The Relative Pricing of Sovereign Credit Risk After the Eurozone Crisis

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Abstract

The paper analyses the relative pricing between sovereign CDS spreads and sovereign bond yields, for European countries, during and after the sovereign debt crisis of 2010-2012. We investigate whether the differences across countries in terms of default risk, priced in the CDS spreads, are consistently priced in the cross-section of the bond yields. We show that an inconsistent cross-sectional relationship between CDS spreads and bond yields emerges during the crisis period for all the European countries. However, after the announcement of the Outright Monetary Transaction (OMT) Programme by the European Central Bank, the consistent cross-sectional relationship between default risk and bond yields is restored for the Eurozone countries only.

JEL classification: C58, E58, G12, G15.

Keywords: Relative Pricing, Bond Yields, OMT programme, Default Risk.

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1. Introduction

Credit derivatives and debt securities are strictly related, since the pricing of both types of financial assets crucially depends on the risk of default of the reference entity. Credit Default Swaps (CDS) and bonds issued by the CDS reference entity produce similar exposure to the investor in terms of risk and return. The CDS provides protection to the acquirer in case of default of the reference entity, while the bond pays out yields to the bondholder as long as the reference entity is able to comply with its obligations.

Hull, Predescu, and White (2004) point out that, under a set of assumptions that ensure absence of frictions in the market, a portfolio including a bond, and the protection on the bond provided by a CDS, generates cash flows equal to a riskless bond in all states of the world. Then, as consequence, the CDS premium should be equal to the excess bond yield over the risk-free rate to prevent arbitrage. This equilibrium condition is called zero-basis condition, where the basis is the difference between the CDS spread and the asset swap spread of the bond.

In this paper, we study the relationship between sovereign CDS and sovereign bonds for the European countries, during and after the sovereign debt crisis of 2010-2012. In particular, we focus on the cross-sectional relationship between CDS spreads and bond yields across European countries. We investigate whether the differences across countries in terms of default risk, priced in the CDS spreads, are consistently priced in the cross-section of the bond yields. Our main finding is the following: an inconsistent cross-sectional relationship between CDS spreads and bond yields emerges during the crisis period for all the European countries, while after the announcement of the Outright Monetary Transaction (OMT) Programme, by the European Central Bank, the consistent cross-sectional relationship between default risk and bond yields is restored for the Eurozone countries only.

We start our analysis by documenting that the equilibrium condition between CDS premium and bond yields is violated before the announcement of the OMT programme for all the European countries, and is restored afterwards for the Eurozone countries only, and in particular for the peripheral countries of the Eurozone. Instead, the deviation from the equilibrium condition persists also after the OMT announcement for the European countries out of the Eurozone.

Since the violation of the equilibrium condition generates arbitrage opportunities, we corroborate the result with a portfolio analysis based on the deviation from the zero-basis condition. We show that arbitrage opportunities are large and persistent before the annnouncement of the OMT across all European countries, and then quickly disappear after the annnouncement of the OMT for Eurozone countries only. Instead, arbitrage opportunities persist also after the OMT announcement for countries outside the Eurozone.

Mispricing has been documented for both corporate (Longstaff, Mithal, and Neis (2005), Blanco, Brennen, and Marsh (2005)), and sovereign securities (Palladini and Portes (2011), Arce, Mayordomo, and Pena (2013), Fontana and Scheicher (2016)). These papers argue that CDS spreads are faster in price discovery, thus reacting quicker to changes in credit condition. As a consequence, the relationship CDS spread - bond spread does not hold in the short-term. However, they show that CDS spreads and bond yields exhibit strong co-movements in a long-term perspective. While Palladini and Portes (2011), Arce et al. (2013), and Fontana and Scheicher (2016) provide evidence of the relative pricing of the sovereign credit risk before and during the sovereign crisis, we extend the analysis to the period following the ECB intervention, including also countries out of the Eurozone, with the aim of highlighting the differential effects of the unconventional monetary policy.

We proceed with our analysis by showing that the deviation from the zero-basis condition does not imply the violation of the positive monotonic relationship between CDS spreads and bond yields, across countries. In fact, we show that the cross-sectional rank correlation between CDS spreads and bond yields is always close to 1, for both Eurozone and No Eurozone countries. This result provides evidence that riskier countries issue debt securities that pay out higher yields.

In general, in a consistent relationship between risk and return, the riskier security should generate higher expected return, compared to a less risky security, in order to induce investors to hold it. Investors are willing to buy risky assets only if they are rewarded with a proper expected return. The higher is the risk associated to a given investment, the higher must be its expected return. It turns out that over a cross-section of assets, we should observe a positive monotonic relationship between risk and expected return. The empirical contradiction of the positive relationship between risk and expected return is known in the financial literature as *distress puzzle*.

The distress puzzle has been widely investigated in the context of corporate securities, by studying the relationship between default risk and expected stock return. The empirical evidence is far from being univocal (see, among others, Vassalou and Xing (2004), Campbell, Hilscher, and Szilagyi (2008), Friewald, Wagner, and Zechner (2014)). To the best of our knowledge, however, an analysis of the puzzle at the sovereign level is still missing. As countries do not issue equity, we focus on debt securities.

In our framework, the positive risk-return relationship implies that a riskier country should issue debt securities that pay out higher yields. Indeed, we observe a positive monotonic relationship between CDS spreads, the price of default risk, and bond yields. However, monotonicity is only a necessary but not sufficient condition for the consistent relationship between risk and return to hold. A riskier security should not only generate higher expected return, compared to a less risky security, in order to attract investors. The riskier security, in fact, should generate an expected return that is also sufficiently higher, that is the difference with respect to the expected return generated by the less risky security should be consistent with the difference in terms of risk across the two securities. Only a consistent difference, then, compensates properly the investor for that particular higher level of risk associated to the riskier security.

In our framework, this relationship implies that a riskier country should pay out bond yields that are higher enough with respect to a safer country, where the difference in terms of bond yields should be then consistent with the difference in terms of default risk priced in the corresponding CDS spreads. We show that an inconsistent cross-sectional relationship between CDS spreads and bond yields emerges during the crisis period for the Eurozone countries, and then is restored after the announcement of the OMT programme. Therefore, while the deviation from the zero-basis equilibrium condition does not affect the monotonicity in the cross-sectional relationship between CDS spreads and bond yields, it generates inconsistency in the cross-section of the bond yields across countries, with respect to the differences in terms of default risk priced in the CDS spreads. In other words, the differences across countries in terms of default risk, priced in the CDS spreads, are not consistently priced in the cross-section of the bond yields.

To determine the proper distance between bond yields across countries, we adopt a contingent claim model. In the model, in fact, bond and CDS are implicitly related at each point in time, as both the securities are derivative contracts on the same underlying quantity, that are the assets and the liabilities of the reference entity. In particular, we adopt a first-passage time model, where the issuer defaults as soon as the value of the assets crosses from above a default boundary, assumed to be deterministic and constant. This framework is an extension of the seminal model of Merton (1974), where the issuer may default only at the maturity of the liability. Gapen, Gray, Lim, and Xiao (2011) introduce contingent claims analysis to study sovereign credit risk, by using a Merton model.

Hence, the default risk of the country is priced in the CDS spread, where the default risk is due to the probability that the leverage of the country, defined as debt-to-asset ratio, reaches a given threshold, to be estimated, that is unsustainable. Then, there is a one-to-one mapping between leverage and CDS spread, where the model provides the specific functional form of the mapping.

We estimate the model with a non-linear Kalman filter in conjunction with maximum likelihood, by using daily data on CDS spreads over three different time horizons, i.e. 1,5, and 10 years. We reconstruct the dynamics of the market value of the leverage for each country, and we estimate the value of the default boundary. Sovereign assets include current and future surpluses, international reserves, and residual items (see Gapen et al. (2011)). With the estimated parameters, we are then able to compute the bond yields implied by the model estimation using Monte Carlo (MC) simulations. These are the yields implied by the

CDS spreads, as we use the observed CDS spreads to estimate the model parameters, and to reconstruct the dynamics of the leverage of each country. Then, we use the relationship between bond yields and leverage, defined by the model, in order to compute the implied bond yields.

Moreover, we corroborate our results with a portfolio analysis based on the difference between the observed and the implied bond yields, and we show again that arbitrage opportunities are large and persistent before the announcement of the OMT across all European countries, and then converge to zero after the OMT announcement for the Eurozone countries only. On the other hand, the arbitrage opportunities do not disappear even after the OMT announcement for the European countries out of the Eurozone.

Finally, we conjecture that the persistent arbitrage opportunities before the OMT announcement were created by high transaction costs. Therefore, we estimate for each country the threshold below which the arbitrage strategies generate profits that are not even sufficient to cover the costs to be implemented. The idea is that arbitrageurs step into the market only if the arbitrage strategy still generates profits once that the transaction costs have been paid. We show that, before the OMT announcement, the arbitrage opportunities are not cleared because of high transaction costs. Then, we estimate a strong reduction in the transaction costs for the Eurozone countries only, following the ECB intervention. As a consequence, the arbitrage opportunities are cleared, and the equilibrium condition in the Eurozone sovereign debt market is restored. However, we do not estimate a similar reduction in the transaction costs for the No Eurozone countries. Therefore, we observe for those countries a persistent CDS spread - bond yield mispricing even after the OMT announcement.

Our paper is organized as follows. We first describe the data in the next section, then we provide empirical evidence on the relationship between CDS spreads and bond yields during and after the OMT announcement, in section 3. In section 4, we focus on the cross-sectional analysis of CDS spreads and bond yields. We detail the underlying credit risk model and our estimation methodology to compute the implied bond yields. Then, we compare observed and implied yields, and we perform the cross-sectional correlation analysis between CDS spreads and bond yields. Finally, we estimate the transaction costs, before and after the OMT announcement, and we compare such costs with the arbitrage profits, in section 5. Section 6 concludes the paper.

2. Data

Our main source of data is Thomson Reuter's DataStream. We download daily data for sovereign CDS spreads and sovereign government bond yields for several European countries, and a sample period going from the 4^{th} January 2010 to the 1^{st} February 2017. Hence, we collect a time series of 1850 daily observations for each country, for both CDS spreads and bond yields, and for three time horizons: 1,5, and 10 years maturity. Datastream provides reference par yields for sovereign bonds at different maturities. The par yield is the internal rate of return (yield to maturity) of a bond traded at par, and it is expressed as an annualized figure. Instead, the CDS spread is expressed in basis points, and represents the percentage of the CDS notional value that the protection buyer must pay, usually at quarterly frequencies, to the protection seller. CDS spreads are also expressed in annualized terms.

We use all the maturities of the CDS spreads to implement the estimation methodology, however we focus throughout the paper on the 5-years maturity in order to show the results of the empirical analysis. We also collect data on the Euribor to represent the European short term risk-free interest rate curve. At longer maturities we proxy the risk-free rate with the euro area yield curve computed exclusively on AAA-rated central government bonds, and we also use a Nelson-Siegel technique to bootstrap the maturities of the risk-free curve needed to obtain the present values of CDS that we use in the arbitrage strategies.

We apply a filter to the sample, excluding those countries which report an excessive number of missing data on bond yields or CDS spreads -more than 40% of the total observations for at least one maturity- thus dropping from the sample Cyprus, Luxembourg, and Malta. We also exclude Greece that deserves a specific analysis due to the dramatic turbulence experienced during the sample period. We drop from the sample Estonia, Latvia and Lithuania, as these countries change their status from Non-Eurozone to Eurozone over the sample period. We end up with a final sample of 22 countries. In particular, 12 countries belong to the Eurozone, and 10 are out of the Eurozone. Throughout the analysis, we also divide the sample of the Eurozone countries in two subgroups: core, and periphery. The list of countries is reported in table I

2.1. Descriptive Statistics

In table I we report data on CDS spreads and bond yields for each single country in the sample. Table I shows that both bond yields and CDS spreads are significantly lower after the announcement of the OMT Programme by ECB governor Mario Draghi on July 26^{th}, 2012. The differences are significant at 5% level (except for the CDS in Slovenia), when considering both mean and median.

In table II we report statistics on the time series of mean and median across countries, before and after July 2012. We also provide a breakdown of mean and median by different groups of countries. Therefore, we observe that bond yields and CDS spreads are generally lower for the core countries with respect to both the peripheral and the No Eurozone countries, before and after the OMT announcement. Yet, the reduction in both spreads and yields is significant at 5% level even for the core countries.

3. The CDS - Bond basis

In this section, we analyse the theoretical equilibrium condition between CDS spreads and bond yields, for each European country, over the time series. CDS spreads and the yields on a risky bond, issued by the reference entity of the CDS contract, are strictly related. The CDS provides protection to the acquirer in case of default of the reference entity, while the bond pays out yields to the bondholder as long as the reference entity is able to comply with its obligations. In particular, Hull et al. (2004) have pointed out that, under a large set of assumptions, the T-years CDS spread should be equal to the T-years excess yield on a risky

Table I. Descriptive Statistics by Country

Statistics:	CDS Spreads			Bond Yields		
Mean	B/OMT	A/OMT	Diff	B/OMT	A/OMT	Diff
Eurozone						
Core:						
Austria	78.19	20.22	-57.97*	3.14	1.21	-1.93*
Belgium	143.11	33.93	-109.19*	3.77	1.44	-2.33*
Finland	46.50	24.74	-21.76*	2.79	1.14	-1.65*
France	83.17	31.86	-51.31*	3.13	1.37	-1.76*
Germany	39.15	12.58	-26.57*	2.48	0.93	-1.55*
Netherlands	67.26	31.74	-35.53*	7.63	2.31	-5.31*
Peripheral:						
Ireland	485.07	80.00	-405.07*	4.94	2.81	-2.13*
Italy	229.15	138.40	-90.75*	2.80	1.15	-1.65*
Portugal	633.77	247.09	-386.67*	8.85	4.35	-4.49*
Slovakia	136.00	61.90	-74.10*	4.18	1.89	-2.29*
Slovenia	164.69	168.27	3.58	5.10	2.90	-2.20*
Spain	243.27	115.66	-127.62*	5.62	3.07	-2.55*
No-Eurozone						
Bulgaria	258.99	130.61	-128.39*	6.53	4.28	-2.25*
Croatia	316.38	274.95	-41.43*	3.72	1.30	-2.41*
Czech Republic	98.95	49.67	-49.28*	2.56	1.08	-1.48*
Denmark	60.44	17.83	-42.61*	7.86	4.66	-3.20*
Hungary	353.35	191.21	-162.14*	6.75	6.36	-0.39*
Norway	26.58	16.23	-10.35*	5.17	3.85	-1.32*
Poland	160.49	71.75	-88.74*	5.51	2.47	-3.04*
Romania	301.57	145.09	-156.47*	3.01	1.98	-1.02*
Sweden	36.48	12.96	-23.52*	5.79	3.45	-2.34*
UK	65.54	27.81	-37.73*	7.51	4.49	-3.02*

The table reports the mean over time of the sovereign CDS spreads and bond yields, for each country, across the periods before (January 1, 2010 - July 25, 2012) and after (July 26, 2012 - February 1, 2017) the OMT announcement date. The CDS spreads are expressed in basis points, the bond yields are expressed in percentage terms. The third column is the difference between the two periods. The * indicates that the difference is significant at the 5% level.□

bond, issued by the reference entity, over the T-years riskless bond.

The reason is simple: if the assumptions listed by Hull et al. (2004) hold, a portfolio including a T-years CDS and a T-years par yield bond, issued by the reference entity, generates cash flows equal to a T-years par yield riskless bond in all states of the world, and

Table II. Descriptive Statistics by Asset

	Average of Means			Average of Medians		
	B/OMT	A/OMT	Diff	B/OMT	A/OMT	Diff
All Sample:						
CDS	183.10	86.57	-96.53*	125.70	52.40	-73.30*
Yields	4.95	2.66	-2.29*	4.70	0.24	-4.45*
Countries Group:						
Eurozone-Core						
CDS	73.23	25.84	-50.39*	70.57	26.24	-44.33*
Yields	3.82	1.40	-2.42*	3.13	0.13	-3.01*
Eurozone-Periphery						
CDS	315.33	135.22	-180.11*	239.24	125.14	-114.10
Yields	5.25	2.69	-2.55*	4.84	0.27	-4.58*
No-Eurozone						
CDS	167.88	93.81	-74.07*	129.99	60.74	-69.24*
Yields	5.44	3.39	-2.05*	5.84	0.36	-5.48*

The table reports statistics of the sovereign CDS spreads and bond yields, before (January 1, 2010 - July 25, 2012) and after (July 26, 2012 - February 1, 2017) the OMT announcement date, and the relative difference, across all countries and the three groups of countries. The "Average of Means" is computed as mean over time of the cross-sectional average CDS spreads and bond yields, across countries. The "Average of Medians" is computed as mean over time of the cross-sectional median CDS spreads and bond yields, across countries. The CDS spreads are expressed in basis points, the bond yields are expressed in percentage terms. The * indicates that the difference is significant at the 5% level.□

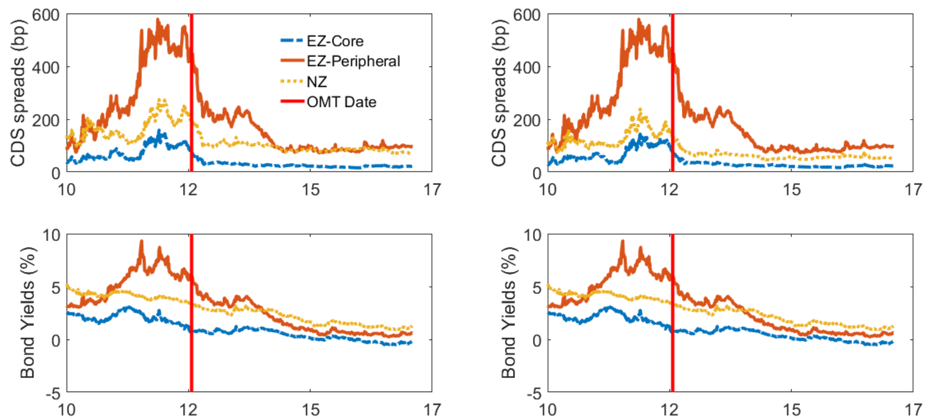
so

$$s = y - r, \tag{1}$$

where s is the T-years CDS spread, y is T-years yield on the risky bond, and r is the T-years yield on the riskless bond. The *basis* is the difference between the T-years CDS spread and the T-years excess yield on a risky bond, issued by the reference entity, over the T-years riskless bond. Hence, in equilibrium, the basis must be equal to zero. If the basis is different from zero, then an arbitrage opportunity arises in the market by trading CDS, risky bond, and riskless asset.

Therefore, the basis is a straightforward signal to detect a relative mispricing between

Figure 1. CDS spreads and Bond Yields



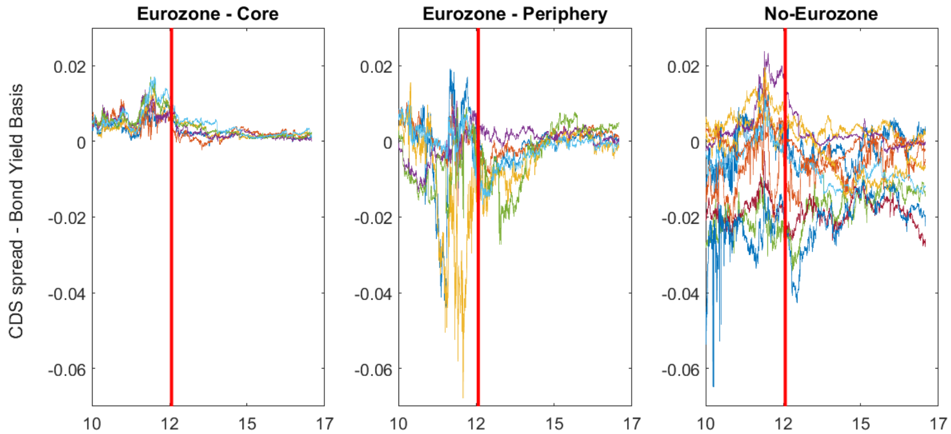
The figure reports the mean and the median across countries for the sovereign CDS spreads and bond yields, between the 1^{st} January 2010 and the 1^{st} February 2017, at the 5-years maturity, for three different groups of countries: Eurozone-Core (blue line), Eurozone-Peripheral (red line), and No-Eurozone (yellow line). The CDS spreads are expressed in basis points, the bond yields are expressed in percentage terms. The red line is the OMT announcement date.□

CDS spreads and bond yields for a given country, that can be analysed by simply using observed data. We group our sample countries in three sub-samples: Eurozone-Core (EC), Eurozone-Peripheral (EP), and No-Eurozone (NZ). Figure 2 shows the dynamics of the basis for each country. The core countries have basis substantially lower than both the peripheral and the No Eurozone countries. More importantly, the basis of both core and peripheral countries of the Eurozone converge to zero right after the OMT announcement, and then remains around zero over the following years. The No Eurozone countries, instead, do not show the same convergence in terms of basis, and appear to be spread around zero, before and after the OMT announcement.

This result is also evident looking at the average of the absolute basis across groups of countries. Table III reports that the absolute basis has substantially reduced for the Eurozone countries in the second period of the time series(-65% for the EC, -55% for the EP, respectively), while the decrease is much lower for the NZ countries (-10%).

This empirical observation provides evidence on the disequilibrium between CDS spreads and bond yields for all the European countries before the OMT announcement, that persists

Figure 2. CDS spreads - Bond Yields basis



The figure reports the CDS spread - Bond Yield basis for each country, between the 1^{st} January 2010 and the 1^{st} February 2017, at the 5-years maturity, for the three different groups of countries. The names of the countries belonging to each group are provided in Table I. The basis is expressed in percentage terms. The red line is the OMT announcement date.□

Table III. Average Absolute Basis (CDS Spreads - Bond Yields)

	Euro - Core	Euro - Periphery	No Eurozone
Before OMT	0.0063	0.0078	0.105
After OMT	0.0022	0.0036	0.090

The table reports the average CDS Spreads - Bond Yields basis across countries, for the three groups of countries, before (January 1, 2010 - July 25, 2012) and after (July 26, 2012 - February 1, 2017) the OMT announcement date. The basis is expressed in percentage terms. Both CDS spreads and bond yields are at 5-years maturity.□

even after the OMT announcement for the No Eurozone countries only. This deviation from the equilibrium condition should generate arbitrage opportunities in the market, before the OMT announcement, for all countries in the sample. The potential riskless profits should then disappear, only for Eurozone countries, after the OMT announcement date. Next, we compute the potential profits obtained by exploiting the violation of the no arbitrage condition.

3.1. Arbitrage strategy

First, we recall the definition of the no-arbitrage condition, obtained from the definition of the CDS spread - bond yield basis.

$$s = y - r, \tag{2}$$

If this relationship does not hold, then an arbitrage opportunity arises in the market by trading CDS, risky bond, and the riskless asset, under the set of assumptions exhaustively explained in Hull et al. (2004). Here, we report only the most relevant assumptions that support the flow of our argument.

1. Market participants can short sovereign bonds
2. Market participants can short the risk-free bond (they can borrow money at the risk-free rate)
3. The "cheapest-to-deliver bond" option is ruled out, so that the profit is not affected by the ability of the protection seller to find a cheaper bond to deliver in case of default
4. The recovery rate of the bond in case of default is equal to zero

We express all the variables in monetary terms, thus computing the present value of the CDS, the risk-free bond, and the risky bond, by using continuous compounding, such that the no-arbitrage condition can be rewritten as follows

$$P_{CDS} = P_{BY} - P_{RF},$$

where P_{CDS}, P_{BY}, P_{RF} denote the present value of the CDS, the risky bond, and the riskless bond respectively, and we omit the subscripts i and t to save in notation.

The arbitrage strategy is then based on the CDS spread - bond yield basis. When such relationship is not in equilibrium, then it is a signal that an arbitrage opportunity is coming on the market. Suppose that for the i-th country, at time t,

$$P_{CDS} > P_{BY} - P_{RF}$$

then the arbitrageur can sell the risk-free asset, and purchase the CDS and the risky bond issued by the CDS reference entity. The mispricing of the bond generates a positive difference that is exactly the risk-free arbitrage profit. Conversely, if

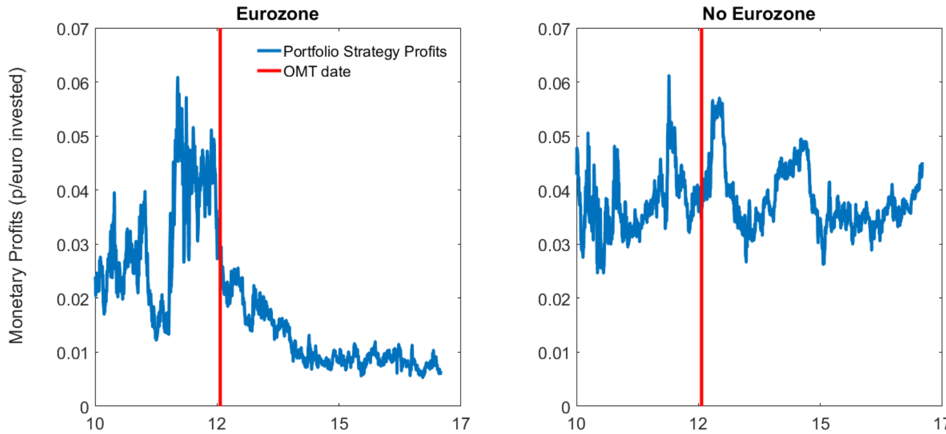
$$P_{CDS} < P_{BY} - P_{RF}$$

the arbitrageur obtains the same arbitrage profit by reversing the strategy. In practice, the arbitrageur purchases the risk free asset, and sells the mispriced risky bond and the CDS to obtain the risk-free profit.

Figure 3 shows the arbitrage profits generated by a portfolio equally weighted in terms of countries. The left panel shows the profits that an arbitrageur can obtain by trading assets of the Eurozone countries, while the right panel shows the potential profits by trading assets of the No Eurozone countries. The profits are large and volatile before the OMT announcement in both the Eurozone and No Eurozone areas. After the announcement, however, the profits drop immediately, and start to converge to zero, for the Eurozone countries. Instead, the riskless profits remain positive and volatile for the countries outside the Eurozone.

Finally, table IV reports the mean and the standard deviation of the potential profits obtained with the arbitrage strategy, before and after the OMT announcement, and for the Eurozone and the No Eurozone countries, respectively. Table IV reports the results for the Eurozone countries, and shows a pronounced difference in the average profits between the two subperiods. Further, the standard deviation drops sensibly after the announcement. Such numbers indicate that after the OMT announcement the arbitrage opportunities are approximately zero, or immediately cleared. Instead, for the No Eurozone area, table IV reports similar figures for mean and standard deviation, across the periods before and after the OMT announcement. All the differences reported, in fact, are not statistically different

Figure 3. Arbitrage Profits - Strategy 1



The figure shows the arbitrage profits on an equally weighted, across countries, portfolio of sovereign CDS and bonds, using the portfolio strategy 1, between the 1^{st} January 2010 and the 1^{st} February 2017. The strategy is implemented using either Eurozone sovereign CDS and bond only (left panel), or No-Eurozone sovereign CDS and bond only (right panel). The profits are expressed in monetary terms assuming nominal value of 1 for the bonds, and where the CDS price is computed as present value of the CDS spreads expressed in percentage terms. The red line stands for the OMT announcement date.□

from zero.

Therefore, consistently with the empirical evidence on the dynamics of the basis over the European countries, we observe that potential arbitrage profits are large and persistent for all the sample countries before the OMT announcement, then they quickly converge to zero for the Eurozone countries only. Instead, even after the OMT announcement, we do not observe any difference in the potential arbitrage profits by trading assets of the No Eurozone countries.

4. Cross-Sectional Analysis

The previous section analyses the dynamics of the relationship between CDS spreads and bond yields over time, for each country, and highlights the deviations from the equilibrium condition along the sample time series for the European countries. However, our main target is to investigate the consistency of the relationship between CDS spreads and bond yields of

Table IV. Arbitrage Profits - Strategy 1

Statistic:	Before OMT	After OMT	Difference
Eurozone			
Mean	0.034	0.014	-0.020*
Std. Dev.	0.012	0.005	
No Eurozone			
Mean	0.036	0.036	-0.000
Std. Dev.	0.006	0.006	

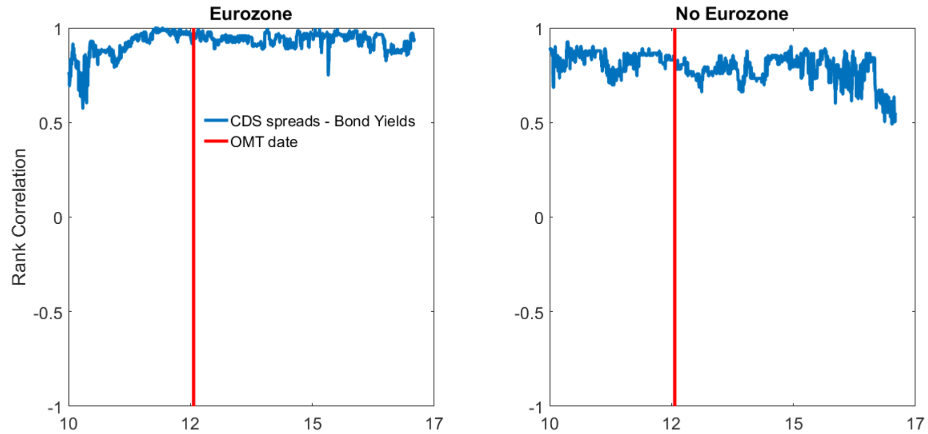
The table reports the mean and the standard deviation of the profits on an equally weighted, across countries, portfolio of sovereign CDS and bonds, using the portfolio strategy 1, before (January 1, 2010 - July 25, 2012) and after (July 26, 2012 - February 1, 2017) the OMT announcement date. The strategy is implemented using either Eurozone sovereign CDS and bond only, or No-Eurozone sovereign CDS and bond only. In the last column we report the difference across the two periods. The * indicates that the difference is significant at 5% level.□

European countries over the cross-sectional dimension.

A consistent relationship implies that a riskier country should issue debt securities that pay out higher yields, and therefore we should observe a monotonic positive relationship between CDS spreads, the price of default risk, and bond yields. We use the Spearman correlation coefficient, that evaluates the rank correlation, to perform our analysis. If a positive monotonic relationship between CDS spreads and bond yields exists, in fact, then the rank correlation between CDS spreads and bond yields is equal to one, over the cross-section of countries, for a given point in time.

Figure 4 shows that the correlation between CDS spreads and observed yields is close to 1, over the all time series, and for both groups of countries. This result implies that the relationship between CDS spreads and observed yields is monotonically positive, and so the riskier countries, in terms of default risk priced in the CDS spreads, pay out higher bond yields with respect to the safer countries. Therefore, this result suggests that the deviation from the equilibrium condition of zero CDS spread - bond yield basis, over the time series, documented in the previous section, does not affect the monotonic relationship between CDS spreads and bond yields over the cross-sectional dimension across countries. That is, even when the CDS spreads - bond yields basis for the single countries are far from zero, the

Figure 4. CDS spreads - Bond Yields. Cross-sectional correlations



The plots show the cross-sectional rank correlation between sovereign CDS spreads and bond yields, at the 5-years maturity, between the 1^{st} January 2010 and the 1^{st} February 2017, across Eurozone (left panel) and No-Eurozone countries (right panel). The red line is the OMT announcement date.□

cross-sectional monotonic relationship between CDS spreads and observed bond yields still holds.

However, the cross-sectional monotonicity between CDS spreads and bond yields is only the necessary but not sufficient condition for a consistent relationship. A riskier country, in fact, should pay out bond yields that are not only higher than the bond yields paid out by a safer country, but that are also sufficiently higher in order to compensate properly the bondholder for bearing that particular higher level of risk. In practice, the difference in terms of bond yields should be large enough to be consistent with the difference in terms of default risk priced in the corresponding CDS spreads. To perform this analysis, we examine the rank correlation, over the cross-section of countries, between CDS spreads and net yields. The net yield is simply the difference, for each point in time, and each country, between the actual observed bond yield and the bond yield implied by the CDS spreads, that is the unobservable yield implied by a given level of default risk priced in the CDS spreads of the country.

The idea behind the analysis of the relationship between CDS spreads and net yields should be clear with a simple numerical example. Let consider two countries, A and B, and suppose that the CDS spread of A is larger than the CDS spread of B, that is A is risker than B. Let suppose then the observed yields are $Y(A) = 0.1$ and $Y(B) = 0.05$, respectively. It turns out that country A is paying out a higher yield, and therefore the monotonicity condition between CDS spreads and bond yields is verified. However, is $Y(A)$ higher enough to compensate the bondholders for the higher risk associated to the country A? Let suppose that the yields implied by the CDS spreads, for the two countries, are $I(A) = 0.15$ and $I(B) = 0.02$, respectively. Then, let compute the net yields, that are $N(A) = -0.05$ and $N(B) = 0.03$.

The first consequence is that the bond of country A is overvalued, that is the actual yield is lower than what the yield should be for that level of default risk, and then the price of the bond is larger than what the price should be for that level of default risk. On the other hand, the bond of country B is undervalued. Moreover, the monotonicity condition between CDS spreads and net yields is not verified, thus signaling that the difference between the observed bond yields across the two countries is not consistent with the difference in terms of default risk. The riskier country A, in fact, is paying out a bond yield that does not compensate an investor for bearing that particular higher level of risk, compared with the safer country B, reflected in the difference between the CDS spreads of the two countries.

We compute the implied bond yields, for each country, by estimating a contingent claim model. In particular, we adopt a first-passage time model, where the issuer defaults as soon as the value of the assets crosses from above a default boundary, assumed to be deterministic and constant. Next, we detail the underlying model, the model estimation procedure and results. Then, we describe the Monte Carlo simulations approach that we perform to obtain the implied bond yields, and we compare the implied bond yields with the observed bond yields. Finally, in this section, we implement the cross-sectional correlation analysis between CDS spreads and bond yields, by using both the observed and the implied bond yields. We also corroborate our findings with a portfolio analysis based on the arbitrage strategy described in the previous section.

4.1. Underlying Model

The asset value of the i-th country is described by a geometric Brownian motion on the filtered probability space $(\Omega, \mathcal{F}, \{\mathcal{F}_t : t \geq 0\}, \mathcal{P})$:

$$dV_{i,t} = \mu_{V_i} V_i dt + \sigma_{V_i} V_i dW_{i,t},$$

where μ_{V_i} and σ_{V_i} are the $\mathcal{P}$-drift and diffusion constant coefficients, $W_{i,t}$ is a standard Brownian motion under the physical probability measure $\mathcal{P}$.

We define the i-th market value of leverage as $L_{i,t} = \ln\left(\frac{F_i}{V_{i,t}}\right)$, following an arithmetic Brownian motion,

$$dL_{i,t} = \mu_{L_i} dt - \sigma_{L_i} dW_{i,t}, \tag{3}$$

where $\mu_{L_i} = -\left(\mu_{V_i} - \frac{1}{2}\sigma_{V_i}^2\right)$ is the $\mathcal{P}$-leverage drift coefficient, and $\sigma_{L_i} = \sigma_{V_i}$ is the leverage diffusion component. As result of the inverse relationship between the asset and the leverage values, the minus before the diffusion component stands for the perfect negative correlation between the Brownian motions of the asset value and the leverage dynamics.

In the first-passage time framework, default occurs as soon as the asset value crosses from above a constant and deterministic barrier C_i, that we assume to be below the face value of the debt, at any time s, with $t \leq s \leq T$, where T is the outstanding debt maturity. The country's default risk is priced in the credit default swaps (CDS) issued with different maturity τ_j, with j going from 1 to J, where the longest maturity τ_J matches the debt maturity T. In a CDS contract, the protection buyer pays a fixed premium each period until either the default event or the contract expiration, and the protection seller is committed to buy back from the buyer the defaulted bond at its par value.

Therefore, the price of the CDS, i.e. the premium (the spread) paid by the insurance buyer, is defined at the inception date of the contract in order to equate the expected value of the two contractual legs. Then, by assuming the existence of a default-free money market account appreciating at a constant continuous interest rate r, and M periodical payments occurring during one year, the CDS spread γ with time-to-maturity τ_j, priced at $t = 0$, solves the following equation:

$$\sum_{m=1}^{M} T\frac{\gamma}{M}\exp\left(-r\frac{m}{M}\right)\mathcal{E}_0^{\mathcal{Q}}[1_{t^*>\frac{m}{M}}] = \mathcal{E}_0^{\mathcal{Q}}[\exp(-rt^*)\alpha 1_{t^*<\tau_j}],$$

where t^* stands for the time of default, α is the amount paid by the protection seller to the protection buyer in case of default, and $\mathcal{E}_0^{\mathcal{Q}}$ indicates that the expectation is taken under the risk-neutral measure $\mathcal{Q}$. Therefore, $\mathcal{E}_0^{\mathcal{Q}}[1_{t^*<\tau_j}]$ is the probability that the country defaults at any time before τ_j, that is the probability that the asset value crosses from above the barrier C_i. At t, this probability is equal to:

$$PD_{i,t}^{\mathcal{Q}}(\tau_j) = \Phi\left(\frac{K_i + L_{i,t} - \left(r - \frac{1}{2}\sigma_{L_i}^2\right)(\tau_j - t)}{\sigma_{L_i}\sqrt{(\tau_j - t)}}\right) + \exp\left((K_i + L_{i,t})\left(\frac{2r}{\sigma_{L_i}^2} - 1\right)\right)\Phi\left(\frac{(K_i + L_{i,t}) + \left(r - \frac{1}{2}\sigma_{L_i}^2\right)(\tau_j - t)}{\sigma_{L_i}\sqrt{(\tau_j - t)}}\right), \quad (4)$$

if $\tau_j < T$, otherwise

$$PD_{i,t}^{\mathcal{Q}}(\tau_J) = 1 - \Phi\left(\frac{-L_{i,t} + \left(r - \frac{1}{2}\sigma_{L_i}^2\right)(\tau_J - t)}{\sigma_{L_i}\sqrt{(\tau_J - t)}}\right) + \exp\left((K_i + L_{i,t})\left(\frac{2r}{\sigma_{L_i}^2} - 1\right)\right)\Phi\left(\frac{(2K_i + L_{i,t}) + \left(r - \frac{1}{2}\sigma_{L_i}^2\right)(\tau_J - t)}{\sigma_{L_i}\sqrt{(\tau_J - t)}}\right), \quad (5)$$

as $\tau_J = T$, and we have to consider not only the early bankruptcy risk as in the equation (3), but also the probability of the country not being able to pay back the outstanding debt F_i at time T, even though the asset value never crossed the default boundary.

Φ stands for the cumulative distribution function of a standard normal variable, and $K_i = \ln\left(\frac{C_i}{F_i}\right)$. As the default barrier is below the face value of the debt, K_i assumes only negative values. The larger is the magnitude of the absolute value of K_i, the larger is the distance between the face value of the debt F_i and the default barrier C_i.

4.2. Estimation Methodology

The procedure that we adopt to estimate the model is the following: first, we reconstruct the unobservable dynamics of the leverage, defined as debt-to-asset ratio, for each country, by performing a non-linear Kalman filter, and using the CDS spreads as observable variables. The Kalman filter enables to retrieve the dynamics of a latent variable, by using an observable variable and the ex-ante known relationship between the two variables. The relationship between the observed and the unobserved variables forms the *measurement equation*, while the evolution over time of the latent variable is called *transition equation*. We estimate the model parameters by adopting a quasi-maximum likelihood algorithm, in conjunction with the Kalman filter. Details of the estimation methodology are provided in Appendix **??**.

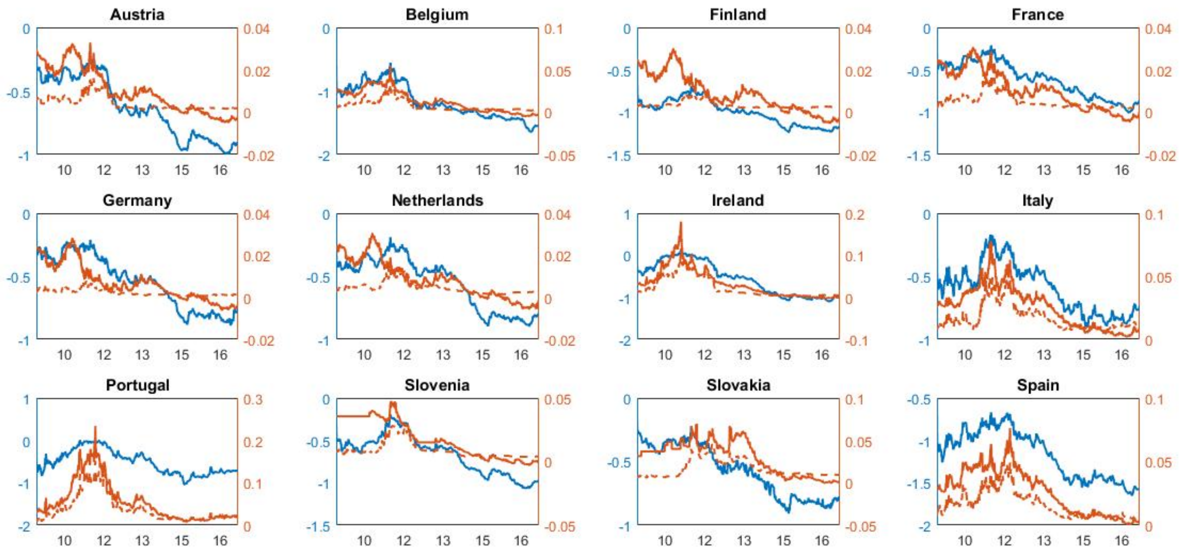
We formulate our problem in a state-space model, where the measurement equations come from (4)-(5). The noise terms associated with the CDS implied-default probability for different time to maturities τ_j are assumed to be uncorrelated, and with equal variance.

$$PD^{\mathcal{Q}}_{i,t}(\tau_j) = g\left(L_{i,t}; K_i, \sigma_{L_i}\right) + \epsilon_{i,t}(\tau_j), [j = 1, 5, 10]$$

where the time to maturity is expressed in years, and $j = 10$ stands for the maturity T of the outstanding debt F_i (i.e., 10 years). The function g defines the non-linear relationships between the observable and the latent variable, and $\epsilon_{i,t}(\tau_a)$ is the measurement noise associated with the CDS implied-default probability equation and the time horizon j. These four measurement noises, for each country i, are assumed to follow a multivariate normal distribution, with zero mean, and diagonal covariance matrix R_i. We assume a homoscedastic covariance matrix, which is country-varying.

On the other side, the transition equation describes the evolution of the country's leverage. It follows from the discretization of the stochastic process defined in (2):

Figure 5. Leverage, CDS spreads and Bond Yields. Eurozone Countries



The plots show the Eurozone countries' leverage (blue line), as defined in equation (3), reconstructed with the non-linear Kalman filter using the 5-years CDS spreads as observable variable, between the 1^{st} January 2010 and the 1^{st} February 2017. Moreover, we report the 5-years CDS spreads (dashed line) and the 5-years bond yields (red line) expressed in percentage terms.□

$$L_{i,t+\delta t} = L_{i,t} + \mu_{L_i}\delta t + \eta_{i,t+\delta t},$$

where $\eta_{i,t+\delta t} = \sigma_{L_i}(W_{i,t} - W_{i,t+\delta t}) \backsim \mathcal{N}(0, Q_i)$ is the transition error, and $Q_i = \sigma_{L_i}^2 \delta t$.

The dynamics of $L_{i,t}$, and the parameters of the model, such as the parameters of the leverage dynamics (μ_{L_i}, σ_{L_i}) and K_i, are then estimated by performing a non-linear Kalman filter in conjunction with quasi-maximum likelihood estimation.

Figure 5 provides an idea of the estimation results, thus comparing the reconstructed dynamics of the leverage, for the European countries, over the sample time series, against the observed dynamics of the 5-years CDS spreads and the 5-years observed bond yields. The dynamics of both CDS spreads and bond yields is in line with the dynamics of the country's leverage. When the CDS spreads and the bond yields approach to very low values, in particular in the last part of the time series, then we estimate a leverage that moves far away from zero, towards negative values.

4.3. Implied and Observed Bond Yields

We obtain the implied bond yields, for each point in time, and for each country, by performing a Monte Carlo simulations analysis. In particular, for each point in time t, and each country, we simulate the dynamics of the leverage for a time interval going from t to $t + M * 360$, where M is the maturity of the bond expressed in years. The leverage of a country is simulated by using the equation (3), where dt is a one-day step. The parameters of the stochastic process are the estimates obtained in the previous step, while we use the estimated leverage at time t as starting point of the simulated dynamics. We generate $M * 360$ normally distributed random numbers for each country to simulate the daily increment of the Brownian motion, thus finally obtaining a simulated dynamics of the leverage of length $M * 360$.

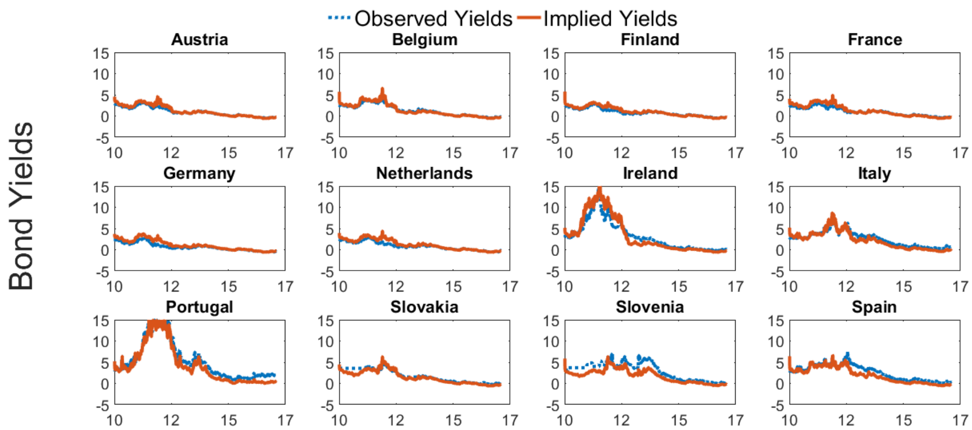
Then, we use the condition of default implied by the model. The country defaults if $V_{i,t} < C$, that corresponds to $L_{i,t} > (-K_i)$. Therefore, if the simulated leverage of the country is above $-K_i$, at least for one point in time over the entire time horizon, then we impose that the bond defaults and the t-value of the bond is zero. Otherwise, the t-value of the bond is equal to the risk-free discount factor, by using the risk-free rate at time t.

We then compute the bond price for each time t as average over 10000 simulations, and the corresponding yield by simple inversion. Let define B the price of the bond obtained with MC simulations, then the implied yield Y is equal to

$$Y = \log\left(\frac{1/B}{M * 360}\right)$$

The difference between observed and implied yields should be zero for each country, and each point in time, if the observed risky yields of a country are consistent with the default risk priced in the CDS spreads. Indeed, the maintained assumption behind this statement is that the model-implied yields are well estimated, and the model is able to fully capture

Figure 6. Implied versus Observed Yields. Eurozone



The plots show the observed (blue line) and the model-implied (red line) bond yields, at 5-years maturity, for the Eurozone countries, between the 1^{st} January 2010 and the 1^{st} February 2017. Bond yields are expressed in percentage terms. We compute the model-implied yields using the estimation methodology described in section 4.□

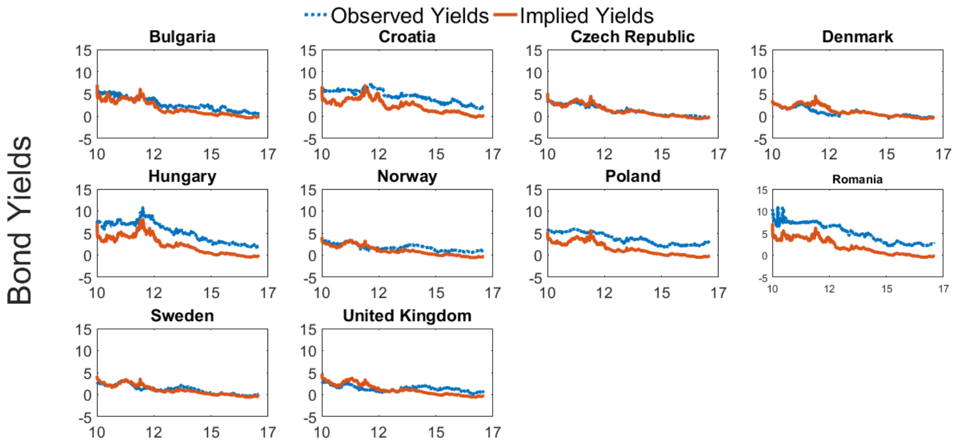
whatever drives the relationship between default risk and bond prices. With these caveats in mind, we compare observed and implied yields for each country, over the sample time-series.

Figures 6 and 7 show that the implied yields are generally closer to the observed yields for the Eurozone countries with respect to the No Eurozone countries. Within the Eurozone group (figure 3), we obtain implied yields that are very close to the observed yields for the core countries in the second part of the time series. At the opposite, the NZ countries show a persistent distance between implied and observed yields, over the all time series.

4.4. Correlations Analysis

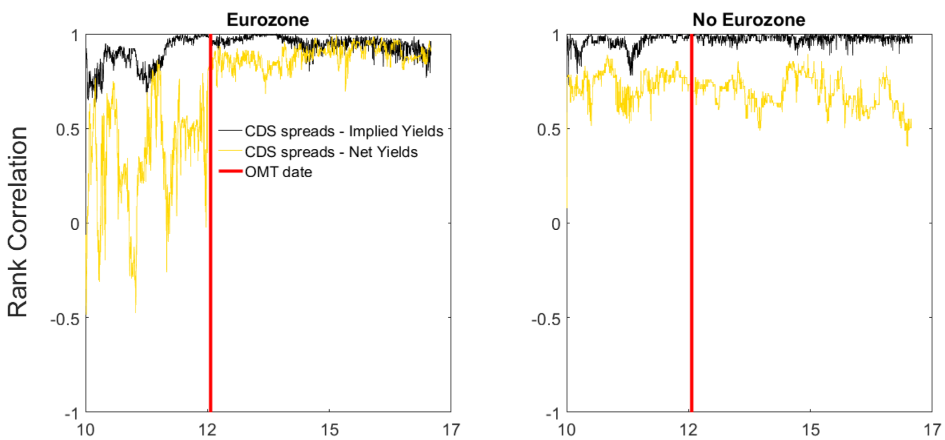
We now focus on the main result of the paper, by computing the cross-sectional correlation, for each point in time, between CDS spreads and the net bond yields, across our sample countries. We compute the Spearman correlation coefficient, over the time series, between CDS spreads and bond yields across the sample countries, by using the implied yields, and the net yields. The next figure represents graphically the main result of the paper. Figure 8 shows the dynamics of the cross-sectional correlations between the 5-years CDS spreads and the implied bond yields, and between the 5-years CDS spreads and the net

Figure 7. Implied versus Observed Yields. No Eurozone



The plots show the observed (blue line) and the model-implied (red line) bond yields, at 5-years maturity, for the No-Eurozone countries, between the 1^{st} January 2010 and the 1^{st} February 2017. Bond yields are expressed in percentage terms. We compute the model-implied yields using the estimation methodology described in section 4.□

Figure 8. CDS spreads - Net Yields. Cross-sectional correlations



The top plots show the cross-sectional rank correlation between sovereign CDS spreads and model-implied yields (black line), and between sovereign CDS spreads and net yields (yellow line) at 5-years maturity, across Eurozone (left panel) and No Eurozone countries (right panel), between the 1^{st} January 2010 and the 1^{st} February 2017. We compute the model-implied yields using the estimation methodology described in section 4, and we compute the net yields as difference between observed and model-implied yields. □

yields, for the Eurozone and the No-Eurozone countries, respectively. Moreover, we compute the corresponding p-values associated to the test on the statistical significance of the correlation.

Table V. Correlation CDS spreads - Bond Yields

	Eurozone			No Eurozone		
	Obs Yields	Imp Yields	Net Yields	Obs Yields	Imp Yields	Net Yields
Before OMT	0.883	0.938	0.367	0.956	0.895	0.737
	(0.003)	(0.000)	(0.275)	(0.000)	(0.002)	(0.026)
After OMT	0.951	0.927	0.885	0.978	0.818	0.683
	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.044)

The table reports the cross-sectional rank correlation between sovereign CDS spreads and observed bond yields, between sovereign CDS spreads and model-implied bond yields, and between sovereign CDS spreads and net yields at 5-years maturity, across Eurozone and No Eurozone countries, before (January 1, 2010 - July 25, 2012) and after (July 26, 2012 - February 1, 2017) the OMT announcement date. We compute the model-implied yields using the estimation methodology described in section 4, and we compute the net yields as difference between observed and model-implied yields. We report p-values in parentheses.□

The top plots show that the correlation between CDS spreads and implied yields is close to 1, over the whole time series, and for both groups of countries. This result is natural, since the implied yields are estimated by using the CDS spreads. Though, the correlation is not perfectly equal to 1, as the model is subject to an error, and because the yields are then generated by MC simulations still subject to an error.

More importantly, the yellow line in figure 8 shows the dynamics over time of the cross-sectional correlations between CDS spreads and net yields. The correlation randomly moves around zero for the Eurozone countries before the OMT announcement, and then approaches 1 right after the OMT announcement, thus remaining stable afterwards. It turns out that, before the OMT announcement, the cross-sectional differences across the sovereign bond yields of the Eurozone countries are not consistent with the cross-sectional differences in terms of default risk, and that right after the announcement this consistency is restored.

This result is even more interesting and stronger if we compare Eurozone and No Eurozone countries. In fact, the NZ countries do not show any change in the cross-sectional correlation between CDS spreads and net yields. The correlation, in fact, is quite stable over the whole time series, however never approaching 1.

Table V reports the average correlation, for the different measures of bond yields, across countries in each group, and within each time interval (before/after the OMT announcement). The average correlation between CDS spreads and both actual and implied yields is very close to 1 for both groups, and in each period. Instead, the average correlation across Eurozone countries between CDS spreads and net yields is more than double in the second period with respect to the first period, thus approaching 1. On the other side, this correlation is very similar across the two periods for the NZ countries, and is even lower after the OMT announcement.

4.5. Net yields and Arbitrage strategy

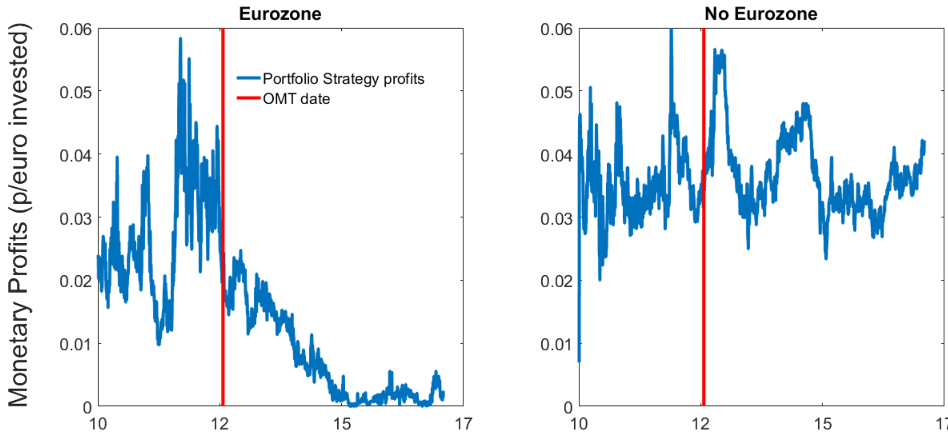
To corroborate our findings, we construct a portfolio strategy that produces riskless arbitrage profits, based on the net yields computed above. With this strategy, we exploit the deviation of the observed yields from the yields implied by the model estimates, that are then consistent with the default risk priced in the CDS spreads. For each point in time, we divide the sample countries between *undervalued*, when the net yield is positive, and *overvalued*, when the net yield is negative.

If the i-th country is undervalued, the arbitrageur can sell the risk-free asset, and purchase the CDS and the risky bond issued by the CDS reference entity. Otherwise, if the i-th country is overvalued, the arbitrageur purchases the risk free asset, and sells the mispriced risky bond and the CDS to obtain the risk-free profit.

The implementation of this strategy works exactly as for the former arbitrage strategy. The difference between the two strategies is only given by the signal that a riskless profit opportunity is coming on the market. While in the first strategy the signal is the zero-basis condition, in this strategy the signal is given by the distance between observed and implied yield.

In figure 9, we compare the potential profits obtained with the second strategy by trading on Eurozone and No Eurozone countries, respectively, with an equally weighted portfolio across countries. The profits plotted in figure 9 are very similar to those presented in fig-

Figure 9. Arbitrage Profits - Strategy 2



The figure shows the arbitrage profits on an equally weighted, across countries, portfolio of sovereign CDS and bonds, using the portfolio strategy 2, between the 1^{st} January 2010 and the 1^{st} February 2017. The strategy is implemented using either Eurozone sovereign CDS and bond only (left panel), or No-Eurozone sovereign CDS and bond only (right panel). The profits are expressed in monetary terms assuming nominal value of 1 for the bonds, and where the CDS price is computed as present value of the CDS spreads expressed in percentage terms. The red line stands for the OMT announcement date.□

ure 3. Arbitrage opportunities are persistent for both sets of countries before the OMT announcement, however they quickly converge to zero for the Eurozone countries after the announcement.

Finally, table VI report the mean and the standard deviation of the potential profits obtained with this arbitrage strategy, before and after the OMT announcement, and for the Eurozone and the No Eurozone countries, respectively. Table VI shows a pronounced difference in the average profits between the two subperiods for Eurozone countries. Further, the standard deviation drops sensibly after the announcement. Such numbers indicate that after the OMT announcement the arbitrage opportunities are approximately zero, or immediately cleared. Instead, for the No Eurozone area, table VI reports similar figures for mean and standard deviation, across the periods before and after the OMT announcement. All the differences reported, in fact, are not statistically different from zero.

Table VI. Arbitrage Profits. Strategy 2

Statistic:	Before OMT	After OMT	Difference
Eurozone			
Mean	0.029	0.003	-0.027*
Std. Dev.	0.012	0.005	
No Eurozone			
Mean	0.020	0.012	-0.008
Std. Dev.	0.013	0.017	

The table reports the mean and the standard deviation of the profits on an equally weighted, across countries, portfolio of sovereign CDS and bonds, using the portfolio strategy 2, before (January 1, 2010 - July 25, 2012) and after (July 26, 2012 - February 1, 2017) the OMT announcement date. The strategy is implemented using either Eurozone sovereign CDS and bond only, or No-Eurozone sovereign CDS and bond only. In the last column we report the difference across the two periods. The * indicates that the difference is significant at 5% level.□

5. Arbitrage and Transaction Costs

Arbitrage opportunities can persist in the market if the riskless profits are not sufficient to cover the costs to implement the arbitrage strategy. The idea is that arbitrageurs step into the market only if the arbitrage strategy still generates profits once that the transaction costs have been paid. Therefore, we control for transaction costs by estimating the threshold beyond which the riskless trading gains become sufficiently profitable.

We estimate a vector error correction model (VECM) that includes the CDS spreads and the bond yields in excess of the risk-free rate, for each country, adjusted for the nonlinearity due to the transaction costs threshold (TVECM). In a linear VECM, any deviation from the long-run equilibrium (zero-basis condition) would trigger trades leading the market back to the equilibrium. It turns out that in absence of frictions, such as transactions costs, we should observe a CDS-bond yield basis moving around zero. Instead, when frictions arise in the market, we expect to observe a persistent deviation from the equilibrium. In particular, with non-zero transaction costs, the deviation should persist as long as the magnitude of the deviation is below a given threshold, which introduces the nonlinearity in the error correction model.

Following Gyntelberg, Hördahl, Tersand, and Urban (2017), we model CDS spread and excess risky bond yields as follows, in vector form:

$$\Delta y_t = [\lambda^L ec_{t-1} + \Gamma^L(\ell)\Delta y_t]d_{Lt}(\beta,\theta) + [\lambda^U ec_{t-1} + \Gamma^U(\ell)\Delta y_t]d_{Ut}(\beta,\theta) + \epsilon_t,$$

where $ec_{t-1} = CDS_{t-1} - \beta_0 - \beta_1 ER_{t-1}$ is the error correction term, with ER standing for the excess risky bond yield, $\Gamma(\ell)\Delta y_t$ is the VAR term of order ℓ, and ϵ_t are white noise shocks. Moreover, d_{Lt} and d_{Ut} are defined as follows:

$$d_{Lt} = I(ec_{t-1} \leq \theta)$$

$$d_{Ut} = I(ec_{t-1} > \theta),$$

where I is an indicator function, and θ is the threshold to be estimated. We force β_1 equal to 1, and we estimate β_0. An estimate of β_0 different from zero stands for a persistent non-zero CDS-bond yield basis. Therefore, the average transactions costs faced by the arbitrageurs are given by $\theta + \beta_0$. We estimate the model following the approach of Hansen and Seo (2002), who estimate a two-regimes TVECM by using a maximum likelihood algorithm. Also, we estimate the model for the two time sub-samples, such as before and after the OMT announcement. As result, we obtain an estimate of the average transaction costs for each country, and for each time period.[1]

We find that, in general, the key threshold is substantially higher before the OMT announcement (the average transaction costs across countries is 922bp) with respect to the second period (384bp). This result is consistent with the findings of Gyntelberg et al. (2017), who estimate a threshold during the Eurozone sovereign debt crisis period more than twice higher with respect to the pre-crisis period. We also find that the core Eurozone countries have much lower average transaction costs in both the time periods (181bp before the OMT announcement, and 44bp after the OMT announcement). Moreover, we find that the drop

[1]The statistical significance of the thresholds is evaluated following the approach of Hansen and Seo (2002), who calculate standard errors by mean of both parametric and non-parametric bootstrap analysis. Gyntelberg et al. (2017) provide a short description of the two alternative bootstrap procedures, and the decision criterion for the threshold statistical significance

Table VII. Average Transaction Costs

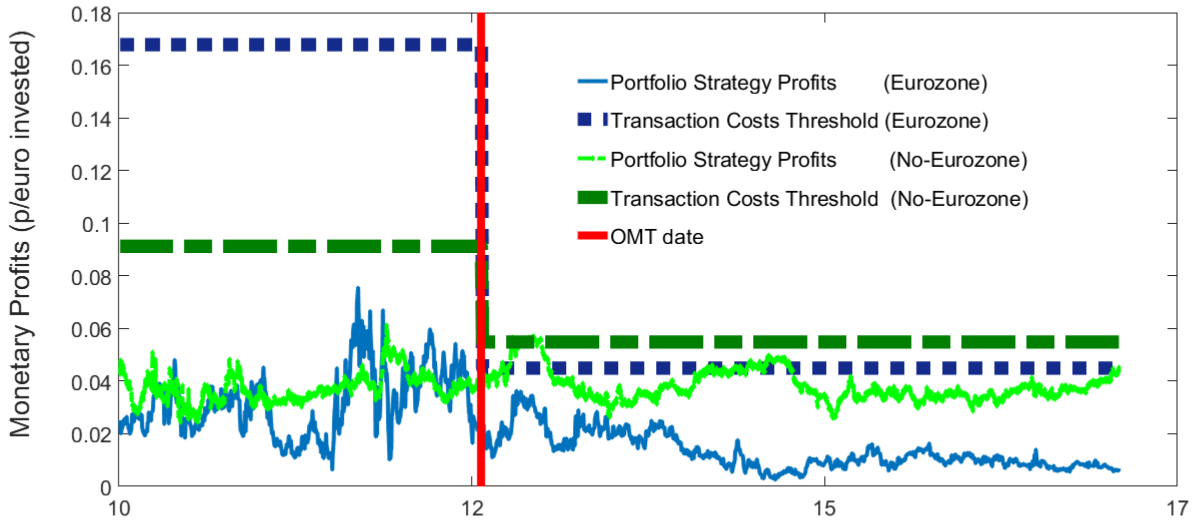
Countries	Before OMT	After OMT	% Diff
Austria	0.0152	0.0025	-83
Belgium	0.0468	0.0073	-84
Finland	0.0105	0.0036	-66
France	0.0131	0.0060	-54
Germany	0.0133	0.0013	-90
Netherlands	0.0098	0.0059	-40
Average Core	**0.0181**	**0.0044**	**-75**
Ireland	0.2466	0.0312	-87
Italy	0.1255	0.0508	-59
Portugal	0.4179	0.0897	-78
Slovakia	0.0723	0.0131	-81
Slovenia	0.0321	0.0368	+14
Spain	0.1123	0.0479	-57
Average Peripheral	**0.1678**	**0.0449**	**-73**
Average Eurozone	**0.0930**	**0.0247**	**-73**
Bulgaria	0.1132	0.0542	-52
Croatia	0.1958	0.1161	-40
Czech Republic	0.0303	0.0084	-72
Denmark	0.0152	0.0044	-71
Hungary	0.2156	0.0975	-54
Norway	0.0111	0.0407	+268
Poland	0.1170	0.0789	-32
Romania	0.2012	0.1034	-48
Sweden	0.0070	0.0109	+56
United Kingdom	0.0057	0.0340	+495
Average No Eurozone	**0.0912**	**0.0548**	**-39**

The table reports the average transaction costs ($\theta + \beta_0$), for each country, before (January 1, 2010 - July 25, 2012) and after (July 26, 2012 - February 1, 2017) the OMT announcement date. The average transaction costs are expressed in percentage terms. The last column reports the variation in percentage terms across the two time periods, for each country. We also report the mean across groups of countries (Eurozone Core, Eurozone Peripheral, No Eurozone).□

in the average transaction costs across the two time periods is much more pronounced for the Eurozone countries (from 930bp to 247bp), and in particular for the peripheral countries (from 1678bp to 448bp), with respect to the No Eurozone countries (from 912bp to 548bp).

Next, we compare the estimated transaction costs in the two periods with the potential arbitrage profits generated by the arbitrage strategies described above. Consistently with the approach followed in the analysis of the arbitrage strategies, we compare the riskless profits

Figure 10. Arbitrage Profits and Transaction Costs



The figure shows the profits generated by the arbitrage strategy 1 for the Eurozone countries (blue line) and the No-Eurozone countries (green line) against the average transaction costs across the Eurozone countries (blue dotted line) and the No-Eurozone countries (green dotted line), respectively, between the 1^{st} January 2010 and the 1^{st} February 2017. The red line stands for the OMT announcement date.□

over the full time series with the estimated transaction costs across groups of countries, by splitting our sample in two groups (Eurozone, No Eurozone). Note that the key insights hold if we split again the Eurozone countries in two sub-samples (Core, Peripheral). The plot in figure 10 offers a straightforward interpretation of our results.

Before the OMT announcement, we estimate average transaction costs similar across groups of countries, and that are above the arbitrage profits for all groups of countries. Therefore, the arbitrageurs do not have incentive to intervene and clear the arbitrage opportunities, as the riskless profits are even not sufficient to cover the costs to implement the strategy. As a consequence, over this period, there is a persistent deviation from the zero-basis equilibrium condition.

After the OMT announcement, instead, we estimate a pronounced reduction of the average transaction costs for the Eurozone countries. Hence, the arbitrageurs find profitable to step into the market and take advantage of the deviation from the equilibrium condition.

The riskless profits, then, quickly converge to zero, and the same happens for the CDS spread - bond yield basis. In other words, the lower transaction costs have created the condition for the traders to profit from the arbitrage opportunities generated by the relative CDS spread - bond yield mispricing, then leading the sovereign debt market back to the equilibrium (zero basis).

On the other hand, this condition does not occur for the No Eurozone countries. The estimated key threshold, in fact, is lower in the second time period with respect to the pre-announcement period, however the threshold reduction is not enough to create the condition for the traders to clear the arbitrage opportunities. Therefore, we observe a persistent CDS spread - bond yield mispricing even after the OMT announcement, with a persistent deviation from the zero-basis condition.

We conjecture two different explanations, though perhaps simultaneously at work, for the reduction in the Eurozone market transaction costs after the OMT announcement, and the consequent alignment of the relative CDS spread - bond yield pricing to the equilibrium condition. First, the announcement of the ECB has stimulated a pronounced inflow of liquidity in the market, thus reducing the trading costs (by reducing, for instance, the bid-ask spread). Moreover, the intervention of the ECB has generated a risk-reduction effect on the sovereign debt market, by reducing the debt securities volatility, and consequently reducing the risk-premium required by the arbitrageurs as compensation to trade. In this case, we can interpret the transaction costs as a lower bound for the risk-premium sought by the traders to step into the market.

6. Conclusion

In the paper, we conduct an empirical investigation of the relationship between sovereign CDS spreads and sovereign bond yields. In a nutshell, we document that, after the announcement of the OMT programme by the ECB, the consistent cross-sectional relationship between CDS spreads and bond yields across Eurozone countries is restored.

We document a deviation from the no arbitrage theoretical relationship between CDS spreads and bond yields, over the time series, for our sample countries. However, we show that such deviation does not affect the monotonicity in the cross-sectional relationship between CDS spreads and bond yields. Then, we show that the violation of the zero-basis equilibrium condition generates instead inconsistency in the cross-section of the bond yields across countries, with respect to the differences in terms of default risk priced in the CDS spreads. The differences across countries in terms of default risk, priced in the CDS spreads, are not consistently priced in the cross-section of the bond yields. This inconsistent cross-sectional relationship vanishes after the OMT announcement for the Eurozone countries only.

Further investigation should focus on the big challenge of isolating the long term effects of the OMT programme on the relative pricing of the sovereign credit securities, in order to prove and identify a robust causal relationship. The main issue in a sovereign analysis is created by the unavoidable interaction between external and internal factors simultaneously at work. With this paper, we want to highlight a crucial evidence for the analysis of the risk-return relationship, linking this cornerstone of the financial theory with macro-economic and monetary events, then awaiting for further and deeper research.

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