if a fundamental determinant, either common or idiosyncratic, of a sovereign spread had remained unchanged, the varying nature of its parameter affected by the underlying market sentiment, would generate a change in the spread.

Our aim is to investigate whether the spread evolution for euro-area members was due to a progressive worsening in the fundamentals and not to pure contagion. Pragidis et al. (2015) find no evidence of contagious effects stemming from the 10-year Greekbond to the periphery or the core European countries. We also seek to determine if a change in market sentiment took place due to a new scenario where a full/partial debt default was possible, or even an eventual EMU-exit was a feasible outcome for some member countries (Giordano et al., 2013).

In the next Section, we present an empirical specification allowing us to disentangle the role of fundamentals from market sentiments to explain sudden changes in sovereign risk.

3. An eclectic time-varying model for EMU sovereign spreads.

In this Section we present the empirical model for spread determination reflecting the existence of a time-varying relationship between sovereign spreads and their determinants based both on fundamentals together with the evolution of market expectations and the credibility of the implemented policies. More specifically, the specification we employ is consistent with Dornbusch et al. (2000), who distinguish two types of variables with explanatory power on the evolution of sovereign yield spreads: fundamentals and investors behavior-based determinants. We follow an eclectic approach, departing from the model initially proposed by De Grauwe and Ji (2013) and extended in Arghyrou and Tsoukalas (2011), and encompassing the different issues raised as explanatory variables by the three generations of currency crisis models applied to EMU membership. In short, these variables are: evolution of current fiscal stance, the credibility of the government in its commitment with the currency union agreement (leading to self-fulfilling prophecies through an increasing currency premium), and the market risk aversion, when changes in the quality of assets appear (through a default premium). Casual empiricism suggests that this class of models appear to match the main features of the recent sovereign debt EMU crisis. Bearing this in mind, the specification of the model that we estimate is as follows:

$$\begin{array}{rcccl} Spread_{it} & = & \bar{\beta}_0 & + & \left(\beta_{0i,t} - \bar{\beta}_0\right) \\ & + & \bar{\beta}_1 GD_{it} & + & \left(\beta_{1i,t} - \bar{\beta}_1\right) GD_{it} \\ & + & \bar{\beta}_2 BAAS_t & + & \left(\beta_{2i,t} - \bar{\beta}_2\right) BAAS_t \\ & + & \bar{\beta}_3 UR_{it} & + & \left(\beta_{3i,t} - \bar{\beta}_3\right) UR_{it} \\ & + & \bar{\beta}_5 LIQ_{it} & + & \left(\beta_{4i,t} - \bar{\beta}_4\right) LIQ_{it} \\ & + & w_{it} & & \end{array} \tag{1}$$

The dependent variable, sovereign spread, is the monthly 10-year government bond yield spread relative to Germany calculated from EUROSTAT[7]

As stated byDe Grauwe and Ji (2015), the spread between the interest rates on two government bonds can be interpreted as reflecting the relative risk of holding these two bonds in the portfolios of investors. It is assumed that one of the two bonds is a benchmark bond with zero risk (e.g. the German government bond), that the spread between the interest rate of country i and the interest rate of the benchmark bond reflects the risk of holding the bond issued by country i. Moreover, as member countries in the Eurozone issue debt in a currency over which they do not have control, only default risk is at stake[8] .

"GD" stands for gross debt-to-gdp ratio compared to Germany[9]. The rationale for this variable derives from the first-generation currency crises models suggesting the inclusion of fiscal variables, which reflect possible inconsistencies between the stance of the domestic fiscal policy and a growing public debt stock. In addition, "LIQ", captures the role of liquidity of the assets considered as a ratio of the volume of Gross Debt in euros relative to the total in the Eurozone. In a bond market with elastic demand, a larger bond market generally

[7]Sovereign credit default swap (CDS) premia have been used extensively as an alternative measure of sovereign default risk. In this paper we have decided not to use the CDS for two reasons. First, as mentioned above, the SCDS market lacked liquidity prior to 2007. In fact, the CDS market begun in the early 1990s but initially restricted to corporate debt. The Bank for International Settlements (BIS) did not begin collecting comprehensive CDS statistics until 2004 which gave us an excessively short sample to successfully implement our econometric approach. Second, the CDS market is an OTC market almost entirely populated by institutional investors and therefore, in contrast with an organised exchange, there is no reliable information on prices. Information on prices must be gathered from market participants on the basis of their voluntary participation on periodic surveys, with all the potential shortcomings such a situation may bring about. CDS premia can be extracted from Bloomberg and Datastream.

[8]Compared to countries that issue debt in their own currencies (e.g. the EMS countries), where both devaluation and default risks exist.

[9]Constructed as the monthly cubic spline interpolation of quarterly government debt-to-gdp ratio relative to Germany, and obtained by drawing a piecewise polynomial function connecting each pair of input data. Cubic spline interpolation force first and second derivatives to be continuous, and gives us a pretty good interpolation between our known quarterly data points.

contributes to lower transaction costs. However, if overall supply of new issuance exceeds existing demand, then there could also be an adverse impact on bond market liquidity. We expect the second effect to be primarily relevant for bond spreads.[10]

Several studies show that sovereign bond yield spreads are not only driven by country-specific risk factors but also by international factors and global investors' risk aversion[11]. Risk aversion is associated with the willingness of investors to take risks (the so-called "risk appetite"). As investors continuously adjust their risk-return preference function, even if the "amount of risk" embedded in a security remains unchanged, the risk premium may vary depending on the "price of risk". As in Bernoth and Erdogan (2012), we use the yield spread between low grade US corporate bonds (BAA) and benchmark US and the 10-year US Treasury bonds as an empirical proxy for this overall investors' risk attitude ("BAAS"). This global factor has also been proxied by US stock market implied volatility obtained from the Chicago Board Options Exchange (CBOE) Volatility Index (VIX)[12], which is constructed using both call- and put-implied volatilities from the S&P 500 index[13]. Although the literature finds a relevant role for both proxies, it can be said, that while BAA spread measures risk appetite, a variation in implied volatility on a market may stem from a change in the quantity of risk on this market and not necessarily from a change in investor risk aversion. We have used both variables in our study as a robustness check exercise.

All three variables above presented are consistent with first generation speculative crisis models. In a complementary way, we add the variable "UR", which stands for the unemployment rate, which seems to be the most successfully used by similar earlier studies testing the second-generation speculative attack models in different contexts. While the traditional approach to credibility has focused on signaling the preferences of the authorities, tough (i.e. austerity) policies with adverse persistent effects make the economy more vulnerable to future adverse shocks and hence increase sovereign risk [14].

As in Schwarz (2015), part of the spreads are due to the fact that government bond markets (other than German bonds) in the Eurozone have become less liquid due to the 'flight to safety' syndrome. To take into account market flight-to-quality, the specification includes for all regressors, both a steady-state fixed parameter, and a time-varying component, which is updated each period, influenced by both past values and the variable "CYAS", which captures cyclical asymmetries for each country's GDP growth compared to the anchor country, Germany. This view is consistent with the OCA theory, which suggests that such asymmetries would add serious difficulties to monetary integration. Fixed parameters are estimated for the whole panel to capture co-movements in the eurozone, while time-varying components of each parameter might reflect idiosyncratic patterns for single countries. In particular, the

[10]Additionally, as highlighted inBeber et al. (2009), the theoretical work by Vayanos (2004) and Acharya and Pedersen (2005) shows liquidity becomes more important in a market with greater volatility.

[11]See, for instance, Codogno et al. (2003) and Favero et al. (2010)

[12]See Caceres et al. (2010) andBekaert et al. (2013)

[13]The VSTOXX is a similar volatility index for European equity markets that is constructed using implied option prices written on the DJ Euro STOXX 50 index

[14]Although there are other alternative relevant macro fundamentals that can affect investors' expectations and the probability of default, like the real exchange rate evolution (as a proxy for competitiveness) compared to Germany or the size of the current account imbalances, unemployment seems to lead to more robust results in our case.

time-varying parameter associated to indebtedness could also disclose market's distrust about the existence of implicit fiscal guarantees of last resort.

It is worth noting that this model contains no lagged endogenous variables in equation (1). Although persistence is usually captured by lagged endogenous variables in similar studies[15], in our analysis it stems from the time-variation of risk perception as in equation (B.10). Given the high adjustment speed in financial markets, today's spread can be assumed to be determined by current information only.

The introduction of unobserved components in our model allows us to capture the time-variant relationships suggested by recent literature on the behavior of sovereign spreads for Southern EMU economies[16]. In order to capture the time-varying relationships, we add a vector of time-varying parameters to traditional fixed coefficients,

$$\xi_{it} = \left(\left(\beta_{0i,t} - \bar{\beta}_0 \right), \left(\beta_{1i,t} - \bar{\beta}_1 \right), \left(\beta_{2i,t} - \bar{\beta}_2 \right), \left(\beta_{3i,t} - \bar{\beta}_3 \right), \left(\beta_{4i,t} - \bar{\beta}_4 \right) \right) \tag{2}$$

whose evolution can be modeled as an unobserved vector following a stochastic process:

$$\xi_{it+1} = \Theta \xi_{it} + \mu CYAS_{it} + \upsilon_{it+1} \tag{3}$$

$$\upsilon_{it} \sim N(0, Q)$$

where the unobserved vector updates each period and includes the cyclical asymmetries of the GDP growth compared to the anchor country, Germany. This variable, "CYAS", according to the OCA theory, is a measure of EMU misalignment among member countries that may influence market expectations regarding the future of the currency union. The explanatory variable used in the state-transition equation is the relative difference in inter-annual GDP growth rate between the countries analyzed. Monthly estimations have been obtained by cubic-spline from EUROSTAT quarterly data [17] .

We estimate the previous model for eleven EMU countries, including both peripheral (Greece, Ireland, Italy, Portugal and Spain) and core members (France, Belgium, Netherlands, Luxembourg, Austria and Finland) using monthly data cfor the period January-2000 to December-2013. Mostly we use data from EUROSTAT database, except for the global risk aversion factor, proxied by the spread between US BAA corporate bonds and the 10-year Treasury Bonds, obtained in this case from FRED database[18].

Figures 2 and 3 plot EUROSTAT and FRED data used for the regressions.

We estimate the model in a panel time-series framework, where instead of an unobserved variable, we model an unobserved vector including all parameters in the sovereign spread determinants equation. The model has also been re-estimated substituting this global risk aversion by CBOE Volatility Index VIX, obtaining similar results. This is not surprising as the correlation coefficient between both variables is very high (0.85) and they present a similar profile.

[15] See, for instance, Masson (1995)

[16] See Afonso et al. (2014)

[17] See [namq_gdp_k] in EUROSTAT.

[18] Federal Reserve Economic Database. Federal Reserve Bank of St. Louis.

Figure 2: EUROSTAT Data (peripheral). 2000-2014.

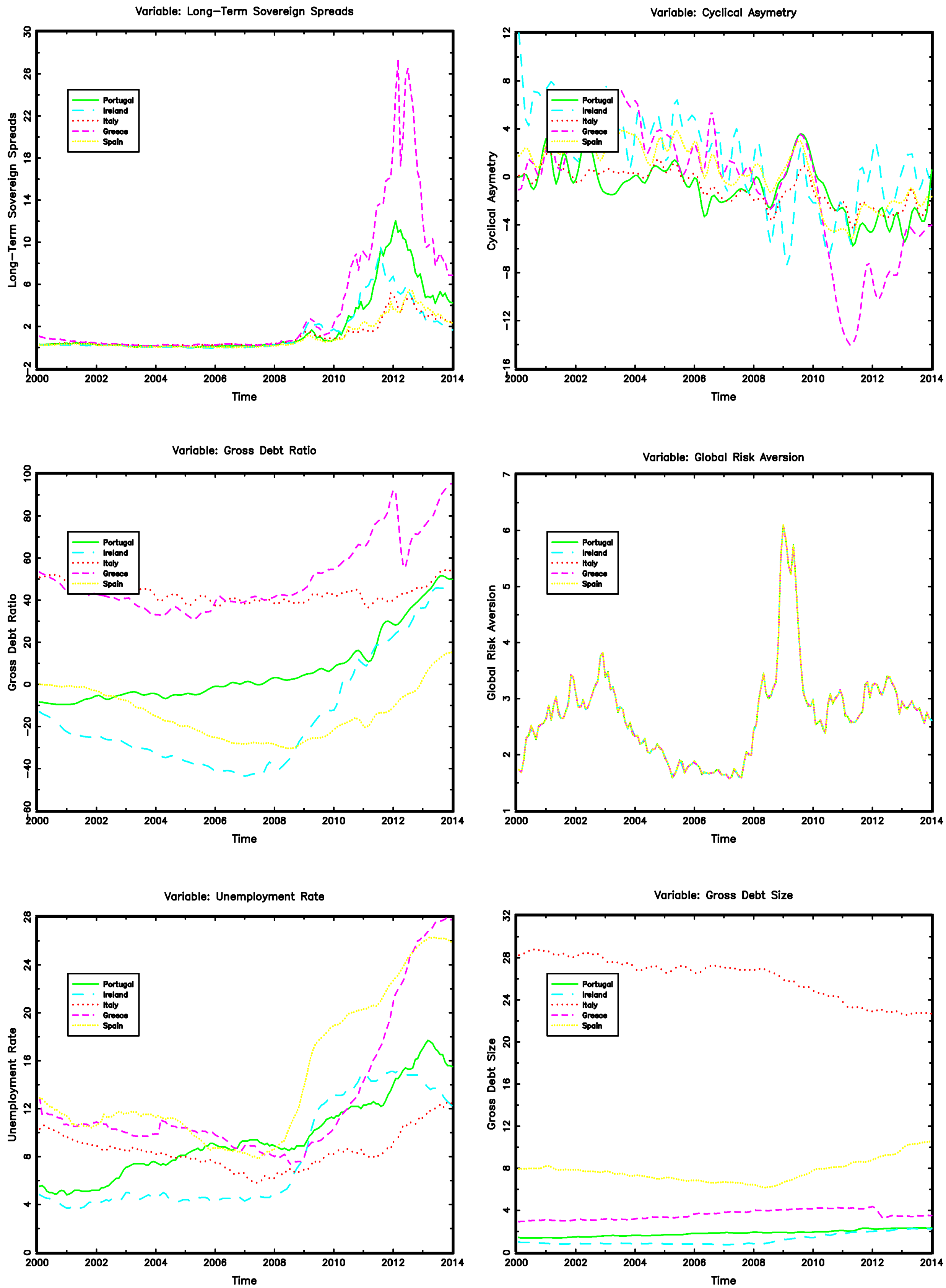
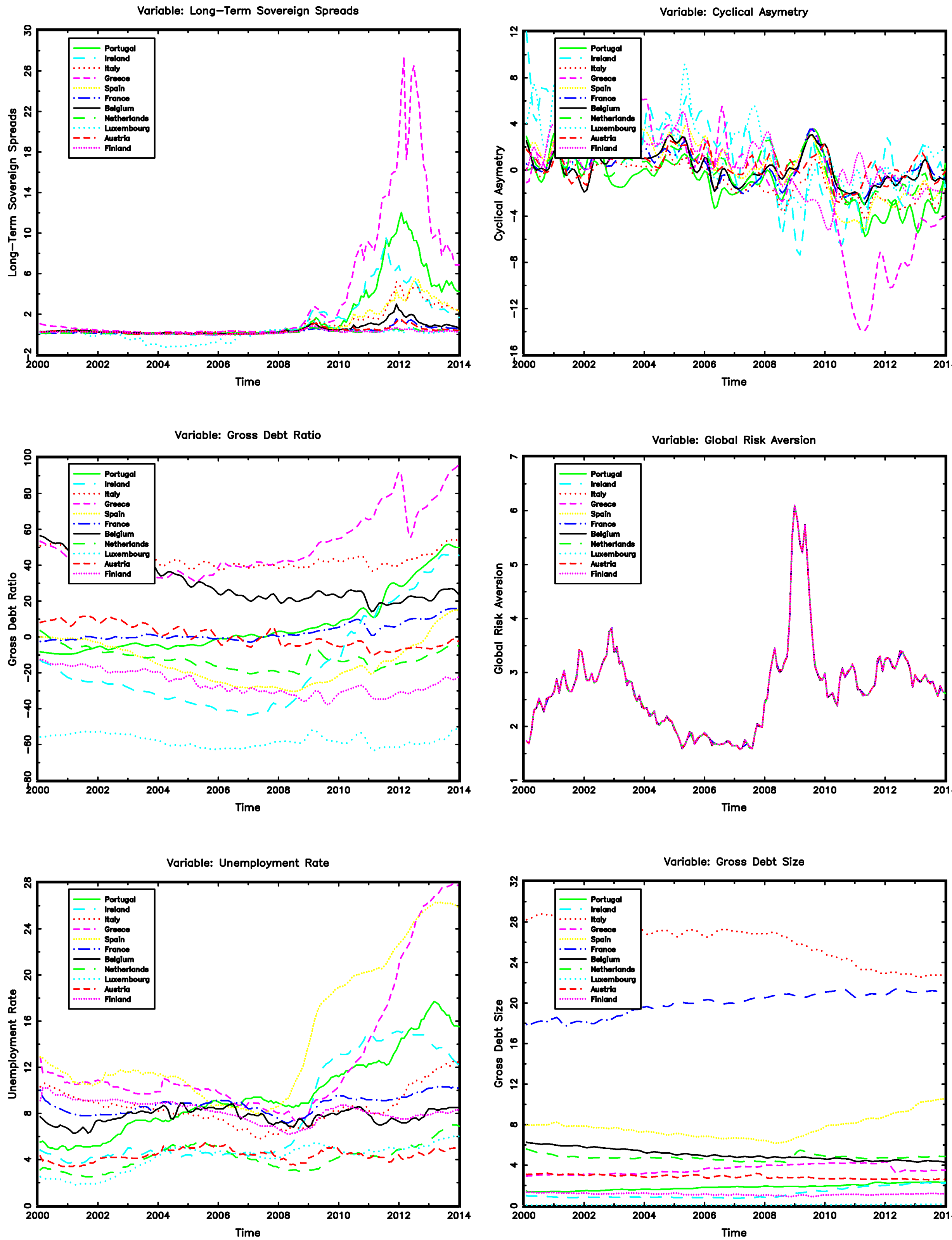


Figure 3: Eurostat Data (all countries). 2000-2014.



4. Estimation, results and discussion

In this Section we estimate the empirical specification described in Section 3 using monthly data for the period 2000:01-2013:12 in a panel of 11 EMU countries, including both core member countries, as well as those members with the highest sovereign risk premia: Greece, Portugal, Ireland, Italy and Spain. Prior to the estimation of our model using TVP, we analyze the univariate properties of the series using panel unit root tests, allowing for both cross-country dependence and structural breaks.

4.1. Univariate properties of the data.

Regarding the analysis of the order of integration of the variables included in the estimated model, we have considered the existence of potential and unknown structural changes. This is a non-trivial feature given that unit root tests can lead to misleading conclusions if the presence of structural breaks is not accounted, as stated in a seminal paper by Perron (1989). As most of the variables (gross debt ratio, unemployment rate, gross debt size and GDP growth asymmetry) have been defined at a country-level, we can construct a panel made up of the different individuals and implement the Bai and Carrion-i Silvestre (2009) panel unit root test. The exception is the BAA spread, whose univariate nature required an alternative unit root test, in this case that developed by Carrion-i Silvestre et al. (2009). Both approaches allow for multiple and unknown structural breaks, while the first also allows for cross-country dependence.

Bai and Carrion-i Silvestre (2009) propose a set of panel unit root statistics that pool the modified Sargan-Bhargava (hereafter MSB) tests (Sargan and Bhargava, 1983) for individual series, taking into account both the possible existence of multiple structural breaks[19], and cross-section dependence modeled as a common factors model[20]. The common factors may be non-stationary processes, stationary processes or a combination of both. The number of common factors is estimated using the panel Bayesian criterion information in Bai and Ng (2002). We have implemented the GAUSS code provided by the authors, allowing for a maximum number of three breaks, determined through the Bai and Perron (1998) procedure[21]. In Table 1 we present the panel-based unit root test results, estimated for a group of eleven Eurozone countries (except Germany), which includes both core and peripheral countries. When allowing for common factors and structural breaks, results do not support clearly a unit-root for most of the series. Although results obtained are inconclusive, it is worth noting that the authors claim that the simplified set of tests are most appropriate for the level and trend break model, and suggest that the Z and P statistics have the best small sample properties.

When conducting this test for a panel covering the eleven member countries of the Eurozone, we also find strong evidence for multiple structural breaks affecting most of the variables analyzed; however, the results differ in number and position for individual countries, as shown in Table 2.

In order to obtain a deeper insight into the results appearing in Table 2, it is convenient to distinguish between common and idiosyncratic breakpoints, as well as between peripheral

[19]Adapting Bai and Perron (2003) methodology to a panel data framework

[20]Following Bai and Ng (2004) and Moon and Perron (2004)

[21]See Bai and Carrion-i Silvestre (2009) for details

Table 1: Bai & Carrion-i-Silvestre Panel Unit Root Test with common factors and structural breaks (2000:01-2013:12)

Variable	Model 2. Trend Break Model									
	Z	P_m	P	Z^*	P_m^*	P^*	T	N	m	fr
$Spread_{it}$	-1.285	1.102	29.307	7.276	-1.352	13.034	168	11	4	55
GD_{it}	2.964***	-2.427***	5.903	14.068***	-2.967***	2.317	168	11	4	55
UR_{it}	1.531*	-2.309**	6.682	6.953***	-2.382***	6.200	168	11	4	55
LIQ_{it}	2.777***	-2.475***	5.584	15.894***	-2.790*	3.496	168	11	4	55
$CYAS_{it}$	-0.467	-0.512	18.605	3.605*	-0.680	17.491	168	11	4	55

Notes: Z, P and Pm denote the test statistics developed by Bai and Carrion-i-Silvestre (2009). Z and P_m follow the standard normal distribution and their 1%, 5% and 10% critical values are 2.326, 1.645 and 1.282; whereas P follows the Chi-squared distribution with critical values for the chi-squared with n*(breaks+1) degrees of freedom (distributed P statistic are *82.292, 73.311 and 68.796*, respectively). The number of common factors are estimated using the panel Bayesian information criterion proposed by Bai and Ng (2002). Z*, P* and P_m^* refer to the corresponding statistics obtained using the p-values of the simplified MSB statistics. The null hypothesis of a unit root is rejected at * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ significance level, respectively, if the statistic is greater than the upper level.

Table 2: Bai&Carrion-i-Silvestre (2009) structural Breaks, (jan-2000 - dec-2013).

	spread	grossdebt	urate	debtsize	cycleas
PT	$jun-2009$ $oct-2011$	$sep-2008$			
IR	$oct-2008$ $jul-2011$	$feb-2008$ $mar-2011$	$feb-2008$ $nov-2010$	$jan-2008$ $mar-2010$	$mar-2007$ $apr-2009$ $nov-2011$
IT	$mar-2009$ $nov-2011$	$nov-2008$	$apr-2007$	$mar-2008$ $feb-2011$	
GR		$nov-2008$ $dec-2010$	$nov-2008$	$nov-2011$	$jan-2009$ $feb-2011$
SP		$aug-2008$	$oct-2007$ $nov-2009$	$apr-2008$	
FR	$nov-2011$	$may-2008$ $jun-2010$	$nov-2002$ $jan-2006$	$feb-2002$	$apr-2007$ $may-2009$
BEL	$aug-2009$ $nov-2011$	$aug-2007$			
NT		$aug-2008$	$feb-2002$ $may-2005$ $feb-2008$ $jun-2011$	$dec-2006$ $jan-2009$	
LUX		$jul-2008$ $aug-2010$	$feb-2002$ $apr-2004$		
AUT					
FL		$sep-2008$ $oct-2010$	$jan-2008$ $feb-2010$		

Notes. Bai & Carrion-i-Silvestre (2009) estimations allowing for up to 4 structural breaks.

and core countries. First, let us consider the common breaks. The first three columns show the breakpoints for the "spread" variable as well as for "gross debt ratio" and the "unemployment rate". Note that these dates for the common breakpoints coincide with those found by Afonso et al. (2014) to explain the evolution of the euro-area spreads allowing for time-varying coefficients. The first one, 2007-2008, coincides with the global credit crunch, while the second, around 2010, is when the crisis mutated into a sovereign debt crisis and the Eurozone entered into recession. Indeed, the credit crunch affected economic activity and employment in the whole euro-area, giving rise to an increase in the gross debt level for all the EMU members, which constitutes the common factor leading to the shock. However, the third and fourth columns represent variables that capture the idiosincratic component of the shock or, al least its asymmetric nature. Therefore, it is useful here to analyze the different behavior of both variables discriminating between peripheral and core countries. The upper part of Table 2 displays the results found for the five peripheral countries considered in our study, while the lower part gathers the results for the core countries considered, where France is a borderline case. Note that while the variables "debtsize" and "cycleas" represent, respectively, the relative liquidity premium for each sovereign State analyzed, and the relative cyclical asymmetry for each country. Both define clear idiosyncratic discontinuities with a direct impact on the evolution of the spread for the case of the peripheral countries (excepting Portugal) for 2008, and especially, 2011. However, they do not present any breakpoint for the core countries with the exception of France and the Netherlands (only for the "debtsize" variable in this latter case) . In the case of France, this is due to its particularly fragile performance in terms of growth and indebtness from the beginning of the present century (the same explanation applies for Portugal in the case of the peripheral countries).

Summing up, Table 2 presents a clear calendar of breakpoints brought about by the credit crunch shock and its decomposition into common and idiosyncratic effects, with asymmetric results in the spreads between core and peripheral countries.

As mentioned earlier, for the monthly data of the BAA yield spread to long-term federal bonds, we have used the GLS-based unit root test statistics proposed in Kim and Perron (2009) and extended in Carrion-i Silvestre et al. (2009). This test solves many of the problems of previous standard tests of unit root with a structural change at an unknown break date [22], and allows multiple breaks at an unknown time under both the null and alternative hypothesis.

The unit root test results for BAA spread are supportive of the unit-root hypothesis, as shown in Table 3.

It seems clear that the null hypothesis of a unit root with structural breaks cannot be rejected for all the series at the 5% level of significance. Accordingly, we can conclude that the variables in Table 2 are I(1) with a structural break.

Table 4 reports the summary statistics and correlations for the variables used in this study (for all countries). The dependent variable (Spread) is positively and significantly correlated with the rest of the variables, except with liquidity. The pair correlation between independent variables is low (below 0.5).

[22]SeeZivot and Andrews (2002), Perron (1997), Vogelsang and Perron (1998), Perron and Vogelsang (1992a,b), among others.

Table 3: BAA Spread. Carrion-i-Silvestre-Kim-Perron (2009) GLS unit roots tests with structural breaks

	Test Statistics	Critical Values
P_T^{GLS}	24.406*	7.125
MP_T^{GLS}	20.480*	7.125
ADF	-2.461*	-3.964
Z_α	-11.596*	-31.672
MZ_α^{GLS}	-10.899*	-31.672
MSB^{GLS}	0.212*	0.125
MZ_t^{GLS}	-2.313*	-3.964
Break dates	abr-2007 / sep-2008 /abr-2010	

Notes: * denotes significance at the 5% level. The critical values were obtained from simulations using 1,000 steps to approximate the Wiener process and 10,000 replications. Note that for the MSB and MP_T tests the null hypothesis is rejected in favour of stationarity when the estimated value is smaller than the critical value.

Table 4: Summary Statistics & Correlations of Variables

	Summary Stat		Correlations			
	mean	sd	Gross debt	BAA	Unemployment	Liquidity
Gross debt	0.965	32.88	1.000			
BAA	2.683	0.807	0.061***	1.000		
Unemployment	8.270	4.486	0.455***	0.106***	1.000	
Liquidity	6.747	8.09	0.446***	-0.023	0.145***	1.000
Spread	0.990	2.54	0.429***	0.181***	0.634***	-0.032

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

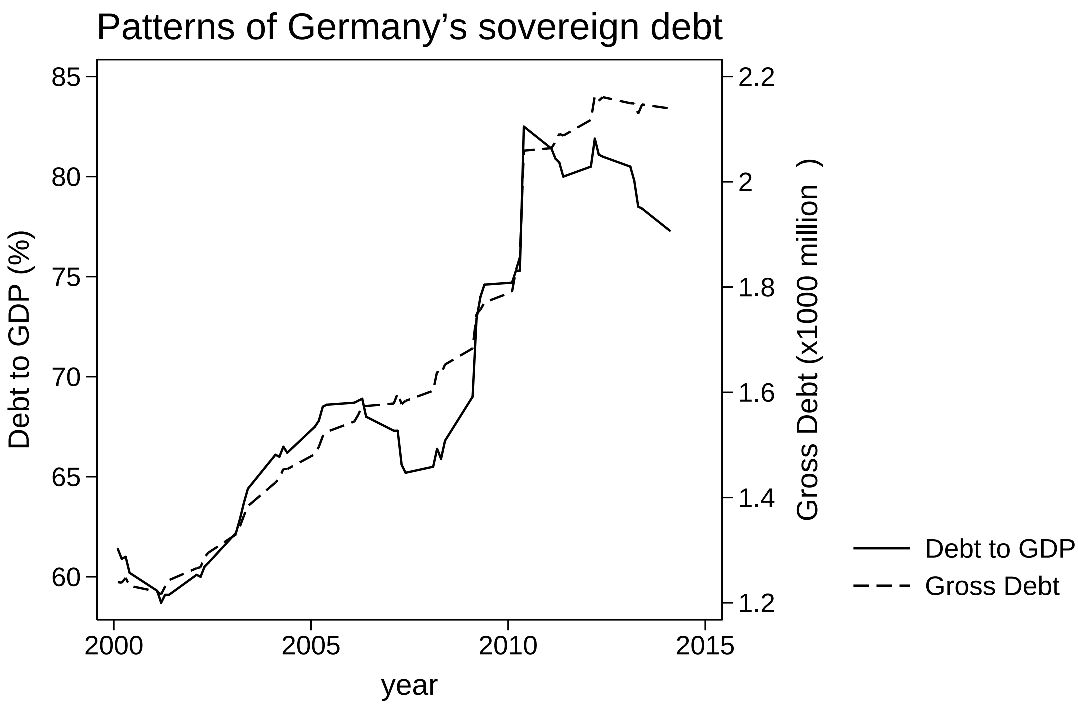
Our dependent variable is calculated in terms of its spread with respect to Germany's debt yield. It is therefore relevant to inspect Germany's sovereign debt pattern, which is displayed in Figure 4. The dashed line represents the debt relative to GDP in the left axis and the solid line is the gross debt in the right axis. Both measures have a similar profile, except for the last part of the series. After 2010, gross and relative debt present a divergent pattern. While the gross debt has reached plateau, the relative debt size has decreased due to Germany's stark growth in this period.

4.2. Kalman Filter estimation of the TVP model.

Equations (1) and (3) have been estimated through Kalman filter methodology allowing for time-varying parameters in the measurement equation described in 1. The time-varying component of each parameter for each country updates each period according to equation 3.

To perform our Kalman Filter estimation, we have modified a GAUSS code provided by J. D. Hamilton that allows the estimation of a single unobserved variable in an univariate context, as described in Hamilton (1994). We have extended this GAUSS code in several

Figure 4: Germany's Debt



directions: first, modifying the code to fit a time-varying multi-parameter model; second, adapting the transition equation to include control (observed) variables, and third, extending the model to a panel data context.

Tables 5 and 6 report our empirical results, for peripheral EMU countries (Portugal, Ireland, Italy, Greece and Spain), and also for an eleven-country panel including, in addition to these countries, the rest of EMU founder countries, i.e. France, Belgium, Netherlands, Luxembourg, Austria and Finland.

Overall, the TVP fits the spread data reasonably well; we obtain a value of pseudo-R^2 of 0.9701 for the five-country panel and 0.9478 for the eleven-country panel. These values can be interpreted as the goodness of fit of our model, meaning that we explain over the 97.01% of the variance of the peripheral panel's spread[23]. For robustness, we use an alternative measure of risk aversion and columns 2 and 4 report the results of using VIX instead of BAA. The values of the pseudo-R^2 (0.9701 vs. 0.9628 for peripheral and 0.9478 vs. 0.8988 for all countries) reveal that the BAA model fits better spread data than VIX, especially when including core countries in the panel.

In Table 5 we present results for fixed-component suggesting that, for the EMU peripheral countries analyzed (and also for the extended country-panel), sovereign debt yield spreads can partially be explained by the conventional theory, where credit risk, measured by the evolution of the debt-to-gdp ratio play a significant role through its fixed parameter. As in second-

[23]The details of how pseudo-R^2 is calculated can be found in the Appendix A.3.

Table 5: Measurement Equation Estimation. 2000-2013

	(1)	(2)	(3)	(4)
	Peripheral		All Countries	
$\bar{\beta}_0$	-0.586*	-0.508*	-0.128	0.060
	(0.350)	(0.341)	(0.147)	(0.122)
$\bar{\beta}_1 GD_{it}$	0.019*	0.022**	0.013*	0.016***
	(0.011)	(0.009)	(0.007)	(0.005)
$\bar{\beta}_2 BAAS_t$	0.099**		0.092***	
	(0.040)		(0.016)	
$\bar{\beta}_2 VIX_t$		0.010**		0.008**
		(0.005)		(0.004)
$\bar{\beta}_3 UR_{it}$	0.150***	0.167***	0.094***	0.091***
	(0.033)	(0.032)	(0.017)	(0.014)
$\bar{\beta}_5 LIQ_{it}$	-0.080**	-0.087**	-0.031	-0.039
	(0.040)	(0.032)	(0.022)	(0.015)
Observations	168	168	168	168
Countries	5	5	11	11
Log likelihood	75.583	10.231	1156.808	1096.343
pseudo-R^2	0.9701	0.9628	0.9478	0.8988

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: State Equation Estimation. 2000-2013

	(1)	(2)	(3)	(4)
	Peripheral countries	Peripheral (VIX)	All Countries	Allcountries (VIX)
$\Theta\xi_{it}$	0.960***	0.982***	0.982***	0.980
	(0.008)	(0.004)	(0.004)	(0.004)
$\mu CYAS_{it}$	-0.0006***	-0.0003***	-0.0003***	-0.0003
	(0.0001)	(0.000)	(0.000)	(0.000)

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

generation currency crises models, worsening fundamentals (measured by the evolution of the unemployment rate) also influence spreads for both country-sets. Finally, change in global risk-aversion and liquidity risk have a non-negligible impact on debt spreads for the EMU countries analyzed, suggesting both a "flight-to-safety" and "flight-to-liquidity" effects.

The negative coefficients on gross debt relative size indicates that higher market-liquidity is associated with a lower yield spread. The low significance of the parameter for the 11-country panel suggests that there is a minimum critical size for debt affecting this liquidity component. Our results are consistent with Caceres et al. (2010) and Barrios et al. (2009), as global risk aversion is generally a positive factor for euro-area government bonds, but its importance increases of the situation of the economies as the economic situation worsens.

In addition to the steady-state parameters, our model also includes the estimation of a time-varying component for all parameters, which represent their deviation from the steady-state mean for the period considered. Figures 5, 6, depict both, for the 5-country panel, and for the 11-country panel, the time-varying component of coefficients for the variables in addition to the steady-state (fixed) parameters.

Our findings show that in the years prior to the financial crisis the response of spreads to their determinants was low (below-the-average). However, in the crisis aftermath, spreads started to react in a much stronger way to fiscal and fundamental imbalances. The above figures represent the five varying coefficients on a common scale.

The visual inspection of the figures show two main findings. First, the estimated time-varying coefficients for unemployment and gross debt do increase sharply to higher values during the crisis period compared to the evolution of debt size and BAA spread. Second, although the figures suggest an important co-movement in all the countries, the magnitude varies across countries. For instance, the increase on BAA spread-varying parameter is clearly higher for Greece than for the rest of countries analyzed, reflecting a higher risk-premium for this country when global-aversion risk increases.

Table 7 reports the summary statistics and cross-country correlations for the time-varying parameters for peripheral countries. Overall, all TVP are highly correlated across all the peripheral countries. The correlation coefficients of gross debt (between -0.215 and 0.920) are significantly lower than the ones corresponding to liquidity (between 0.824 and 0.964), unemployment (between 0.787 and 0.947) and BAA spread (between 0.799 and 0.967). Spain is the only country with a negative mean gross debt (-0.016) and shows a negative correlation with the rest of the countries. The response to BAA spread and unemployment is similar; all countries excepting Ireland are highly correlated. Focusing on liquidity, the correlation between Portugal and Spain is higher than between Greece, Ireland and Italy.

To further unravel the contribution of each TVP to debt spreads, we have used stacked area plots. Figure 7 shows the results for peripheral countries and Figure 8 repeats the exercise for core countries. The solid line represents the real spread, the thin dot-dashed line the predicted spread with TVP and the thick dashed line the spread predictions with constant parameters. The areas represent the contribution of each variable in explaining the spread. Overall the model performs well following the same pattern as the actual spreads.

The weight and composition of the spread determinants reveal a certain heterogeneity among peripheral countries. Portugal, Greece and Italy exhibit a similar composition, where spread is mainly a response to gross debt, followed by a moderate importance of unemploy-

Figure 5: Time Varying Parameter Estimation (peripheral). 2000-2014.

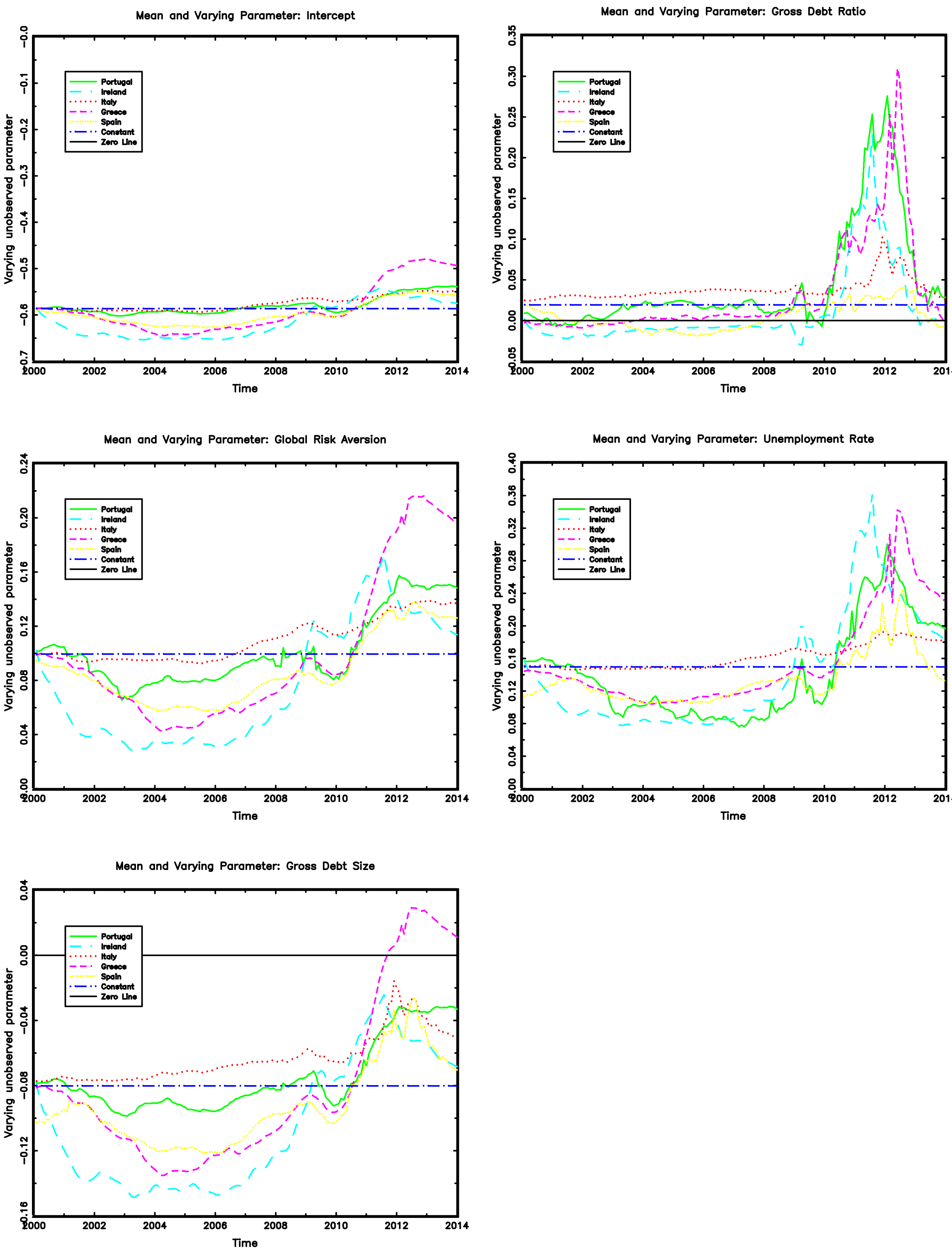


Figure 6: Time Varying Parameter Estimation (all countries). 2000-2014.

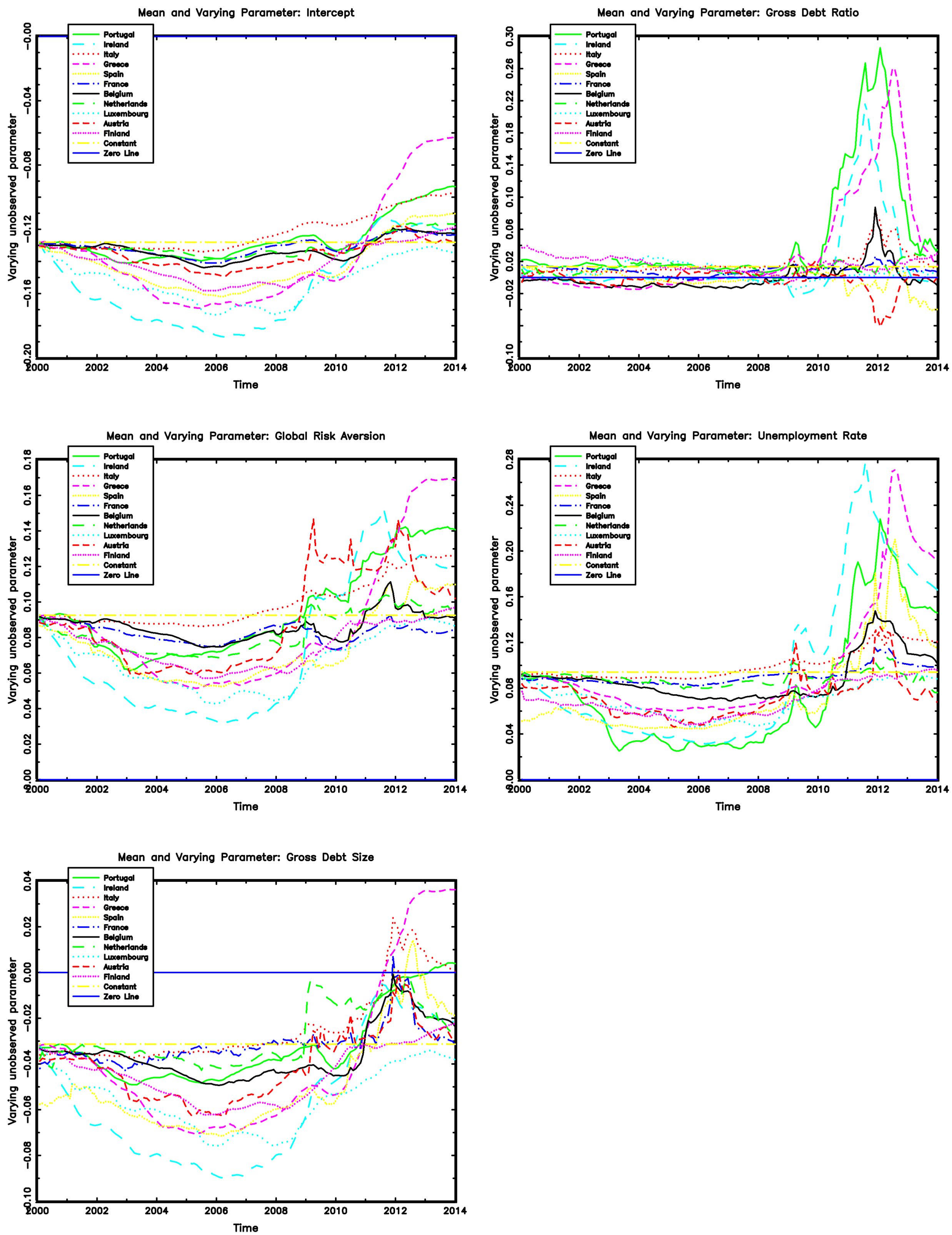


Table 7: Summary Statistics & Cross-country correlations of TVP

Gross Debt

	Summary Stat		Correlations			
	mean	sd	Greece	Ireland	Italy	Portugal
Greece	0.017	0.065	1.000			
Ireland	0.002	0.048	0.718***	1.000		
Italy	0.003	0.014	0.886***	0.708***	1.000	
Portugal	0.034	0.069	0.877***	0.920***	0.848***	1.000
Spain	-0.016	0.010	-0.162**	-0.176**	-0.199***	-0.215***

BAA

	Summary Stat		Correlations			
	mean	sd	Greece	Ireland	Italy	Portugal
Greece	-0.006	0.036	1.000			
Ireland	-0.018	0.038	0.799***	1.000		
Italy	0.007	0.013	0.893***	0.875***	1.000	
Portugal	0.002	0.025	0.900***	0.922***	0.967***	1.000
Spain	-0.018	0.018	0.960***	0.856***	0.863***	0.903***

Liquidity

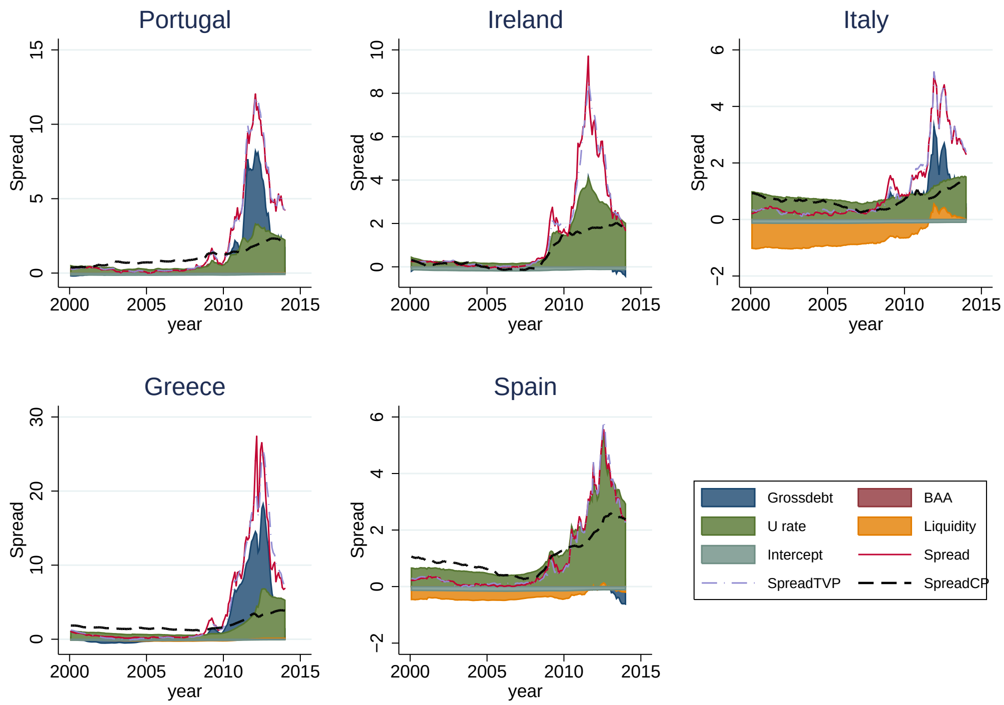
	Summary Stat		Correlations			
	mean	sd	Greece	Ireland	Italy	Portugal
Greece	-0.007	0.033	1.000			
Ireland	-0.025	0.027	0.878***	1.000		
Italy	0.007	0.016	0.890***	0.824***	1.000	
Portugal	-0.001	0.016	0.964***	0.877***	0.932***	1.000
Spain	-0.017	0.021	0.950***	0.898***	0.952***	0.947***

Unemployment

	Summary Stat		Correlations			
	mean	sd	Greece	Ireland	Italy	Portugal
Greece	0.005	0.053	1.000			
Ireland	0.001	0.070	0.787***	1.000		
Italy	0.005	0.012	0.896***	0.897***	1.000	
Portugal	-0.015	0.055	0.887***	0.922***	0.872***	1.000
Spain	-0.019	0.038	0.947***	0.861***	0.947***	0.906***

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure 7: CP & TVP composition for peripheral countries

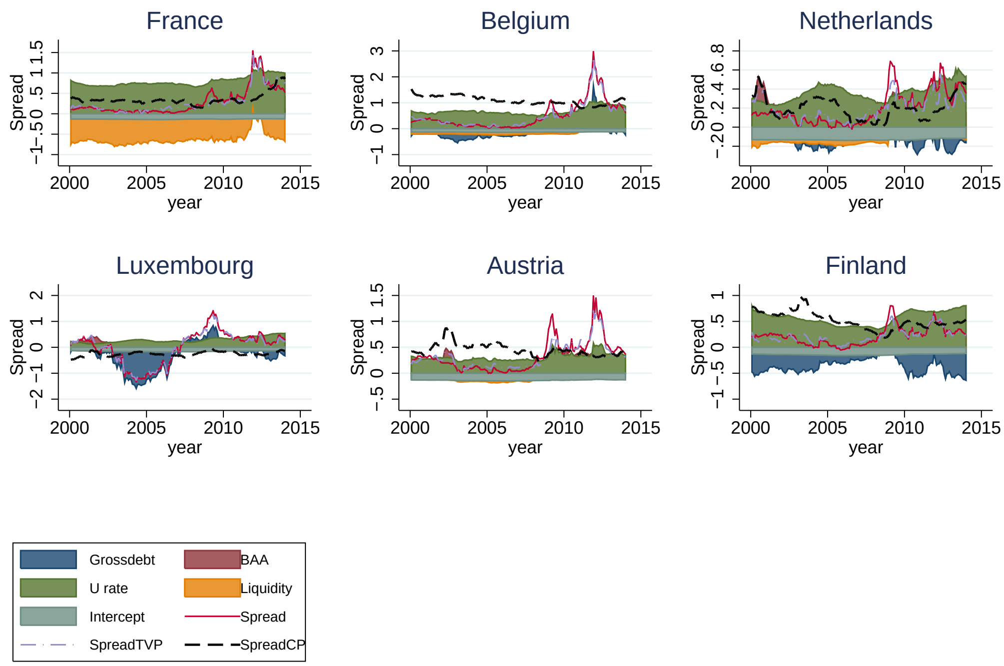


ment towards the end of the period. Liquidity was also an issue for Italy at the beginning of the crisis. Conversely, in Ireland, and especially Spain, the unemployment rate explains most of its spread (there is practically no difference between the predicted spread and the green area). Spain's gross debt has a negative influence on spread, as expected by its sign and negative correlation with the rest of the countries shown in Table 7. This confirms the fact the Spanish fiscal situation was clearly healthier than other EMU countries before the financial crash and that in the latest years, the fiscal stance of the Spanish government has been acknowledged by the markets.

Looking at the evolution of the relative position of the constant parameter (CP), represented by the thick-line and the time-varying parameter (TVP), drawn with a thin-line, we can observe how they have switched after the crisis. In all peripheral countries (excepting Ireland), the CP estimates overestimate the TVP predictions before the financial turmoil. However, after 2008, the CP underestimate the spreads. This result highlights the relevance of time-varying parameters in explaining the over-reaction of spreads after 2007, particularly for peripheral countries.

Turning our focus to the core countries in Figure 8, we observe that unemployment is the main source of their moderate spreads. Some countries like France and Finland are able to offset the negative effect of unemployment with liquidity and gross debt respectively (the latter having a negative net contribution to the spread). We also observe that the TVP estimates obtain a better fit than the CP for these six core countries.

Figure 8: CP & TVP composition for core countries



5. Conclusions

In this article we offer an exploration of the determinants of sovereign debt spreads for a panel of euro-area peripheral countries covering the period 2000:01-2013:12. More specifically, the purpose of our research is to disentangle the role of fundamental variables and market perception regarding attitudes towards risk to explain the evolution of sovereign spreads in the EMU during the recent crisis. The gist of our study is the use of time varying-coefficients for different fundamental variables in a measurement equation, where deviations from steady-state mean of parameters is driven by an unobservable state-variable. As in earlier literature, yield spreads are related both to global risk aversion and to idiosyncratic distrust, the latter being linked both to fiscal indebtness and unemployment. A distinct feature of the present paper is the evidence favouring a time-varying relationship where cyclical asymmetries between peripheral and core economies appear as the drivers of the market distrust about the quality of the sovereign debt.

Our research contributes to the existing literature in several respects. A distinctive feature of our exercise is that we resort to a combination of different theoretical approaches to build our empirical framework. First, we consider the different generations of models on currency crises to single out the variables that we use in the measurement equation. In a complementary way we also rely on the OCA theory to include the cyclical asymmetries as drivers in the transition equation which updates the varying responses to variables chosen. Second, we borrow on literature about credibility and dynamic inconsistency of policies to explain the evolution of sovereign spreads in the Eurozone context, which can be particularly important to derive conclusions from the transition equation.

A second additional contribution of our research lies in the econometric methodology employed which, to the best of our knowledge, is novel in the area. Using the Kalman filter, we have estimated in a panel data setting a time-varying multi-parameter model, allowing for the inclusion of observed (control) variables. Unlike other studies using Kalman filter, we do not modelize simple transition equations assuming a random walk behavior of unobserved components.

According to our results, the explanatory variables have a different behavior and relative importance before and after the financial crisis. It seems clear that before the global financial crisis, EMU was perceived as a solid and fully credible agreement. Therefore, although countries were already exhibiting large external deficits, as long as they were recording high growth rates, good fiscal results (in some cases) and declining unemployment rates, the need for a rebalancing process in the Eurozone was not perceived. In fact, as we can see in our results, trust in financial market led to a "below-the-average" reaction in the variables. However as far as peripheral countries were concened, distrust in markets suddenly erupted with doubts about European integration, and thus our time-varying model shows an "over-the-average" reaction, especially in the Greek case. Before the financial crisis, lower global risk aversion and the little attention paid by the markets to country-specific disequilibria were particularly important in explaining sovereign spreads. However, since then, country-specific factors, in particular gross debt ratio and unemployment, have played an important role in bond yield spreads. Our results suggest that not only fiscal indebtedness, but also a shift in global risk aversion and the worsening of other fundamentals have played a significant role in explaining the evolution of long term spreads in peripheral EMU countries. This change in market perception was driven by the output growth misalignment between peripheral and core economies. The significance of our cyclical asymmetry variable in the transition equation provides a useful example. The evolution of market "sentiment" is, thus, partially driven by asymmetries in output growth across EMU countries. This result is not trivial, since according to OCA theory, this idiosyncratic ('asymmetric') shock may require an exchange rate adjustment. Finally, we find empirical evidence showing that the evolution of the spreads can be due to a lower liquidity in bond markets in the Eurozone (except in the German bond market case) due to the 'flight to safety' syndrome affecting the financial markets.

All in all, the findings obtained are remarkably interesting because our approach relies on the application of credibility models, enhancing the importance of the evolution of market sentiments but linking, at the same time, sovereign spreads and their determinants. In this context, an important output of the paper is the need to arrive at a balance between stubborn governments signaling their commitment to fiscal consolidation (the so-called "austerity" approach), but also paying attention to the time-varying influence of macroeconomic fundamentals on the market sentiment. Therefore, in order to keepthe market sentiment under control, our results suggest the need for greater macroeconomic coordination in the euro-area in order to avoid sovereign-debt attacks. In addition, the role of the ECB might be reconsidered, since the lack of a "lender-of-last-resort" introduces an "original-sin" bias in the risk premium of EMU-countries.

Appendix A. Methodology

Appendix A.1. State-Space models and Kalman Filter.

In this Section we describe the empirical methodology used for the estimation of the above model. We use the Kalman Filter first developed in Kalman (1960), and described in Harvey (1989) and Hamilton (1994). The Kalman filter is, in fact, an algorithm composed by a set of equations, which, performed sequentially, allows to obtain the best estimate (in terms of mean square error) of a state vector at time t taking into account all the information available. State-space representation of dynamic models allows to capture the dynamics of an observed (n x 1) vector in terms of a possibly unobserved (r x 1) vector, known as the state vector for the system.

Structural models allow for (each of) the typical unobserved components determining time-series behavior to possess a stochastic nature:

$$\underset{(r\times 1)}{\xi_{t+1}} = \underset{(r\times r)}{F}\underset{(r\times 1)}{\xi_t} + \underset{(r\times s)}{B}\underset{(s\times 1)}{Z_t} + \underset{(r\times 1)}{\nu_t} \tag{A.1}$$

where F denotes an $(r \times r)$ state-transition matrix for the unobserved component, Z_t is the vector containing any control inputs affecting the state through the control input matrix B, which applies the effect of each control input parameter in the vector on the state vector. Finally, ν_t represents the $(r \times 1)$ vector containing the process noise terms for each parameter in the state vector and is assumed to be i.i.d. N(0, Q).

The state equation takes the following form:

$$\underset{(n\times 1)}{y_t} = \underset{(n\times k)}{\mathbf{A}'}\underset{(k\times 1)}{x_t} + \underset{(n\times r)}{\mathbf{H}'}\underset{(r\times 1)}{\xi_t} + \underset{(n\times 1)}{w_t} \tag{A.2}$$

where y_t represents an (n x 1) vector of variables that are observed at date t, x_t represents a vector of exogenous determinants, their coefficients being included in matrix A . H' is an (n x r) matrix of coefficients for the unobserved components ξ_t, and w_t is an (n x 1) vector that could be described as measurement error and is assumed to be i.i.d. N(0, R), independent of ν_t and for t= 1, 2,... This kind of models is particularly useful for measuring expectations that cannot be observed directly. If these expectations are formed rationally, there are certain implications for the time-series behavior of the observed series that can help to modelize them.

An interesting application of state-space representation is the time-varying coefficient regression models:

$$y_t = x_t\beta_t + \omega_t \tag{A.3}$$

$$\underset{(n\times 1)}{y_t} = \underset{(n\times k)}{\mathbf{A}'} \times \underset{(k\times 1)}{x_t} + \underset{(n\times r)}{\mathbf{H}'(x_t)} \times \underset{(r\times 1)}{\xi_t} + \underset{(n\times 1)}{w_t} \tag{A.4}$$

where A represents a matrix of fixed parameters $\bar{\beta}_i$, and, assuming $\bar{\beta}_i = \bar{\beta}$, the vector of unobserved coefficients, $\xi_t = \left(\beta_{it} - \bar{\beta}_i\right)$, evolves along time according to the expression:

$$\left(\beta_{i,t+1} - \bar{\beta}\right) = F\left(\beta_{i,t} - \bar{\beta}\right) + \underset{(r\times s)}{B}\underset{(s\times 1)}{Z_{it}} + \upsilon_{it+1} \tag{A.5}$$

In the next section we explain in detail different alternatives to estimate time-varying coefficient regression models and their implications. As stated in Hamilton (1994), assuming that the eigenvalues of F are all inside the unit circle, the coefficient can be interpreted as the average or steady-state coefficient vector, and the measurement equation can be written as follows:

$$y_t = x_t'\bar{\beta} + x_t'\xi_t + \omega_t \tag{A.6}$$

Compared to the general model where the elements of the matrices F, Q, A, H and R are treated as constants, in this model H depends on observed regressors, as $[H(x_t)]' = x_t$.

According to Harvey (1989), it does not exist a unique representation of a state-space formulation of a model. That is why the state variables obtained internally in the system have to be specified according to the nature of the problem with the ultimate goal of containing all the information necessary to determine the behavior of the period-to-period system with the minimum number of parameters.

Appendix A.2. Time-varying coefficient regression models.

Unlike in standard linear econometrics, the time-varying parameters approach takes as its point of departure the idea that there is a true, changing economy. Swamy and Tavlas (2003) discuss how this technique, particularly in its second generation models, and by using a set of 'driving' variables, can overcome a wide range of model misspecifications and produce consistent estimates of parameters. All in all, any econometric model is almost certainly a misspecified version of the truth, and this misspecification may take the form of omitted variables, endogeneity problems, measurement errors, and incorrect functional form. In fact, as stated by Granger (2008), the true model tends to be highly non-linear. These problems are expected to lead to coefficients that will be unstable and time-varying.

Although an important number of econometric models with time-varying parameters for panel data have been proposed in the past[24], these models have not become popular in empirical research mostly because of computational difficulties. Wells (1996) distinguishes four different categories of models: Ordinary Least Squares (OLS) models, random coefficients models (RCF), random walk models (RW) and mean reverting models (MRV).

In traditional OLS, regression coefficients remain constant for all periods:

$$\beta_{it} = \bar{\beta}_i \tag{A.7}$$

Hildreth and Houck (1968) and Swamy (1970) proposed RCF models[25], whose coefficients fluctuate randomly about a mean value as follows:

$$\beta_{it} = \bar{\beta}_i + \nu_{it} \tag{A.8}$$

where ν_{it} a random variable following a Gaussian distribution with a zero mean and a fix variance.

The third of the four models is the RW model, first introduced by Rubin (1950) and Rao

[24]See Rosenberg (1973), Hsiao (1974), Hsiao (1975), Min and Zellner (1993), Swamy and Mehta (1977), Zellner et al. (1991) among others.

[25]also known as "dispersed coefficient models" (Schaefer et al., 1975) or also "mean reverting models"

(1965) , which may be written as

$$\beta_{it} = \beta_{it-1} + \nu_{it} \tag{A.9}$$

Finally, the MRV model is presented, as in Bos and Newbold (1984), as:

$$\beta_{it} = \Phi\beta_{it-1} + (1 - \Phi)\,\bar{\beta}_i + \nu_{it} \tag{A.10}$$

where ν_{it} is a gaussian with a zero mean and a fixed variance, making the parameters return to its mean gradually. Mean-reversion model represents a general[26] modelisation of parameters: the OLS model obtains when $var(\nu_{it} = 0)$; when $\Phi = 1$ we obtain a random walk (RW) model for the varying parameters; and when $\Phi = 0$ we have a random coefficient model (RCF) where the coefficient fluctuates randomly about a mean value. If $\Phi < 1$ the model is convergent (even if convergence is slow).

For convenience, MRV model can be rewritten as:

$$\left(\beta_{it} - \bar{\beta}_i\right) = \Phi\left(\beta_{it-1} - \bar{\beta}_i\right) + \nu_{it} \tag{A.11}$$

Equation A.11 represents a simple transition equation to be estimated through Kalman Filter, where $\left(\beta_{it} - \bar{\beta}_i\right) = \xi_t$ represents the unobserved component of our time-varying parameter, while the fixed component is also included at the measurement equation as $\bar{\beta}_i$. One can also assume (as we do in our model) that constant mean parameter is equal for all the individuals of the panel, and then $\bar{\beta}_i = \bar{\beta}$, representing ξ_t the TVP deviation from this common mean.

For the estimation of our model, we employ a MRV-type modelisation of the measurement equation, which includes both a common fixed parameter, $\bar{\beta}$, and a TVP deviation from this mean $\left(\beta_{it} - \bar{\beta}_i\right) = \xi_t$. with an autoregressive evolution (with coefficient Φ) of the unobserved time-varying parameters of our model (state transition equation). But, in addition to this "standard" MRV autoregressive transition, our unobserved vector is also influenced by the evolution of observed variables, Z_t. These control variables are frequently employed in engineering but are not so commonly applied to state-space economics models. Their use could be interpreted as the "coefficient-drivers" in second-generation TVP models, described in Swamy and Tavlas (2003) and related work. As stated in Gourieroux and Monfort (1997), with the introduction of an input in the "transition equation" or in the "measurement equation", all the formulae of the filter remain valid with the exception of the introduction of the variable in the update equation.

Appendix A.3. pseudo-R^2 in a TVP model

We have calculated the pseudo-R^2 for our TVP parameters with the following formula:

[26] Ohlson and Rosenberg (1982) formulate a general version of the MRV model that allows for both autocorrelated (predictable) and random (unpredictable) variation within the same model, combining mean reversion to a random mean for parameters, where $\left(\beta_{it} - \bar{\beta}_i\right) - \xi_{it} = \Phi\left[\left(\beta_{it-1} - \bar{\beta}_i\right) - \xi_{it}\right] + \nu_{it}$. In this model, the constant "true" mean of the parameter, $\bar{\beta}_i$, is perturbed by a random variable, ν_{it} which has a zero mean and a variance of λ (if $\lambda = 0$, then this model becomes the MRV presented above). $y_{it} = \left(\bar{\beta}_i + \xi_{it}\right) x_t + \left[\beta_{it} - \left(\bar{\beta}_i + \xi_{it}\right)\right] x_t + \omega_{it}$. This model allows an heteroscedastic variance in the measurement equation, induced by the tendency of the mean of the parameter to vary randomly about its "true" value, being then $u_{it} = x_{it}\xi_{it} + \omega_{it}$

$$\text{pseudo-}R^2 = \frac{\sum(Y_{it} - \bar{Y})^2 - \sum(\hat{Y}_{it} - Y_{it})^2}{\sum(Y_{it} - \bar{Y})^2},$$

where Y_{it} is the real values of spread, $\bar{Y}$ the spread's mean and $\hat{Y}_{it}$ the predicted values from our TVP equation.

Appendix B. Sovereign risk, credibility and market expectations: An eclectic model of EMU-exit and debt default.

Appendix B.1. Sovereign debt spreads and currency crisis models.

The literature on currency crisis can be very useful to explain the recent sovereign debt crisis in EMU. In the first-generation of currency crisis models proposed by Krugman (1979) and Flood and Garber (1984), the inconsistency between domestic macroeconomic policy and the exchange rate peg leads to the continuous depletion of a finite stock of reserves. The speculative attack is due to full predictability of the peg's ultimate collapse. The model combines linearity behavior (log-linear money demand functions) with perfect foresight, to produce a unique timing of the speculative attack when the stance of domestic monetary and fiscal policy is inconsistent with the exchange rate peg (loss of competitiveness). For this argument can be applied in the sovereign bonds market, we have to assume a fully predictable, or at least highly likely, default on public debt, which does not seem to be realistic when agents expect some kind of bail-out mechanism. Debt default is a much less likely event, in special for a euro area country with access to IMF emergency cash. Therefore, the deterioration of fundamentals, although it could have played a key role triggering the Greek debt crisis, the escalation of the crisis in November 2009 is unlikely to have been caused by market fears of an imminent debt default (Arghyrou and Tsoukalas, 2011).

To find a proper explanation we have to resort to the second generation of currency crisis models developed by Obstfeld (1986). While Krugman (1979) first-generation model is based on full predictability and the uniqueness of equilibrium, the essential characteristic of the second-generation currency crisis models is that a speculative attack may be successful even when the stance of monetary and fiscal policy is consistent with the level of the exchange rate. In this second type of models there must, however, be a temptation for the authorities to abandon the peg altogether in order to pursue a more expansionary domestic policy. Even when there are high political costs to devaluing (defaulting or quitting a currency union in our case), the fact that the speculators know that the authorities are tempted to do so may in fact be enough to bring about the crisis, that is to say, that speculative attacks can be self-fulfilling. Formally, this shows up in a model having multiple solutions so that very small disturbances can lead to a discrete jump from an initial equilibrium with a fixed exchange rate (common currency) to another equilibrium with a devalued exchange rate or even to a floating rate with zero commitment of the authorities. Under this framework the emphasis is generally on nonlinearities in the policy rules, such a shift in monetary policy (i. e. the OMT program) conditional on whether or not there is a speculative attack. In other words, if the time and intensity of the attack depend upon whether or not there is a shift in monetary policy and vice versa, then the possibility of multiple equilibria (i. e. the non-uniqueness of the timing of the attack), together with the possibility that the attack may be self-fulfilling by leading to a shift in policy, becomes intuitively clear. The possibility of multiple equilibria in such circumstances may be viewed in some ways as a co-ordination problem: if there were one large trader able to undertake massive speculation (i. e. George Soros in 1992-93 against the sterling pound) then the multiple equilibria may collapse to a unique equilibrium. If speculators are dispersed, with heterogeneous expectations and liquidity constraints, however, the possibility of multiple equilibria is greater[27]. However, some authors, like Morris and Shin (1998), have criticized the second generation models arguing that there is not rationale in them to justify sudden shifts in expectations. Even if multiple equilibria are possible, there is a unique equilibrium when speculators face a small amount of noise in their signals about the fundamentals. All in all, this unique equilibrium depends not only on the fundamentals but also on financial variables, such as the quantity of hot money in circulation and the costs of speculative trading.

A third generation of currency crisis models has been developed more recently to explain in a proper way the 1997-8 East Asian financial crisis. This crisis did not seem to be fully explained by previous theoretical models as it was not characterized by the fiscal deficits which typically trigger a crisis in first-generation currency crisis models, nor it did appear to be any strong temptation for the authorities to abandon a fixed exchange rate. Third-generation models have as a consistent central feature a “moral hazard” view of the underlying causes of the financial crises.[28] According to this view, a crucial role in the generation of currency crisis is played by financial intermediaries whose liabilities are perceived as having an implicit government guarantee, but which may be essentially unregulated. Obviously, this may create a moral hazard problem, in which financial intermediaries are able to raise money at safe interest rates and then lend it at a much higher rate to finance risky investments, thus generating asset price bubbles. Eventually, bubbles burst leading to a massive capital flight and a collapse in the external value of the currency, which cannot be defended by the authorities. Different third generation models offer various mechanisms through which these distortions may lead to a currency crisis. Some models stress how distortions may emerge in the form of credit constraints.

According to Arghyrou and Tsoukalas (2011), let us assume that a country joins EMU at a fixed exchange rate against the euro given by $\bar{s}$ in logs. The essence of the model is that policy makers are not committed to the currency union under all circumstances. Each period after the accession, the government faces the dilemma about staying or quitting the euro. The decision is based on a cost benefit analysis, where the cost is assumed to be given at a fixed level, *C,* and the benefit is measured by a positive quadratic function of the overvaluation of $\bar{s}$ relative to the country's equilibrium exchange rate against the euro, consistent with the PPP, and denoted by s^*. Obviously, an overvalued exchange rate level $\bar{s}$ relative to s^* denotes a loss of external competitiveness, and therefore, a cost in terms of output, unemployment,

[27]Second-generation models have not been extensively tested empirically to date, although they seem particularly appealing for explaining the crises faced by some ERM countries in the 1990s. In particular, the attack on the French franc during the 1992-93 ERM crisis is often cited as an example. Although there was no initial inconsistency between the exchange rate peg and the stance of domestic macroeconomic policy, the relatively high level of French unemployment at this time suggests that the authorities were tempted to devaluate (Jeanne, 1997). See Masson (1995) for the UK case or Esteve et al. (1998) for the Spanish one.

[28]See, for example, Krugman (1999).

budget deficits, current account deficits and debt. The problem is that everyone, notably investors, knows it and they will adjust their expectations accordingly.

The government's optimization problem is solved conditional upon private sector expectations, which may fall in three regimes. In the first one, markets perceive the country's future EMU participation as fully credible and outstanding government bonds to be fully guaranteed by the country's EMU partners. In that case, the loss of staying in the euro is given by L_1 :

$$L_1 = \left[\gamma_1 \left(s^* - \bar{s}\right)\right]^2, \gamma_1 > 0. \tag{B.1}$$

The second possible regime is that markets perceive future EMU membership as non-credible and fiscal liabilities continue to be guaranteed by the country's EMU partners, in which case the interest rate of government bonds incorporates a currency premium that increases the cost of staying inside the monetary union, leading to the following loss function:

$$L_2 = \left[\left(\gamma_1 + \gamma_2\right)\left(s^* - \bar{s}\right)\right]^2, \gamma_1,\gamma_2 > 0. \tag{B.2}$$

Last, a third regime applies when markets consider the sustainability of the participation in EMU as non-credible and without fiscal guarantees of government bonds from EMU partners. In this case, the interest rates on government bonds include on top of a currency premium, also a default premium. According to this, for every level of overvaluation, the cost of keeping EMU membership increases further and is given by the following expression:

$$L_3 = \left[\left(\gamma_1 + \gamma_2 + \gamma_3\right)\left(s^* - \bar{s}\right)\right]^2, \gamma_1, \gamma_2, \gamma_3 > 0. \tag{B.3}$$

Under any of the three regimes, the government decides to stay in EMU if the participation cost is lower than the cost of euro exit, that is, if:

$$L_i < C, i = 1, 2, 3. \tag{B.4}$$

Normalizing by taking $\bar{s} = 0$, the condition for staying in the euro is as follows:

- Under credible EMU commitment and guaranteed fiscal liabilities:

$$s^* < \frac{\sqrt{C}}{\gamma_1}. \tag{B.5}$$

- Under non-credible EMU commitment and guaranteed fiscal liabilities:

$$s^* < \frac{\sqrt{C}}{\gamma_1 + \gamma_2}. \tag{B.6}$$

- Under non-credible EMU and non-guaranteed fiscal liabilities:

$$s^* < \frac{\sqrt{C}}{\gamma_1 + \gamma_2 + \gamma_3}. \tag{B.7}$$

As $\gamma_2, \gamma_3 > 0$,thus:

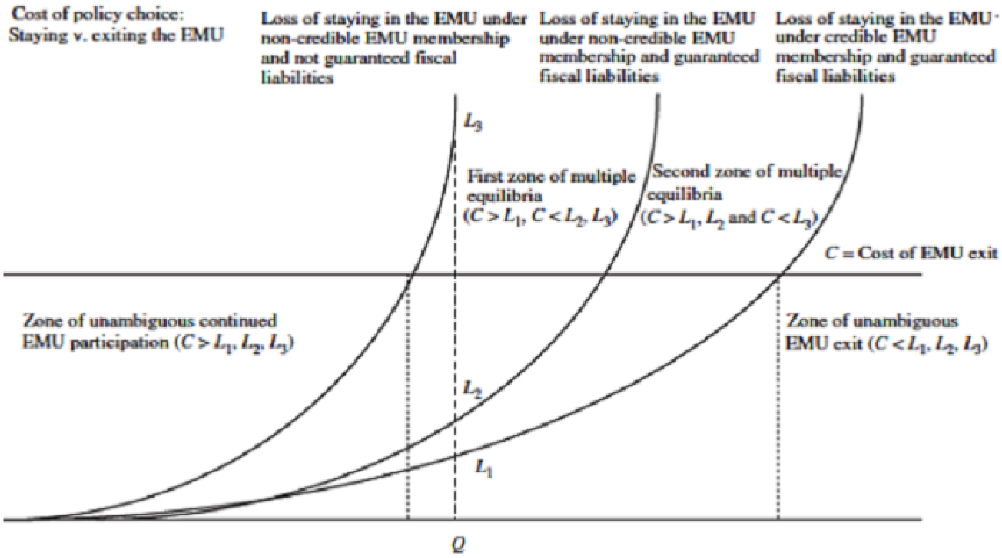
$$\frac{\sqrt{C}}{\gamma_1 + \gamma_2 + \gamma_3} < \frac{\sqrt{C}}{\gamma_1 + \gamma_2} < \frac{\sqrt{C}}{\gamma_1}. \tag{B.8}$$

Conditions (B.5), (B.6) and (B.7) make clear that for every scenario, there exists a critical threshold of overvaluation above which EMU membership is suboptimal. In case of an overvaluation, the cost may take the form of a negative output gap, increasing unemployment and/or higher interest on public debt. Below a critical overvaluation threshold, abandoning the currency union is costlier than staying, so the government finds it optimal to honor the agreement; however, above this critical threshold, the opposite holds. Again, as in the first generation models, an excessive deterioration in fundamentals will lead to a break of the monetary agreement. However, in the second generation models, the cost of honoring the agreement is endogenous to the private sector's expectations giving rise to multiple equilibria. Bearing this in mind, for every level of overvaluation, defending the currency union is less costly under credible commitment. Condition (B.8) signals that this threshold reduces with negative shifts in expectations regarding the country's commitment to future EMU participation and the existence of fiscal guarantees. The model is depicted in Figure 1 where three loss functions appear associated with EMU participation; the first one (L_1) is the flattest and applies to credible EMU with fiscal guarantees; the second one (L_2) is related a non-credible EMU under fiscal guarantees, showing an intermediate slope position, and the third one (L_3) applies to a non-credible EMU without fiscal guarantees, presenting the steepest slope. In the vertical axis the cost level of the policy choice appears, whereas the horizontal axis measures the level of overvaluation (Q). The model allows for two zones of multiple equilibria: the same level of overvaluation (Q) corresponds to two possible outcomes, the final result being ambiguous and will depend on what is expected from the markets.

If L_1 applies, only if there is a big shock in terms of competitiveness, the incentive to leave the currency union will overpass the cost. In case we are in a situation as in L_3, the incentive to leave the currency union will take place at a lower shock level. Note that the spread increases along the slope of any of the loss functions considered L_i depending on the stance of macro policies. However, the relevant L in every case (i= 1, 2 or 3) will critically depend on the credibility of the EMU commitment (subject to the evolution of some macro variables) and the quality of sovereign bonds (if they are guaranteed or not) that will be reflected as well in the spread through market expectations. Within the two intermediate multiple equilibria zones, a shift in expectations from credible to no-credible commitment or a reduction in the guarantees given to the sovereign bonds, tilts the government's optimal response from maintaining to abandoning EMU membership leading to three possible equilibria (L_1, L_2 or L_3) any of them consistent with expectations. The selection of one of these three points only depends on what investors expect. If the latter expect a default, there will be one but if they do not expect a default, there will be none. This remarkable result is due to the self-fulfilling nature of expectations.

Now, to validate the model, the empirical question is how to disentangle the factors embedded in the spread that are determining its evolution over time. This question is not trivial from an economic policy point of view and presents also important econometric challenges.

Figure B.9: A Model of EMU Exit



Source: Arghyrou and Tsoukalas (2011).

Appendix B.2. Sovereign risk, credibility and reputation.

In the previous Section we have presented a simple model that posits an objective, or loss function guiding the actions of the authorities in the face of domestic or external shocks. However, a second factor will also crucially affect the spread: the uncertainty about policy-maker's preferences. The valuation of risk is, perhaps, one of the main issues in financial economics. The problem arises when agents are perceiving a changing uncertainty in assets returns. If we apply standard models to time series reflecting the spread for holding risky assets, any variation in the expected rate of return of an asset when it becomes riskier will be identified as a risk premium (Engle et al., 1987). In case of sovereign debt, this issue is even more complicated: sovereign debt (and its risks) differs from private debt in two important aspects (Eaton and Fernandez, 1995). First, unlike individuals or companies, there is often little that a sovereign entity can use as collateral to guarantee the value of a loan. Second, the ability of a court to force a sovereign entity to comply with its wishes is extremely limited, especially when debt has been issued under their own law, which states can change retroactively to reduce what they owe. Country-risk refers not only to the economic situation of a country (credibility), but also to the political willingness of a government to honor its commitments (reputation). In this context, credibility of policies in order to keep debt in a sustainable path plays a central role, not only in the assessments of rating agencies, but also for market pricing of sovereign. The spread will thus reflect assessments about policymaker's type, as captured by the relative weights that authorities attach to each of their policy objectives, which are not known by private agents. The probability that policymakers put a low weight on maintaining EMU membership, is modeled using Bayesian updating, on the assumption that there are two possible types of policymakers, each with a known set of weights on its objectives. Weight γ_i can take on one of two values γ^W and γ^T, for weak and tough governments respectively, with $\gamma^T > \gamma^W$.

Credibility is usually defined as the expectation that an announced policy will be effectively carried out. Much of the literature about credibility has its inspiration in the problem of time-consistency of policies since Kydland and Prescott (1977) and Backus and Driffill (1985) seminal papers. According to early studies as Giavazzi and Pagano (1988), joining the European Monetary System (EMS) was understood as a way of changing the set of incentives faced by weak-nosed governments (mainly those in charge at Southern-Europe countries). By maintaining their exchange-rate commitment they would see its reputation improve over time. In the same vein, joining the EMU by irrevocably fixing the exchange rate and delegating monetary policy to a supranational independent central bank was considered a radical way (a perfect commitment) of keeping the promise of tough inflation-fighting policies. From this credibility approach, after the sharp increase in sovereign spreads in 2009, fiscal consolidation was perceived as the only solution to enforce credibility and to step down the risk premium. However, fiscal consolidation has not been a sufficient condition to ensure credibility: the deterioration of other macroeconomic fundamentals, such as competitiveness divergences and unemployment gave rise to cyclical disparities among euro member countries. This asymmetric shock called for fully-fledged macroeconomic policy coordination in the EMU within a new governance framework of the euro that started in 2012 and is still under construction.

As stated by Drazen and Masson (1994) and Masson (1995), the traditional approach to gaining credibility of policies announced by a government, involves increasing its reputation. They consider a government minimising a loss function which depends on the squared deviations of unemployment from the natural rate and on the (squared) change in the exchange rate:

$$L_t = (ur_t)^2 + \Theta\,(\Delta e_t)^2 \tag{B.9}$$

The second term of the loss function reflects the policy-maker's concern for exchange rate stability, where a tough government has a larger value for Θ than a weak government does ($\Theta_T > \Theta_W$). The private sector updates its assessment of the probability that the government is weak (π) on the basis of observed behavior. In this model, increasing reputation is equivalent to decreasing π_t which can be achieved by the government eiher by keeping its commitment overtime, but can be also signaled by a vector of observed variables (Z_t). In this approach, the unobserved reputation evolves over time and gets updated each period as in the following equation:

$$\pi_{t+1} = \alpha\pi_t + \mu Z_t + \upsilon_{t+1} \tag{B.10}$$

In the context of a irrevocably fixed exchange rate mechanism, such as EMU, differences between tough and weak government preferences can be characterized, instead of by the probability of devaluation, by its commitment to debt sustainability[29]. This means that the government will avoid a path of debt accumulation leading to a certain threshold, which

[29] Recently, De Grauwe and Ji (2013) have made a theoretical argument to interpret the euro-area sovereign debt crises as a new manifestation of a speculative market attack on a sovereign, but in this case through yield spreads rather than through foreign exchange rates, since currency crises have essentially been precluded by the creation of the euro. Therefore, the action has now shifted from monetary to fiscal policy and the sovereign market.

increases the credit risk due to the impossibility to honor the debt service. In a monetary union, where state members have irrevocably "tied their hands" in monetary policy, fiscal policy becomes the key policy at the state-level, and the concept "credibility" does not refer anymore to the exchange-rate commitment, but to fiscal sustainability, that is, there is monetary dominance and fiscal developments must comply with the monetary constraints. In fact, all the institutional arrangements introduced in the euro area explicitly intended to preclude a path toward fiscal dominance and therefore prevent governments financing their public deficits through money creation.

But as Drazen and Masson (1994) state, whether a policy is carried out, however, will reflect not only the policymaker's preferences, but also the state of the economy, particularly when worsening fundamentals are characterized by persistence, which could increase the cost of keeping tough in the future. This fact could be interpreted as a conflict between the time-consistency approach (credibility) and the theory of optimal currency areas (fundamentals) initially due to Mundell (1961) and concerned with the flexibility and effectiveness in the adjustment mechanism to shocks. Thus, as in Masson (1995), credibility of an economic policy commitment, such as fixing the exchange rate or the capability of achieving a sustainable path for sovereign debt, can be decomposed into the policy-makers (perceived) reputation and the fundamentals of an economy. Empirically the model is applied to long-term bonds, so the yield differentials can be identified with the expected default as follows, with the addition of an error term ω_t:

$$spread_t^i = \rho^T d + \pi_t(\rho^W - \rho^T)d + \beta X_{t-1} + \omega_t \tag{B.11}$$

Equation (B.11) decomposes sovereign spread into two components. First, on the one hand, an assessment of the preferences of the government, defined as the probability of occurrence of a weak-nosed government (π_t) assigned by the private sector, being ρ^W and ρ^T the steady-state probabilities of default for each type of government and d the relative size of default, in percentage of total. In addition, the model also incorporates the effect of worsening fundamentals (X_{t-1}) like unemployment, competitiveness or economic activity on the sustainability of the commitment (a fixed parity in Masson model or to debt sustainability in our research). The more the fundamentals deteriorate, the less credible is the commitment made by the government. This is an elaboration of Obstfeld (1997) and the "escape clause" in Flood and Isard (1989).

A similar approach is developed by Neut and Velasco (2003) who stress the dilemma between enhancing credibility to honor debt service through tighten policies, and at the same time, the circumstances under which hard-nose governments may reduce credibility giving rise to non-intended self-fulfilling defaults.

Equation (B.11) constitutes the model to be estimated, where π_t is an unobservable state whose transition is described by equation (B.10) assuming that ϑ_t and ω_t are i.i.d and follow a N (0, Q and a N(0, R), respectively.

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