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AN ANALYSIS OF SOVEREIGN CREDIT RISK PREMIA IN THE EURO AREA: ARE THEY EXPLAINED BY LOCAL OR GLOBAL FACTORS?

by Sara Cecchetti*

Abstract

We study the determinants of sovereign credit risk in the euro area in a time period that includes the financial and sovereign debt crisis, as well as the unconventional monetary policy adopted by the European Central Bank. First, we detect the presence of commonality in sovereign credit spreads of different countries, justifying the search for the common factors that drive CDS prices. Building on the work of Longstaff et al. (2011), we employ the econometric model used in Cecchetti (2017) to decompose sovereign credit default swap spreads into expected default losses and risk premia, finding evidence of a significant contribution of the latter component. We use the model to understand to what extent the variations in CDS spreads and in the two embedded components of selected euro-area countries are more linked to local or euro area economic variables. The results point to the importance of both global and local factors, which have a greater impact on the risk premium component. Finally, we estimate the contribution of the objective probability and risk premium components of redenomination risk (as measured by the ISDA basis) to the related CDS spread components, detecting some differences between countries.

JEL Classification: B26, C02, F30, G15.
Keywords: bond excess return, credit default swap, distress risk premium, credit losses.
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Contents

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1 Introduction[1]

In the last decade the linkages between financial factors and macroeconomic developments have increasingly gained attention. Contagion between different sovereigns, banks and firms has emerged as one of the main channels through which they influence each other. In particular, changes in the prices of different financial assets may amplify (or attenuate) the dynamics of the economic cycle by means of the risk premia, which directly reflect the financial tensions and markedly vary according to the economic cycles.

The object of this paper is sovereign credit risk premia in the euro area, analysed through the lens of sovereign CDS spreads. In particular, we focus on the commonality between different countries, the decomposition of the spreads into effective default losses and risk premia components, and on their determinants. Our analysis focuses on three countries: Italy, France and Spain. Looking at pairwise correlations and principal components, we find evidence of an important commonality between the CDS dynamics of different countries. We employ the model of Cecchetti (2017) to decompose the CDS spreads into risk premium and default risk (or credit losses) components and find that risk premium makes a significant contribution. Using a statistical method, we select a set of country and euro-area financial and macroeconomic variables that could be possible drivers of the sovereign credit risk of Italy, France and Spain. We then investigate their contribution to the sovereign CDS spreads and their components by estimating linear regressions and partial correlations. According to our results, both country and euro-area financial variables influence the variations of CDSs and their components in different degrees for each of the three countries and to a greater extent in the risk premium component. What is common to all three countries is the deep connection between the sovereign and banking sectors. Lastly, we focus on redenomination risk, which has recently been considered an important source of a country's default risk: as a measure of local redenomination risk for each country, we use the ISDA basis, that is the difference between the premiums on CDSs on government securities governed by the new ISDA 2014 rules, which offer protection from redenomination risk, and those on CDS contracts governed by the old rules. We look at the ISDA basis of the three countries and, using our model, we estimate the risk premium and ob-

[1]I would like to thank Lorenzo Braccini, Fabio Busetti, Davide Delle Monache, Antonio Di Cesare, Giuseppe Grande, Marcello Pericoli, Marco Taboga and Gabriele Zinna for their useful comments. The views expressed in this paper are those of the author and do not necessarily reflect those of the Bank of Italy. All the remaining errors are my own. E-mail: sara.cecchetti@bancaditalia.it

jective probability component of the ISDA basis, finding a much higher component of risk premium in Italy. We study the contribution of both the redenomination risk premium component to the CDS risk premium component and of the objective probability of redenomination to the objective CDS default risk component. In so doing, we detect some differences between the countries: in particular, unlike France and Spain, in Italy the redenomination risk contribution to the default risk premium implicit in the CDS price is higher than the objective probability counterpart.

Our study belongs to the literature concerning the analysis of the determinants of sovereign credit spreads. This research question has been dealt with by other papers using different perspectives. Among these, Calice et al. (2014) use a Markov-switching unobserved component model to decompose the daily CDS term premium into two components of statistically different natures (nonstationary and stationary) and link them in a vector autoregression to various daily observed financial market variables. A regime switching approach is also used by Blommenstein et al. (2015) to study the main drivers of changes in sovereign CDS spreads, allowing for variations of the factors' impacts with varying market uncertainty. Galariotis et al. (2016) examine the determinants of CDS spreads and potential spillover effects for Eurozone countries during the recent financial crisis in the EU employing a Panel Vector Autoregressive (PVAR) model. In a reduced-form framework, Li and Zinna (2018) model the default intensity that enters CDS pricing, assuming that sovereigns can default either in the event of a country/sovereign-specific shock, or in conjunction with a systematic shock, which can lead to a cascade of sovereign defaults but in which each sovereign has a different probability. Doshi et al. (2017) specify and estimate a no-arbitrage model for sovereign CDS contracts in which a country's default intensity depends on economic and financial indicators.

In our paper we adopt the approach of Longstaff et al. (2011)[2] to analyse the commonality between different sovereign CDSs and to study the extent to which sovereign credit spreads can be explained by local or global factors. We also use that approach to disentangle the two components embedded in their prices. However, we depart from it under a number of critical dimensions that constitute our four main contributions to the literature: (i) we develop our analysis of euro-area sovereign CDSs during a time interval that includes both of the recent crises (financial and sovereign debt) and the recent unconventional monetary policy measures implemented by the European Central Bank (ECB); (ii) we first decompose sovereign CDS spreads into the expected losses and risk premium components, and

[2]Which builds on the Pan and Singleton (2008) model of sovereign CDS spreads.

then investigate the determinants of these components and of CDSs as a whole; in principle, the two components could be driven by different factors or by the same factors but to a different extent; (iii) we adopt a robust statistical method to select the main economic and financial variables that possibly drive the dynamics of the CDSs and of the two components; and (iv) we are the first, as far as we know, to analyse the contribution of redenomination risk components on the corresponding CDSs components.

The paper is organized as follows. Section 2 analyses the commonality in sovereign spreads of selected euro-area countries. Section 3 briefly recalls the model adopted to estimate the risk premium and the credit losses components embedded in sovereign CDSs. Section 4 describes the variables that may be related to sovereign risk and the statistical method used to select a subsample of more representative variables; then, focusing on Italy, France and Spain, it also presents the estimation results of the regressions of monthly changes in CDS spreads and their components on the explanatory variables selected, and the relative contributions of these explanatory variables in terms of partial correlations. Section 5 describes the results obtained in terms of the contribution of redenomination risk components (risk premium and objective probability) to CDS risk premium and default risk components. Section 6 concludes.

2 Evidence of commonality in euro area sovereign credit default swap

The first purpose of this paper is to detect possible commonality in sovereign credit spreads of the euro area. Although in the other sections we develop our analysis for Italy, France and Spain[3], to check for the commonality in the dynamics of CDSs in different countries, we use a larger sample of euro area countries.

2.1 The data

We consider a sample of six representative countries of the euro area: Germany, France, Italy, Spain, Portugal and Ireland. We focus on a time interval between January 2007 and November 2018, a period that includes both the global financial crisis, the sovereign debt crisis in the euro area and the unconventional monetary policy measures adopted by the ECB. For each country we consider the monthly

[3]These countries are considered as particularly representative for the purpose of the paper; moreover, for all these countries all the local variables that we consider potential explanatory variables are available.

time series of the 10-year sovereign CDS (with source Capital IQ). These time series are shown in Figure 1.

Observed 10Y CDS prices of different countries
(*basis points*)

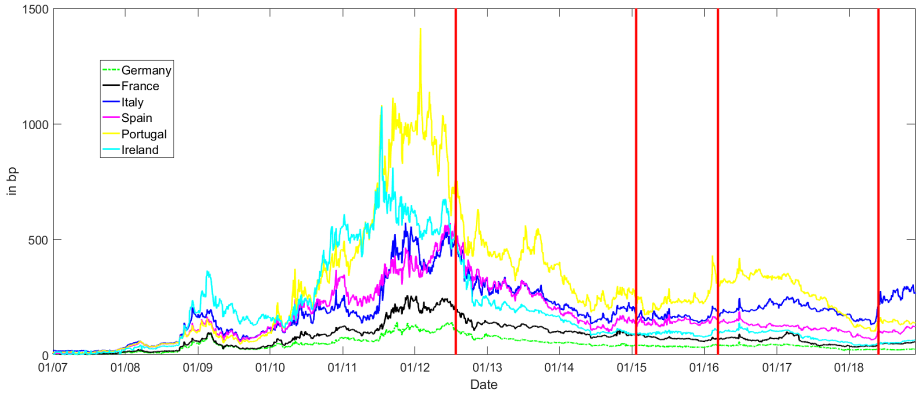

Figure 1 – Time series of 10-year observed CDS prices.
The figure shows the observed 10-year CDS prices for six euro area countries. The sample period runs from January 2007 to November 2018. The red vertical bars coincide with the following dates: 26 July 2012 (*"Whatever it takes"* speech by ECB President Draghi), 22 January 2015 (ECB announcement of the EAPP), 10 March 2016 (ECB expansion of the APP), 29 May 2018 (peak of political uncertainty in Italy).

Observing the temporal dynamics of CDS prices for different countries a common trend is evident.

2.2 Correlation

As a first step to detect commonality in sovereign credit spreads in the euro area, we calculate the correlation matrix of the monthly spread changes of the 10-year sovereign CDS of the six different countries considered (see Table 1).

January 2007 - November 2018

	Ger	*Fra*	*Ita*	*Spa*	*Por*	*Ire*
Ger	1	0.76	0.56	0.47	0.31	0.39
Fra	0.76	1	0.74	0.64	0.20	0.61
Ita	0.56	0.74	1	0.81	0.37	0.57
Spa	0.47	0.64	0.81	1	0.45	0.64
Por	0.31	0.20	0.37	0.45	1	0.28
Ire	0.39	0.61	0.57	0.64	0.28	1

Table 1 – Correlation matrix between sovereign CDSs in the entire review period (between January 2007 and November 2018)
The table reports tha pairwise correlations of monthly changes of sovereign CDSs of different countries. The sample period is between January 2007 and November 2018.

All pairwise correlations are positive and quite high. The average pairwise correlation is about 60 percent.

To highlight possibly different behavior over time, we also calculate the correlation matrices estimated in five different sub-periods (Table 2): from January 2007 to August 2008 (before the global financial crisis); from September 2008 to September 2009 (during the global financial crisis); from October 2009 to July 2013 (going through the euro area sovereign debt crisis); from August 2013 to April 2018 (after the crisis and before the beginning of the recent political uncertainty in Italy); from May 2018 to November 2018 (political uncertainty in Italy). The mean pairwise correlation is 75, 86, 59, 61 and 84 percent, respectively, in the five periods.

January 2007 - August 2008

	Ger	*Fra*	*Ita*	*Spa*	*Por*	*Ire*
Ger	1	0.72	0.52	0.65	0.56	0.54
Fra	0.72	1	0.55	0.63	0.49	0.70
Ita	0.52	0.55	1	0.91	0.95	0.68
Spa	0.65	0.63	0.91	1	0.95	0.81
Por	0.56	0.49	0.95	0.95	1	0.75
Ire	0.54	0.70	0.68	0.81	0.75	1

September 2008 - September 2009

	Ger	*Fra*	*Ita*	*Spa*	*Por*	*Ire*
Ger	1	0.97	0.80	0.73	0.77	0.80
Fra	0.97	1	0.85	0.83	0.84	0.88
Ita	0.80	0.85	1	0.82	0.89	0.70
Spa	0.73	0.83	0.82	1	0.97	0.83
Por	0.77	0.84	0.89	0.97	1	0.81
Ire	0.80	0.88	0.70	0.83	0.81	1

October 2009 - July 2013

	Ger	*Fra*	*Ita*	*Spa*	*Por*	*Ire*
Ger	1	0.77	0.60	0.48	0.32	0.26
Fra	0.77	1	0.76	0.64	0.15	0.58
Ita	0.60	0.76	1	0.82	0.34	0.61
Spa	0.48	0.64	0.82	1	0.43	0.66
Por	0.32	0.15	0.34	0.43	1	0.26
Ire	0.26	0.58	0.61	0.66	0.26	1

May 2018 - November 2018

	Ger	*Fra*	*Ita*	*Spa*	*Por*	*Ire*
Ger	1	0.85	0.54	0.83	0.68	0.91
Fra	0.85	1	0.73	0.93	0.88	0.82
Ita	0.54	0.73	1	0.84	0.96	0.61
Spa	0.83	0.93	0.83	1	0.93	0.83
Por	0.68	0.88	0.96	0.93	1	0.70
Ire	0.91	0.82	0.61	0.83	0.70	1

Table 2 – Correlation matrix between sovereign CDSs in different subperiods
The table reports the pairwise correlations of monthly changes of sovereign CDSs of different countries in different sample periods.

The periods in which the pairwise correlations are higher are the period of global financial crisis and the most recent period which includes political uncertainty in Italy.

2.3 Principal Component Analysis

As a second step to detect the commonality between sovereign CDSs of different countries, we use the correlation matrices reported in the previous Section to calculate the principal components. Table 3 describes the results for the entire time period (from January 2007 to November 2018).

January 2007 - November 2018		
PrincipalComponent	*PercentExplained*	*Total*
First	61.51	61.51
Second	14.68	76.18
Third	11.26	87.44
Fourth	7.22	94.66
Fifth	3.00	97.65

Table 3 – Principal Components Analysis results
The table reports summary statistics for the principal components analysis of the correlation matrix of monthly sovereign CDS spread changes. The sample period is between January 2007 and November 2018.

These results confirm that there is a strong commonality in the behavior of sovereign CDS spreads. In particular, the percentage of variation in sovereign CDS spreads explained by the first PC is around 62 percent over the entire period, while the first three PCs account for almost 90 percent of the variation. Figure 2 plots the loadings or weighting vectors for the first PC, resulting in an approximately uniform weighting of the credit spreads for most sovereigns in the sample.

First PC for different countries

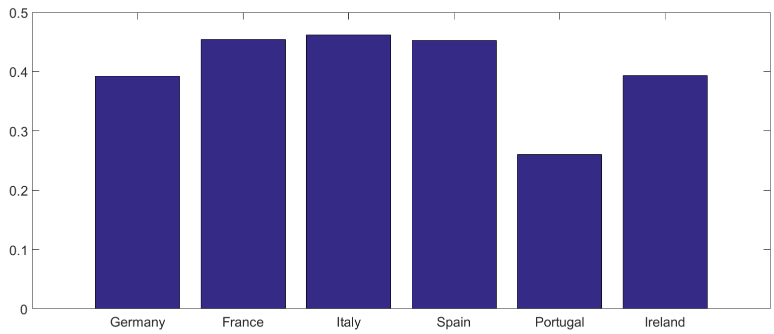

Figure 2 – First Principal Component loadings of monthly changes in CDS spreads.
The figure shows the first Principal Component for the sovereign 10-year CDS spreads for six euro area countries. The sample period runs from January 2007 to November 2018.

Table 4 shows the results of the principal component analysis for five sub-periods. In the second sub-period, between September 2008 and September 2009, the percentage of the variation ov sovereign CDS spreads explained by the first PC increases to around 86 percent, showing the highest commonality in the behavior of sovereign CDS spreads during the global financial crisis.

January 2007 - August 2008

PrincipalComponent	*PercentExplained*	*Total*
First	75.04	75.04
Second	13.49	88.53
Third	6.78	95.31
Fourth	3.66	98.97
Fifth	0.75	99.72

September 2008 - September 2009

PrincipalComponent	*PercentExplained*	*Total*
First	86.14	86.14
Second	6.70	92.84
Third	5.01	97.85
Fourth	1.65	99.50
Fifth	0.38	99.88

October 2009 - July 2013

PrincipalComponent	*PercentExplained*	*Total*
First	61.11	61.11
Second	15.24	76.35
Third	13.42	89.77
Fourth	5.72	95.49
Fifth	2.69	98.17

August 2013 - April 2018

PrincipalComponent	*PercentExplained*	*Total*
First	61.90	61.90
Second	14.16	76.05
Third	9.32	85.38
Fourth	6.67	92.04
Fifth	4.87	96.91

May 2018 - November 2018

PrincipalComponent	*PercentExplained*	*Total*
First	83.75	83.75
Second	11.44	95.19
Third	2.69	97.88
Fourth	1.20	99.08
Fifth	0.79	99.87

Table 4 – Principal Components Analysis results in different sub-periods
The table reports summary statistics for the principal components analysis of the correlation matrix of monthly sovereign CDS spread changes in different sample periods.

3 Breakdown of sovereign credit default swaps in risk premia and credit losses

Credit spreads can be expressed as the sum of a component related to the default and an associated risk premium. The possible drivers of sovereign credit risk premia that we will introduce in Section 4 could in principle affect in a different way these two components. In this Section we use the Pan and Singleton (2008) framework (which we briefly recall below), already used in Cecchetti (2017), to break down sovereign CDS spreads. Thus, in Section 4 we will examine both the relationships between the CDS spreads and the factors, and between the single components resulting from the decomposition and the factors. In this way we will be able to detect which factors, local or global, are most significant in explaining the variations of sovereign CDSs and embedded components.

3.1 The Model

Let us recall the formula for the risk neutral price of a CDS contract with maturity M:

$$CDS_t^{\mathbb{Q}}(M) = \frac{(1-R_t^{\mathbb{Q}})\int_t^{t+M}\mathbb{E}_t^{\mathbb{Q}}\left[\lambda_u^{\mathbb{Q}}e^{-\int_t^u(r_s+\lambda_s^{\mathbb{Q}})ds}\right]du}{\int_t^{t+M}\mathbb{E}_t^{\mathbb{Q}}\left[e^{-\int_t^u(r_s+\lambda_s^{\mathbb{Q}})ds}\right]du} \tag{1}$$

where r_t is the risk-free interest rate, $\lambda_t^{\mathbb{Q}}$ and $(1-R_t^{\mathbb{Q}})$ are the default intensity[4] and the loss given default under the risk-neutral probability measure $\mathbb{Q}$ at time t, and $\mathbb{E}_t^{\mathbb{Q}}$ denotes expectations based on $\lambda_t^{\mathbb{Q}}$ following a risk-neutral stochastic process. As in Pan and Singleton (2008), we assume the independence between r_t and λ_t and a constant recovery rate R. Furthermore, we consider that the annual spread is usually paid quarterly. It follows that we can rewrite equation (1) like

$$CDS_t^{\mathbb{Q}}(M) = 4 * \frac{(1-R^{\mathbb{Q}})\int_t^{t+M}D(t,u)\mathbb{E}_t^{\mathbb{Q}}\left[\lambda_u^{\mathbb{Q}}e^{-\int_t^u\lambda_s^{\mathbb{Q}}ds}\right]du}{\sum_{i=1}^{4M}D(t,t+0.25i)\mathbb{E}_t^{\mathbb{Q}}\left[e^{-\int_t^{t+0.25i}\lambda_s^{\mathbb{Q}}ds}\right]du} \tag{2}$$

where $D(t,u)$ is the price of a default-free zero-coupon bond (issued at date t and maturing at date u). As shown in Cecchetti (2017) for corporate CDSs, the price of a CDS under the risk-neutral measure $\mathbb{Q}$ can be written in terms of the price under the objective measure $\mathbb{P}$ like

$$CDS^{\mathbb{Q}} = CDS^{\mathbb{P}} + (CDS^{\mathbb{Q}} - CDS^{\mathbb{P}}), \tag{3}$$

where $CDS^{\mathbb{P}}$ represents the price component related to the objective (also called actual or historical) probability of default, while $(CDS^{\mathbb{Q}} - CDS^{\mathbb{P}})$ represents a component of risk premium. The price of a credit default swap can therefore be broken down into a component of expected losses, approximated by the price of the CDS under the objective probability measure, and a component of risk premium. In Cecchetti (2017), following Dìaz et al. (2013), the risk premium component is furtherly decomposed into the *distress risk premium* and the *jump-at-default risk premium* components. To estimate the latter component, an estimate of the default

[4]Discounting by $r_t + \lambda_t^{\mathbb{Q}}$ captures the survival-dependent nature of the payments.

intensity under the objective probability measure is required; this estimate is obtained from the Expected Default Frequency data provided by Moody's KMV. This type of data is not available for sovereign CDSs, and therefore we limit the estimate of the risk premium to the distress risk premium, while the residual CDS price can be considered as the component of credit losses (or default risk).

To estimate the distress risk premium component, we impose an Ornstein-Uhlenbeck process for the logarithm of the default intensity $\lambda_t^{\mathbb{Q}}$ under the risk-neutral measure $\mathbb{Q}$:

$$d \ln \lambda_t^{\mathbb{Q}} = K^{\mathbb{Q}}(\theta^{\mathbb{Q}} - \ln \lambda_t^{\mathbb{Q}})dt + \sigma_\lambda dW_t^{\mathbb{Q}} \tag{4}$$

where the parameters $K^{\mathbb{Q}}$, $\theta^{\mathbb{Q}}$ and σ_λ capture the mean-reversion rate, the long-run mean and the volatility of the process, respectively. By adopting this framework, intensity is guaranteed to be positive. In order to manage the same stochastic process under the objective measure $\mathbb{P}$, we assume a market price of risk Λ_t, underlying the change of measure from $\mathbb{P}$ to $\mathbb{Q}$, to be an affine function of $\ln \lambda_t$:

$$\Lambda_t = \gamma_0 + \gamma_1 \ln \lambda_t. \tag{5}$$

In fact, the dynamics of the logarithm of the risk-neutral mean arrival rate of default $\lambda_t^{\mathbb{Q}}$ under the objective measure $\mathbb{P}$ results in[5]

$$d \ln \lambda_t^{\mathbb{Q}} = K^{\mathbb{P}}(\theta^{\mathbb{P}} - \ln \lambda_t^{\mathbb{Q}})dt + \sigma_\lambda dW_t^{\mathbb{P}}, \tag{6}$$

where the mean-reversion rate and the long-run mean of the process under the objective probability measure, in terms of the market price of risk parameters, are

$$K^{\mathbb{P}} = K^{\mathbb{Q}} - \gamma_1 \sigma_\lambda$$

and

$$K^{\mathbb{P}}\theta^{\mathbb{P}} = K^{\mathbb{Q}}\theta^{\mathbb{Q}} + \gamma_0 \sigma_\lambda.$$

To measure the size of the distress risk premium, we follow Longstaff et al. (2011): as the dynamics of the objective (under $\mathbb{P}$ measure) and risk-neutral (under $\mathbb{Q}$) processes for $\lambda_t^{\mathbb{Q}}$ coincide when there is no risk premium ($\Lambda_t = 0$) since, from the previous discussion, they would have the same parameters, the size of the risk premium can be deduced simply by taking the difference

$$DRP_t = CDS_t^{\mathbb{Q}}(M) - CDS_t^{\mathbb{P}}(M) \tag{7}$$

where $CDS_t^{\mathbb{Q}}(M)$ is the price of the CDS implied by the risk-neutral process $\lambda_t^{\mathbb{Q}}$ (taking expectations in equation (2) using the risk-neutral probability distribution $\mathbb{Q}$ implied by equation (4)), $CDS_t^{\mathbb{P}}(M)$ is the price of the CDS implied by the objective process (taking expectations in equation (2) but using the probability distribution $\mathbb{P}$ implied by the objective process in equation (6)).

For the calculation of the CDS price we use the general approximation formula used in Lando (2004) and numerically calculate the expectation terms embedded in that formula.[6]

[5] See Appendix in Cecchetti (2017) for a technical proof.

[6] As is described in Cecchetti (2017).

3.2 Maximum likelihood estimates of risk-neutral default intensity

As in Longstaff et al. (2011), we estimate the model for sovereign CDS prices via maximum likelihood. To identify λ and model parametersl, we need a term structure of CDS prices for each country. We collect sovereign CDS spreads from Capital IQ for 3-year, 5-year and 10-year contracts.

For every time t, we have an unobservable factor, λ_t, and three corresponding CDS prices, with different maturities. Consequently, we must include additional random variables in order to perform a change of variables from unobservable state variables to CDS prices. To this end, we assume that CDSs with a 5-year maturity (CDS^{5Y}) are perfectly priced,[7] and we add standard normal measurement errors u^{3Y} and u^{10Y} for CDSs with maturities 3 and 10 years (CDS^{3Y} and CDS^{10Y}), respectively.

$$CDS_t^{sY} = f^{CDS^{sY}} + u_t^{sY} \quad s = 3, 5, 10 \tag{8}$$

where

$$u_t^{5Y} = 0$$

$$\phi(u_t^{3Y}, u_t^{10Y}) = \frac{1}{\sqrt{(2\pi)^2|\Omega|}} e^{-\frac{1}{2}\mathbf{u_t}\prime\Omega^{-1}\mathbf{u_t}}$$

and Ω is the diagonal covariance matrix for the measurement errors, with the variances of the measurement errors σ_{3y}^2 and σ_{10Y}^2 on the diagonal.

To build the maximum likelihood estimator for the parameters of our model, we develop a likelihood function for the observed CDS prices as functions of the unobserved default intensities.[8]

3.3 Empirical results

Table 5 provides summary statistics of the maximum likelihood estimates of the parameters of the risk-neutral process of the default intensity $\lambda_t^{\mathbb{Q}}$ relating to the CDSs of the six euro-area countries.

	$K^{\mathbb{Q}}$	$\theta^{\mathbb{Q}}$	σ_λ	$K^{\mathbb{P}}$	$\theta^{\mathbb{P}}$	σ_{3y}	σ_{10y}
Mean	0.3276	-4.5556	1.1949	0.4308	-6.6736	0.0024	0.0023
Std	0.0249	0.3808	0.0045	0.0009	0.0140	0.0017	0.0012
Median	0.3287	-4.5191	1.1957	0.4305	-6.6801	0.0019	0.0021

Table 5 – Parameters of $\lambda^{\mathbb{Q}}$ process under $\mathbb{Q}$ and $\mathbb{P}$ measures
Summary statistics of maximum likelihood estimates of risk-neutral $\lambda_t^{\mathbb{Q}}$ process. $K^{\mathbb{Q}}$ and $K^{\mathbb{P}}$ denote the mean-reversion rates of $\lambda_t^{\mathbb{Q}}$ under the risk-neutral and actual measures, respectively. $\theta^{\mathbb{Q}}$ and $\theta^{\mathbb{P}}$ are the long-run mean of $\lambda_t^{\mathbb{Q}}$ under the risk-neutral and actual measures, respectively. σ_λ is the instantaneous volatility of the process. σ_{3y} and σ_{10y} represent the volatility of the mispricing errors for 3- and 10-year maturities.

[7] 3 years is the maturity considered for the contract perfectly priced in Pan and Singleton (2008), Dìaz et al. (2013) and Cecchetti (2017), but the choice is not related to different liquidity conditions of CDS contracts with different maturities; we choose 5 year in this paper to be able to work with estimated prices for 10-year maturity, and we'll motivate this choice in Section 4.

[8] See Cecchetti (2017) for details.

Looking at these results we can see that, on average, mean-reversion rates are higher under the objective measure compared to under the risk-neutral measure ($K^{\mathbb{P}} > K^{\mathbb{Q}}$). In contrast, long-term mean parameters are higher under $\mathbb{Q}$ than under $\mathbb{P}$ measure ($\theta^{\mathbb{Q}} > \theta^{\mathbb{P}}$). These results are consistent with the empirical evidence in the literature (see, for example, Pan and Singleton (2008) and Diaz et al. (2013)) and imply that $\lambda^{\mathbb{Q}}$ will tend to be greater under $\mathbb{Q}$ with respect to under $\mathbb{P}$; in other words, the arrival of credit events is more intense in the risk-neutral (higher long-run means) than in the actual environment. Moreover, for a given level of $\lambda^{\mathbb{Q}}$, there is more persistence under $\mathbb{Q}$ than under $\mathbb{P}$ (bad times last longer in the risk-neutral world because the speed of mean reversion is lower under $\mathbb{Q}$).

In Figure 3 are shown the average (of the six countries) 10-year CDS prices estimated under the risk-neutral measure $\mathbb{Q}$ and the objective measure $\mathbb{P}$ (that is the default risk component), the risk premium component and the observed prices.

Observed and estimated 10-year CDS prices and embedded components (*basis points*)

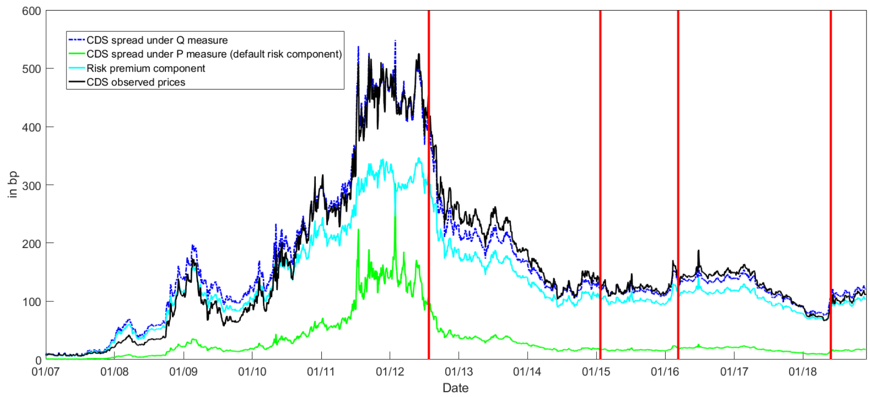

Figure 3 – Average 10-year CDS prices observed and estimated under the two probability measures, and risk premium component.
The figure shows the average 10-year CDS prices, observed, estimated under the $\mathbb{Q}$ and $\mathbb{P}$ measures, and risk premium component. The sample period covers from January 2007 to November 2018. The red vertical bars coincide with the following dates: 26 July 2012 (*"Whatever it takes"* speech by ECB President Draghi), 22 January 2015 (ECB announcement of the EAPP), 10 March 2016 (ECB expansion of the APP), 29 May 2018 (peak of political uncertainty in Italy).

According to the intuition and the empirical evidence in the literature, both the risk premium and the default risk component have increased considerably during the periods of the sovereign debt crisis (and, to a lesser extent, during the financial crisis).

4 The drivers of sovereign credit default swap and embedded components

In Section 2 the empirical evidence confirmed the presence of commonality in the sovereign credit spreads of the euro area. In this Section we focus on three countries in particular: Italy, France and Spain. First, we enumerate the potential sources of this commonality and describe an appropriate statistical method to identify which of them could determine the a sovereign credit spread. Then we examine the relationship between sovereign credit spreads, as well as embedded credit losses and risk premium components, and the selected variables.

4.1 The potential explanatory variables

As potential explanatory variables we consider both local and euro area variables, appropriately rescaled in the same unity of measure (basis points). In particular, as local (or national) factors, we consider three variables that should represent the state of the local economy; as euro area factors, we consider three different types of variables, for a total of ten variables, to capture broad changes in the state of the euro area economy and shifts in the relative price performance of different asset classes: i) financial variables (mainly because the reallocation of capital in different asset classes could create correlations between the prices of asset classes); ii) macroeconomic variables (since the sovereigns included in the study have extensive economic relationships with other euro area countries, a country's ability to repay its debt may also depend on the state of the economy, i.e. the economic juncture, in the euro area as a whole); iii) risk premium variables (as intuitively one might expect some commonality in the properties of the risk premium across markets).

LOCAL VARIABLES:

- The monthly returns of the country bank stock market price index (BANKSIT, BANKSFR and BANKSES price indices for Italy, France and Spain respectively, source Thomson Reuters Datastream);
- The monthly percentage change of the country Economic Policy Uncertainty Index (source FRED and Factiva);
- The monthly net flows to the country bonds sector (source EPFR).

EURO AREA FINANCIAL VARIABLES:

- The monthly change of the 10-year yield of the German Bund (source Bloomberg);
- The monthly change of BofA Merrill Lynch high yield corporate spreads (ICE BofAML Euro High Yield Index, OAS, source Thomson Reuters Datastream);
- The monthly change of the average of the 10 year CDS spreads in the ITraxx Europe index (source Capital IQ);
- The monthly returns of the euro area stock market price index (DJEURST price index, source Thomson Reuters Datastream);
- The monthly percentage change of the euro area implied stock market volatility (VSTOXX volatility index, source Thomson Reuters Datastream).

EURO AREA MACROECONOMIC VARIABLES:

- The monthly percentage changes of the euro area Markit Flash PMI Composite (source Thomson Reuters Datastream);
- The euro area Consensus Forecasts one year ahead Inflation rate.
- The euro area Consensus Forecasts one year ahead GDP growth.

EURO AREA RISK PREMIUM VARIABLES

- As a proxy for the variation in the equity risk premium, we use monthly percentage changes in the earnings-price ratio of the aggregate stock market index for the euro area (TOTMKEM (PE), source Thomson Reuters);
- As a proxy for changes in the term premium we use the monthly changes in the estimates of the term premium embedded in 10 year German Bund yield, as estimated by Adrian et al.(2013).

We regress the monthly changes of the Italian, French and Spanish sovereign 10 year CDSs and embedded risk premium and expected losses components on all these explanatory variables.

Let us remark that we focus on the 10-year maturity because CDS contracts with this maturity should be more influenced by macroeconomic variables.

According to the regression results and statistics, several variables are not significant; for this reason we adopt a method largely used in the literature to select a reduced sample of explanatory variables.

4.2 The model selection method

To select a sub-sample of most significative variables we use *Elastic Net Regularization* regression method.[9]

Elastic Net is a regularization technique for performing linear regression, that is a hybrid of *ridge regression* and *lasso regularization.* Like lasso, elastic net can generate reduced models by generating zero-valued coefficients. Empirical studies have suggested that the elastic net technique can outperform lasso on data with highly correlated predictors.

The elastic net technique solves the following regularization problem. For an α strictly between 0 and 1, and a non-negative λ, elastic net solves the problem

$$\min_{\beta_0,\beta}\Big(\frac{1}{2N}\sum_{i=1}^{N}(y_i-\beta_0-x_i^T\beta)^2+\lambda P_\alpha(\beta)\Big),$$

where

$$P_\alpha(\beta)=\frac{1-\alpha}{2}||\beta||_2^2+\alpha||\beta||_1=\sum_{j=1}^{P}\Big(\frac{1-\alpha}{2}\beta_j^2+\alpha|\beta_j|\Big)$$

- N is the number of observations;
- y_i is the response at observation i;

[9]See Tibshirani (1996), Zou and Hastie (2005) and Hastie at al. (2008) for details.

- x_i is data, a vector of P values at observation i;
- λ is a positive regularization parameter;
- the parameters β_0 and β are scalar and P-vector respectively.

Elastic net is the same as lasso when $\alpha = 1$. As α shrinks toward 0, elastic net approaches ridge regression. For other values of α, the penalty term $P_\alpha(\beta)$ interpolates between the L^1 norm of β and the squared L^2 norm of β.

Of course as λ increases, the number of coefficients $\beta_i = 0$ increases as well.

To perform our model selection (choosing α and λ properly), we construct a grid for α and λ, with $\alpha \in [0.1, 0.9]$, $\lambda \in [0.01, 99.99]$, and we use a BIC criterium solving the problem

$$\min_{\lambda,\alpha} \Big[\log(SSE) + \Big(\frac{\log(N)}{N}\Big) * NC \Big],$$

where NC is the number of coefficients different from 0 and

$$SSE = \sum_i (y_i - \hat{y}_i)^2.$$

4.3 Empirical results of the selected reduced model

After performing model selection, a limited number of different explanatory variables is left in the reduced regression models for CDS, risk premium and expected losses variation in the three countries for which we perform our analysis.

Table 6 reports the regression results and the statistics for the reduced models for Italy, France and Spain. As we will explain below, these results confirm our intuition that both local and global (at the euro area level) factors drive changes in CDS spreads. Even in terms of the different impact of the determinants on the two components embedded in the CDS prices, we find what we would reasonably expect a priori: the impact is greater on the risk premium component, as it is correlated with the risk aversion of investors which increases (decreases) when the state of the economy worsens (improves).

Let us examine the results in detail. First we find that both national and euro area financial factors influence Italian sovereign CDSs, while macroeconomic and risk premium factors are not significant: by observing standardized regression coefficients, there is evidence of important relationships between local banking sector and the sovereign sector, as well as between the euro area corporate sector and the Italian sovereign sector. In particular, looking at Italy, the regression coefficients are negative for the Italian banking stock return and the change in the German 10-year yield, which means that an increase in these variables is associated with a decrease in Italian sovereign CDS; this is consistent with what we would expect in theory, since a decrease in these financial variables is associated with a bad state of the economy. Conversely, the change in Italian sovereign CDS and embedded components is positively correlated with the increase in euro area corporate CDSs and euro area stock market implied volatility, since these two variables increase in the periods of financial stress. As regards the two components of the CDS, the impact of

	Italy			France			Spain		
	CDS	RP	EL	CDS	RP	EL	CDS	RP	EL
Country Bank Stock	$-11.97^{***}_{(-4.60)}$	$-7.39^{***}_{(-4.80)}$	$-2.04^{***}_{(-3.94)}$	$-4.30^{***}_{(-2.81)}$	$-3.46^{***}_{(-3.41)}$	$-0.93^{***}_{(-3.45)}$	$-12.27^{***}_{(-5.03)}$	$-7.31^{***}_{(-4.93)}$	$-2.71^{***}_{(-4.79)}$
Country EPU							$3.37_{(1.54)}$	$1.44_{(1.35)}$	
10Y Ger	$-5.32^{**}_{(-2.37)}$	$-3.05^{**}_{(-2.30)}$	$-0.98^{**}_{(-2.22)}$				$-1.18_{(-0.56)}$	$-2.86^{*}_{(-1.70)}$	
EA HY OAS					$0.88_{(0.96)}$				
EA Corp CDS	$8.02^{***}_{(2.97)}$	$5.85^{***}_{(3.68)}$	$1.75^{***}_{(3.30)}$	$3.05^{**}_{(2.54)}$	$1.50_{(1.56)}$	$0.51^{**}_{(2.41)}$	$3.43_{(1.29)}$	$3.46^{**}_{(2.15)}$	$1.04^{*}_{(1.73)}$
EA Stock				$-0.20_{(-0.09)}$	$-0.88_{(-0.81)}$	$-0.24_{(-0.90)}$			
EA Imp Vol	$4.33^{*}_{(1.74)}$	$3.71^{**}_{(2.51)}$	$1.03^{*}_{(1.89)}$				$3.09_{(1.25)}$	$1.65_{(1.06)}$	$0.82_{(1.32)}$
EA PE Ratio				$-0.37_{(-0.23)}$					
Ger TP								$2.84^{*}_{(1.80)}$	
R^2	0.50	0.56	0.48	0.35	0.47	0.44	0.39	0.46	0.34
Adj R^2	0.48	0.55	0.47	0.33	0.45	0.43	0.36	0.43	0.33

Table 6 – Regression results for the reduced model for CDS, RP and Exp Loss variation for Italy, France and Spain.
The table displays the estimated standardized regression coefficients (and related t-statistics in parentheses), as well as th R^2 and adjusted R^2 of the entire regressions. The p-values of the estimated coefficients are marked by $***p < 0.01$, $**p < 0.05$,$*p < 0.1$. The cells are empty if the explanatory variable on the corresponding row has not been selected by the model selection method for the dependent variable on the column.

the explanatory variable, both positive and negative, is greater on the risk premium than expected losses.

As in the case of Italy, also for France and Spain the most significant variable in the linear regression output is the banking stock return, which underlines the deep connection between the sovereign and banking sectors. Changes in corporate CDS also play a role in explaining changes in French CDS and expected losses component and in Spanish risk premium and expected losses components. Spanish risk premium is also negatively related to the yield on 10-year German government bonds and positively related to the embedded term premium component.

Given the empirical confirmation of the important expected contribution of local banking stock returns in explaining the chenges in the CDS, and aware of the negative feedback loop between the sovereign sector and the banking sector which is well known in the literature[10], we repeated our analysis by replacing the variable corresponding to the local banking stock returns with the country general stock index returns. However, the results of our variables selection method and of the related regressions did not substantially change, since basically the country stock returns takes the place of the banking stock returns in the degree of contribution in explaining the variations of the CDS.[11]

4.4 Relative contributions of the explanatory variables

The relative contributions of the selected explanatory variables to the variation of the sovereign CDS and their components can also be evaluated by looking at the partial correlations between the dependent variables and each of the independent variables selected in the reduced model. With respect to correlation, the partial correlation provides a better measure of the degree of association between the dependent variable and each independent variable, as it controls for the other explanatory variables that could be numerically related to both variables of interest (while the simple correlation could provide misleading information). Table 7 shows the partial correlation coefficients for Italy, France and Spain.

Looking at the partial correlation coefficients, as we would expect a priori, we find confirmation that the variation of the Italian sovereign CDS is negatively correlated to[12] the Italian banking stock return and to the change in the yield of the 10-year German government bond, while it is positively correlated with the change of euro area corporate CDS and of the euro area implied stock volatility.

Also for France and Spain, the most inversely correlated variable with the CDS and the embedded components is again the country banking stock return and there is a significant positive correlation with the corporate CDSs of the euro area. In the case of Spain, however, other partial correlation coefficients are in absolute value above10 percent: precisely, between CDS and political uncertainty and euro area implied volatility, between risk premium and political uncertainty, German 10-year yield and German term premium, and between expected losses and euro area implied volatility.

[10]See, for instance, Angelini et al. (2014).

[11]For this reason we do not report the results of the model with the variable corresponding to the country general stock index returns instead of that of the national banking stock index returns.

[12]In descending order of importance.

	Italy			**France**			**Spain**		
	CDS	RP	EL	CDS	RP	EL	CDS	RP	EL
Country Bank Stock	−0.3655	−0.3794	−0.3189	−0.2331	−0.2798	−0.2817	−0.3959	−0.3907	−0.3779
Country EPU							0.1311	0.1158	
10Y Ger	−0.1981	−0.1931	−0.1862				−0.0477	−0.1449	
EA HY OAS					0.0817				
EA Corp CDS	0.2460	0.2999	0.2715	0.2118	0.1320	0.2008	0.1103	0.1820	0.1460
EA Stock				−0.0080	−0.0692	−0.0761			
EA Imp Vol	0.1467	0.2098	0.1595				0.1065	0.0908	0.1116
EA PE Ratio				−0.0194					
Ger TP								0.1532	

Table 7 – Partial correlations between variation in CDS, RP, Exp Loss and selected explanatory variables for Italy, France and Spain.

5 Contribution of redenomination risk

In recent years, and in particular in the last year for Italy, as an important source of risk, the risk of redenomination has emerged, that is the risk that the country leaves the euro; this source of risk is different from the risk that increased deficit spending might make the country's public finances unsustainable, leading to a default, possibly while remaining in the euro.

In this section we focus on redenomination risk, which we can consider as a local risk factor, to study the contribution of the components of the redenomination risk, both the risk premium and the objective probability of redenomination, to the corresponding components of CDS prices. As a proxy measure for the risk of redenomination we consider the ISDA basis, which is the difference between the CDS premia on the Italian government securities governed by the new ISDA 2014 rules, which offer protection from redenomination risk, and those on CDS contracts regulated by the old rules.[13]

For the three considered countries, Figures 4, 5 and 6 show the observed 10-year CDS prices and the ISDA basis. The ISDA basis increases considerably for all countries during periods of political tensions: political uncertainty in Italy since May 2018, elections in France in the spring of 2017 and referendum on Catalan independence in Spain in the autumn 2017. In France and Spain are observed even small increases together with the recent increases observed in Italy, indicating a phenomenon of even limited contagion; however, the ISDA basis in these countries has reached much lower values than the corresponding Italian basis, where we can say that from spring 2018 over a third of Italian sovereign credit risk is attributable to fears of redenomination of Italian sovereign bonds.

10y CDS price and ISDA basis of Italy

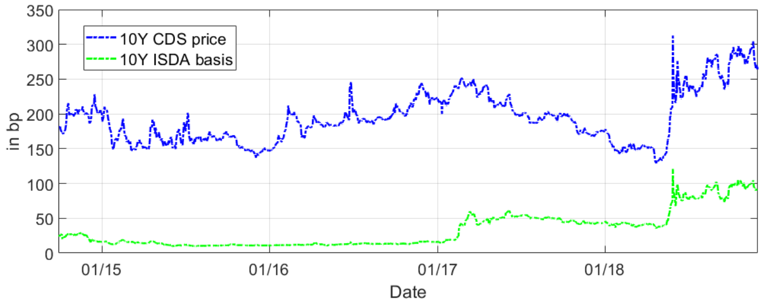

Figure 4 – The figure shows the 10-year CDS price and 10-year ISDA basis for Italy. The sample period runs from October 2014 to November 2018.

[13] Of course the ISDA basis does not only represent redenomination risk, as the contracts stipulated in 2014 include also other protection clauses, however to economic analysts, this spread represents a good proxy of redenomination risk, see for instance recent Bank of Italy Economic Bulletins 2018 and 2019.

10y CDS price and ISDA basis of France

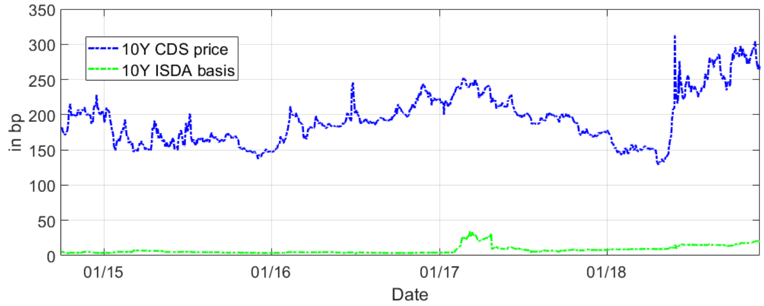

Figure 5 – The figure shows the 10-year CDS price and 10-year ISDA basis for France. The sample period runs from October 2014 to November 2018.

10y CDS price and ISDA basis of Spain

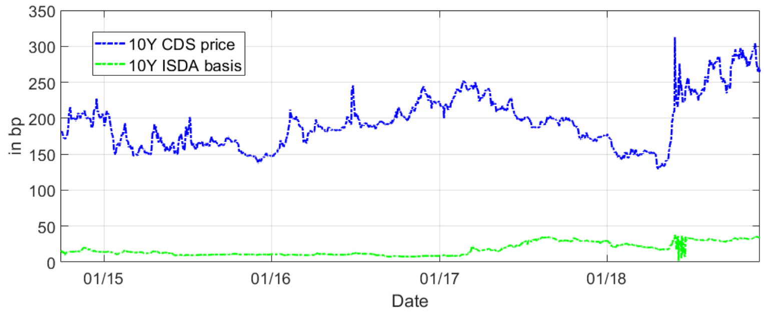

Figure 6 – The figure shows the 10-year CDS price and 10-year ISDA basis for Spain. The sample period runs from October 2014 to November 2018.

To estimate the components of objective probability of redenomination and risk premium implicit in the ISDA basis, we treat it as a CDS price and use our model described in Section 3 to break it down into the two components.

Figures 7, 8 and 9 show the estimated risk premium and objective probability components of the ISDA basis. The time series of both components are highly correlated for all countries. However, while they are of a similar size in France and Spain (with the objective probability component always higher than the component of risk premium, and with a slightly negative risk premium during calm periods in France), in Italy, from the beginning of political tensions, the premium component for the redenomination risk is almost twice the corresponding objective probability component.

Estimated 10y risk premium and objective probability components of the ISDA basis of Italy

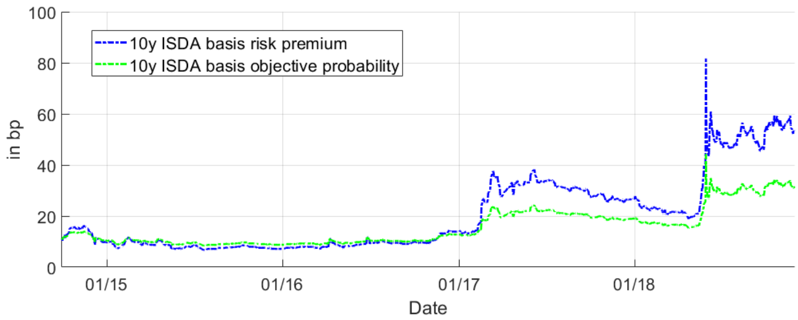

Figure 7 – The figure shows the estimated 10y risk premium and objective probability components of the ISDA basis for Italy. The sample period runs from October 2014 to November 2018.

Estimated 10y risk premium and objective probability components of the ISDA basis of France

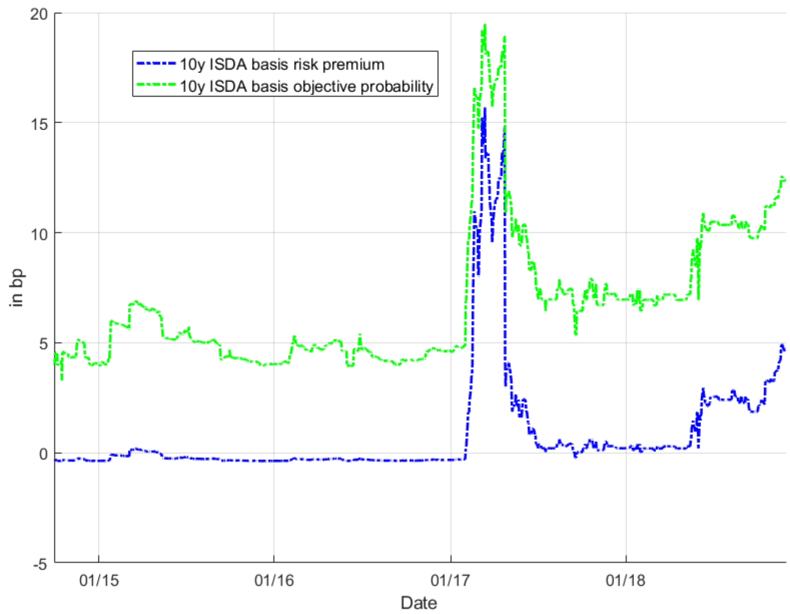

Figure 8 – The figure shows the estimated 10y risk premium and objective probability components of the ISDA basis for France. The sample period runs from October 2014 to November 2018.

Estimated 10y risk premium and objective probability components of the ISDA basis of Spain

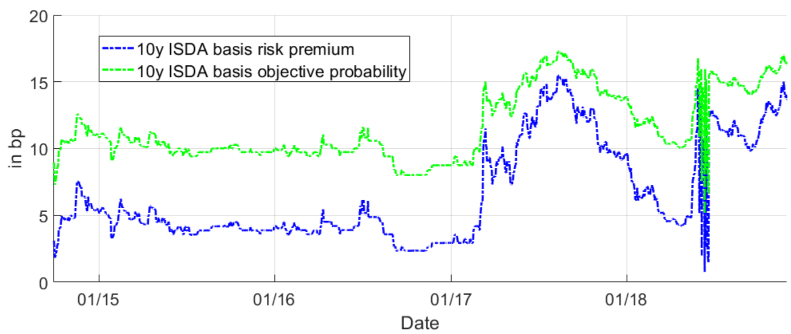

Figure 9 – The figure shows the estimated 10y risk premium and objective probability components of the ISDA basis for Spain. The sample period runs from October 2014 to November 2018.

To estimate the contributions of the redenomination risk to the total price of the 10-year CDS and the related components of risk premium and objective probability of default, we calculate the ratios[14] between the respective components of the ISDA basis and the counterparties of the CDS price. Figures 10, 11 and 12 show these ratios for the three countries.

Estimated redenomination risk contributions in terms of 10y asset price and two embedded components for Italy

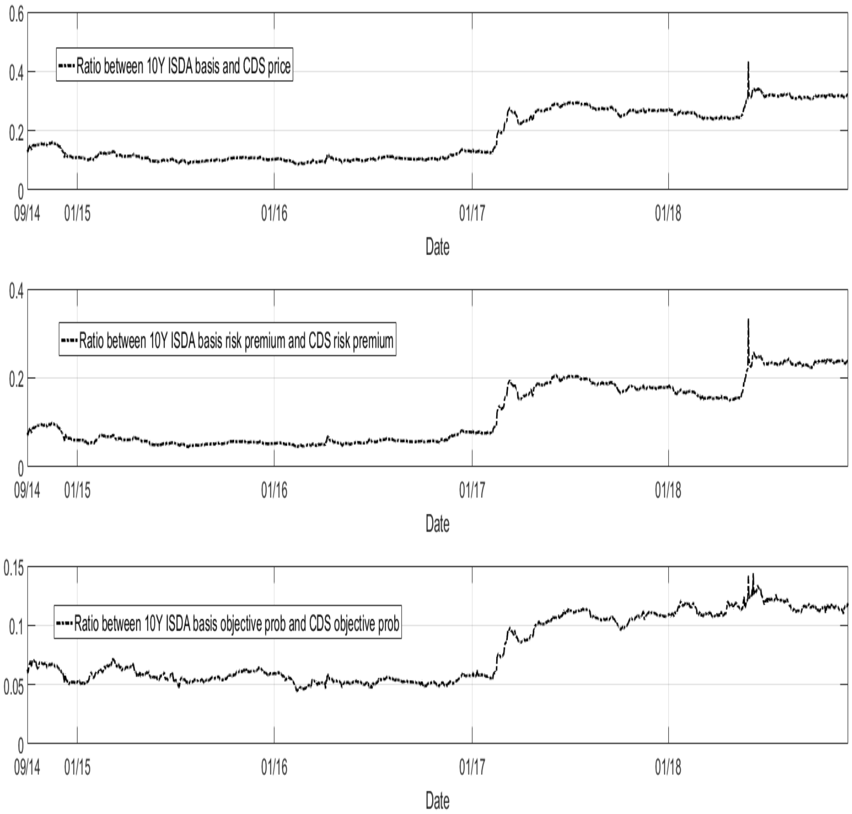

Figure 10 – The figure shows the estimated redenomination risk contributions in terms of 10y asset price and two embedded components for Italy. The sample period runs from October 2014 to November 2018.

[14]A linear regression approach as in Section 4 is not possible, as our measure of redenomination risk representing the independent variable is computed using the same CDS price that would represent the dependent variable.

Estimated redenomination risk contributions in terms of 10y asset price and two embedded components for France

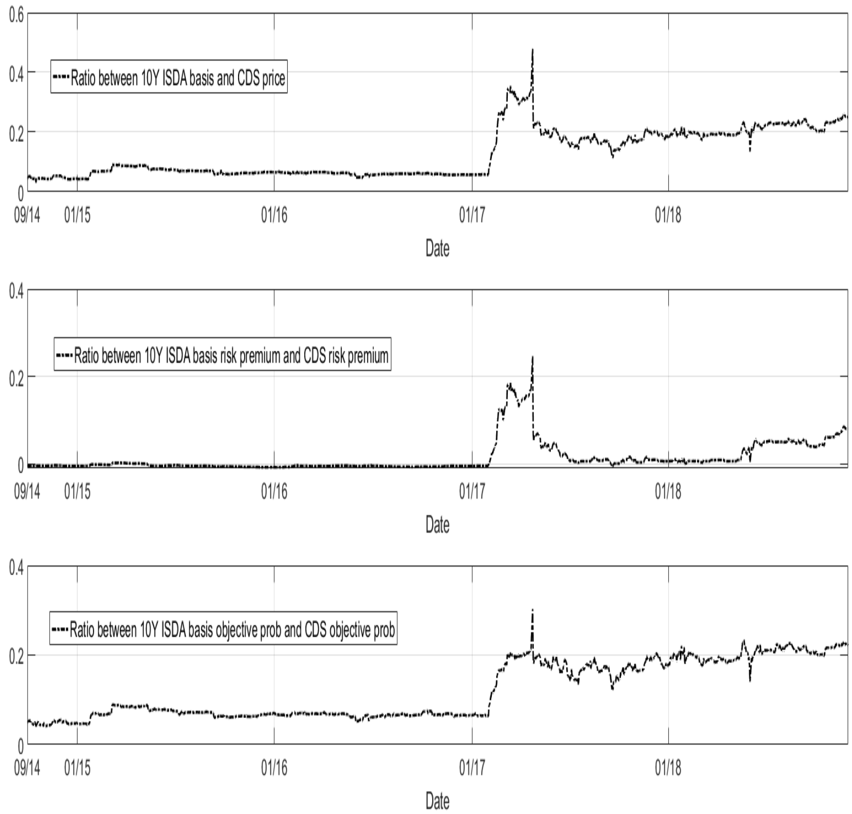

Figure 11 – The figure shows the estimated redenomination risk contributions in terms of 10y asset price and two embedded components for France. The sample period runs from October 2014 to November 2018.

Estimated redenomination risk contributions in terms of 10y asset price and two embedded components for Spain

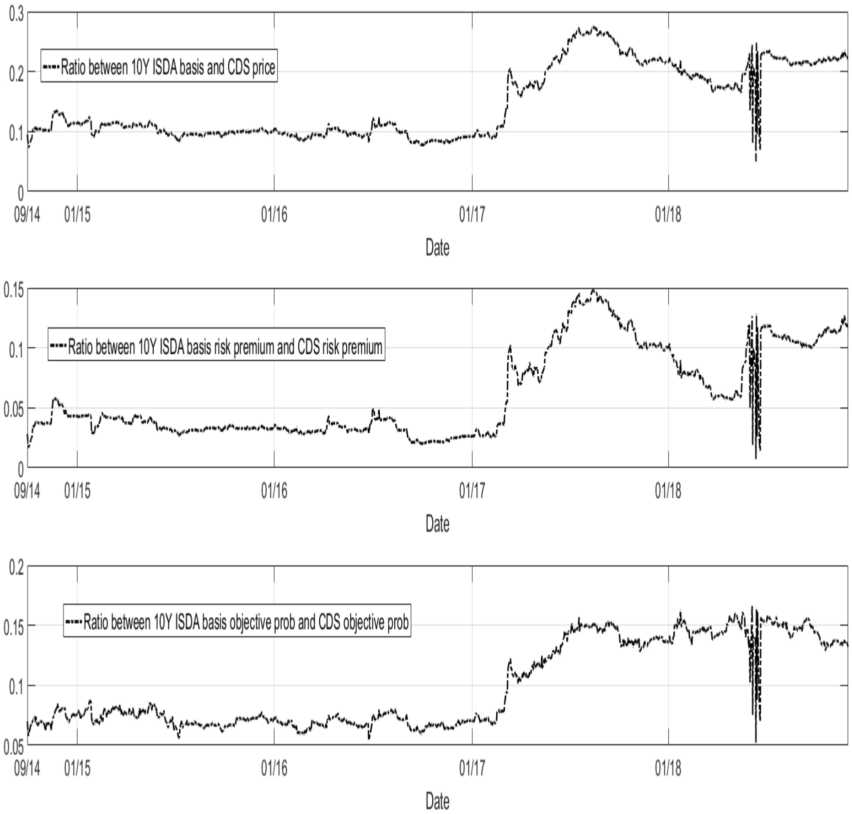

Figure 12 – The figure shows the estimated redenomination risk contributions in terms of 10y asset price and two embedded components for Spain. The sample period runs from October 2014 to November 2018.

Looking at these ratios, we can see that all contributions increase during periods of political tensions. However, some differences emerge between the countries: in France and Spain, while the total price ratio and the risk premium ratio decrease after the peak of political tensions, the objective probability ratio is more persistent; this difference is less evident in Italy, where all three ratios remain rather high after the peak of political tensions. Furthermore, the contribution of the redenomination risk in the default risk premium in Italy is substantially double the contribution of the objective probability counterparty, while in France and Spain the highest contribution is provided by the objective probability of redenomination. These results show that the fairly persistent increase in the prices of Italian sovereign CDS recorded in the spring of 2018 was mainly driven by an increase in the premium required from investors to be exposed to the redenomination risk of the country.

6 Conclusions

We study the sovereign credit risk premia in the euro area, analysing the sovereign CDSs of six different countries in the last decade. Using statistical techniques, we highlight the commonality between their dynamics. Employing an econometric model we decompose the sovereign CDS spreads of each country into risk premium and default risk (expected losses) components. Then we focus on three countries: Italy, France and Spain. We consider a set of possible drivers of the sovereign CDSs potentially affecting both the embedded components. These factors are both at a country and euro-area level, and consist of financial, macroeconomic and risk premium variables. Employing a linear regression technique we study which of these variables better explains the dynamics of the Italian, French and Spanish sovereign 10-year CDS spreads and their components. To select a smaller sample of more representative factors, we use the Elastic Net regularization statistical method and we regress the monthly variations of the dependent variables of interest on the variations of the selected independent variables. We find that, notwithstanding some differences between the countries considered, both country level and some euro-area financial variables significantly affect the sovereign CDSs and the embedded components; in particular, the strongest negative relationship is found between sovereign CDSs and local banking stock returns, underlying the deep linkages between sovereign and banking sectors. The same evidence about the relative contributions is found when looking at partial correlations between the dependent variables and each of the selected independent variables. Finally, we focus on the redenomination risk of the three countries, as measured by the ISDA basis, to investigate the contributions of the risk premium and of the objective probability components of this kind of risk to the related CDS components. Some differences between the countries emerge from this analysis: first of all, looking at the redenomination risk components, we find that they are of similar magnitude in France and Spain (with the objective probability being slightly higher), while in Italy, since the start of political tensions in Spring 2018, the risk premium component is basically twice the objective probability counterpart, representing about two thirds of the ISDA basis. Looking at the contributions of the redenomination risk components to the CDS price counterparts, measured in terms of ratios, while all the contributions increase during the periods of heightened political tensions, they all remain quite high afterwards in Italy, while the only ratio that remains high in France and Spain is the objective probability ratio. These findings, taken together, point to a more persistent and much stronger risk premium component of redenomination risk in Italy. This component increases the prices of Italian sovereign CDSs, which are affected by the greater perception by market operators of this type of risk in Italy and by the relative greater compensation required to bear it.

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