A Structural View of Sovereign Risk Contagion in the Euro Zone

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Abstract

This paper explores the impact of the European debt crisis on the valuation of sovereign debt in the euro area using data from sovereign countries' stock markets, CDS markets, and their national finances. Estimating a structural model over the period from July 2007 to July 2013, we find a structural break in the valuation of sovereign debt at the beginning of the European debt crisis. While for core euro-area countries this structural break takes the form of an upward shift of their default barriers, i.e. an upward shift of their market-implied debt levels, a downward shift is observed for peripheral euro-area countries. These findings are consistent with markets pricing in guarantees and bailout payments between core and peripheral euro-area countries.

Keywords: Sovereign Debt, Credit Risk, Credit Default Swap, European Debt Crisis.

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1 Introduction

During the recent sovereign debt crisis, several member states of the Eurosystem were shut out of the bond markets. In response to these dramatic developments, the EU set up a temporary European Financial Stability Facility (EFSF) in May 2010 which could issue bonds guaranteed by member states to provide funding to these countries. Subsequently, the European Stability Mechanism (ESM) was adapted to provide funding. Introduction of these rescue facilities led to intense political discussions. In particular core countries such as Germany were concerned about possible cross-country subsidies and contingent transfers from their tax payers to periphery countries.

While the public and political discussions of these issues are intense and ongoing, little academic work exists on the economic magnitudes and the cross-country distribution of the costs and benefits of rescue facilities within the Eurosystem. Although the lending capacities of the EFSF and its successor, the ESM, are explicitly known, the present value of the resulting contingent claims and liabilities for a country is subject to considerable valuation uncertainty. First, its value depends on the probability that the country itself will face a distress scenario triggering payments from the rescue facility and second, it depends on the probability that one or several other countries will need to rely on the rescue mechanism. Finally, the present value of the contingent claims and liabilities also depends crucially on the magnitude of the rescue payments in a distress scenario.

This paper develops a framework that allows us to obtain an estimate of the market valuation of these guarantees. More specifically, we derive a structural model for the valuation of sovereign debt, where we proxy the stochastic process of the present value of the sovereign's tax revenue by its stock market index. We then use this structural model to back out the country's market implied default barrier by inverting the pricing formula for a country's CDS spread.

Estimating default barriers of euro-area countries over the period from July 2007 to July 2013 reveals a structural break in the valuation of sovereign debt since the creation of the EFSF. For core euro-area countries the model identifies an upward shift of default barriers that can be interpreted as an upward shift of their market-implied or implicit debt levels. At the same time a downward shift is observed for peripheral euro-area countries. These results are consistent with market participants pricing in guarantees and bailout payments between core and peripheral euro-area countries.

In particular, we identify Spain, Ireland, and Greece as the main beneficiaries of guarantees with a downward shift of their average market-implied debt levels of 42%, 34%, and 31%. At the same time, Germany, Belgium, and the Netherlands are identified as the main providers of guarantees with an upward shift of average implied debt levels of 26%, 31%, and 29%. In absolute terms the shifts in default barriers range from a decrease in the average debt level of 285 bn euros for Spain to an increase of 380 bn euros for Germany.

This study is related to Moody's Analytics (2011) who quantify the value of government guarantees of large financial institutions using a market value-based approach by comparing observed CDS spreads with Fair-value Spreads (FVS) derived from equity markets. In the same sense Schweikhard & Tsesmelidakis (2012) provide evidence of a structural break in the valuation of U.S. bank debt during the latest financial crisis by using a structural model for the pricing of credit default swaps of U.S. firms. They show that a possible explanation for this finding are explicit or implicit government guarantees for large financial institutions.

In a wider sense this paper is also related to studies that explore the interrelations between sovereign credit risk and the financial system. Acharya et al. (2011) examine the two-way feedback between bank and sovereign credit risk and provide empirical evidence for this effect using CDS data of Eurozone countries and banks for the period from 2007 to 2011. Gennaioli et al. (2012) build a model in which a sovereign and its financial sector are linked via bank bond holdings of public debt. They conclude that the willingness of a government to repay its debt and hence its ability to borrow in the first place depends on the development of private financial markets. Using a large sample of countries they find empirical evidence for these predictions.

Billio et al. (2013) investigate the interconnections between sovereign credit risk of European countries and credit risk of major European, U.S., and Japanese banks and insurers based on Granger-causality networks and contingent claims analysis. They find that sovereigns and financial systems are highly dynamically connected and they propose financial network measures that can be used for early warning systems. Gray et al. (2013) analyze the interactions between banking risk, sovereign risk, corporate sector risk, growth, and credit for a sample of 15 EU countries and the United States. Based on contingent claims analysis they construct risk indicators for banks, sovereigns, and corporates and investigate their mutual dependencies in a global vector autoregressive model. Simulating negative and positive shock scenarios their framework can be used to study policies such as bank capital increases, purchases of sovereign debt, and guarantees.

Based on a measure of the foreign exposure risk of a country's banking system Kallestrup et al. (2012) show that cross-border financial linkages are priced in CDS spreads. Furthermore, they show that foreign exposures of banks affect the dynamics of sovereign CDS spreads. Ejsing & Lemke (2009) show that the announcement of rescue packages for large financial institutions led to a structural break in the co-movement between sovereign and bank CDS spreads in the latest financial crisis. They find that these rescue packages induced a decrease in CDS spreads of banks at the expense of a significant increase in sovereign CDS spreads.

From a technical perspective this paper is related to the strand of the literature that develops structural models for sovereign debt in the tradition of Merton (1974), Black & Cox (1976), and Leland (1994). This literature includes Gibson & Sundaresan (2001), Westphalen (2002), Gray et al. (2007), Andrade (2009), Jeanneret (2013), and Jeanneret (2014). In a broader sense this study is also related to the literature that uses a reduced-form approach to model sovereign credit spreads, such as Duffie et al. (2003), Pan & Singleton (2008), and Longstaff et al. (2011).

The paper is organized as follows. Chapter (2) presents a structural model for the valuation of sovereign CDS. Chapter (3) discusses the dataset and model estimation. Chapter (4) concludes.

2 A Structural Model for Sovereign CDS

2.1 Basic Framework

Consider an economy that is inhabited by a representative unlevered firm which generates an operating income stream Z. Under the risk-neutral measure $\mathbb{Q}$, Z is governed by the process:

$$dZ_t = \mu Z_t dt + \sigma Z_t dW_t^{\mathbb{Q}}, \tag{1}$$

where $W_t^{\mathbb{Q}}$ is a Brownian motion defined on the probability space $(\Omega, \mathcal{F}, \mathbb{Q})$ and $F = \{\mathcal{F}_t : t \geq 0\}$ is the information filtration. The parameters μ and σ represent the drift and volatility of the diffusion process.

The sovereign's tax income is obtained from taxing operating income at a rate τ and the sovereign's assets V are defined as the expected discounted value of future sovereign tax income:

$$V_t = \mathbb{E}_t^{\mathbb{Q}}\left[\int_t^{\infty} e^{-r(s-t)}\tau Z_s ds\right] = \frac{\tau Z_t}{r-\mu}, \tag{2}$$

where r denotes the riskless rate. Equity of the representative firm is a tradeable asset and its price satisfies:

$$S_t = \mathbb{E}_t^{\mathbb{Q}}\left[\int_t^{\infty} e^{-r(s-t)}(1-\tau) Z_s ds\right] = \frac{(1-\tau) Z_t}{r-\mu}. \tag{3}$$

Consequently, the sovereign country's assets satisfy:

$$V_t = \frac{\tau}{1-\tau} S_t, \tag{4}$$

and since V, S, and Z are proportional to each other, they share the same dynamics:

$$dV_t = \mu V_t dt + \sigma V_t dW_t^{\mathbb{Q}}, \tag{5}$$

$$dS_t = \mu S_t dt + \sigma S_t dW_t^{\mathbb{Q}}. \tag{6}$$

It follows from (2) and (3) that:

$$\frac{dV_t + \tau Z_t dt}{V_t} = r dt + \sigma dW_t^{\mathbb{Q}}, \tag{7}$$

$$\frac{dS_t + (1-\tau) Z_t dt}{S_t} = r dt + \sigma dW_t^{\mathbb{Q}}. \tag{8}$$

Hence, the total risk-neutral return on a claim to operating income Z - which is shared between the government and equity holders - equals the risk-free rate.

In order to value sovereign CDS on the basis of the framework described above we use a modified version of the CreditGrades (CG) model as presented in Finger et al. (2002), which is considered an industry standard and is also well-known in academia. As in the CG model, it is assumed that the sovereign's default barrier is proportional to the face value of government debt denoted by D:[2]

[2] Sovereign debt contracts are not subject to enforceable law. Following the seminal papers of Eaton & Gersovitz (1981) and Bulow & Rogoff (1989), a large part of the sovereign debt literature

$$V_B = ED. \tag{9}$$

In the spirit of Duffie & Lando (2001) we allow the proportionality factor E in equation (9) to be stochastic, following a lognormal distribution with mean $\overline{E}$ and standard deviation λ. This is also consistent with the CG model.

The stochastic default barrier is introduced to capture potential unobservability of the asset value, as featured in Duffie & Lando (2001) and/or jumps in the asset value process, as first introduced by Merton (1976). Introducing a stochastic default barrier raises short term credit spreads to more realistic levels by capturing the possibility of an instantaneous default, thereby providing a remedy for the well-documented underestimation of short-term default probabilities in structural models. While E is defined as the global recovery rate in the CG model, here it is rather viewed as an adjustment factor that is estimated from market data. The sovereign default time ϕ is defined as:[3]

$$\phi = \inf\{t > 0 \mid V_t \leq V_B\}. \tag{10}$$

A stationary default boundary together with an asset value process V that grows with a positive drift implies that the probability of default goes to zero over time. For this reason and in line with Finger et al. (2002), a stationary environment is assumed in which the debt level grows at the same rate as that of the assets. Furthermore, since for pricing a credit default swap the drift of the assets relative to the drift of the default boundary is relevant, and not the growth rate of the asset value or the

has investigated the economic costs of sovereign default that make sovereign debt contracts feasible. These costs may arise from various different channels such as capital market exclusion, reductions in foreign trade, losses in reputation, or increased risk of a banking crisis. See Panizza et al. (2009) and Borensztein & Panizza (2009) for an overview. In the theoretical literature a sovereign's default decision is typically seen to be governed by the trade-off between the economic costs of default and the reduction in the level of government debt. If for example sovereign default costs are assumed to be proportional to economic output, then the sovereign's incentive to default increases after negative economic shocks. This argument is strongly supported by empirical evidence showing that sovereign defaults are countercyclical, i.e. they tend to occur after large output contractions. See for example Levy-Yeyati & Panizza (2011), Tomz & Wright (2007), and Panizza et al. (2009). The dominant view in the theoretical and empirical literature that sovereign defaults are countercyclical and that a sovereign's incentive to default increases with its debt level is the motivation for assuming the specification given in (9).

[3] For simplicity it is assumed that the sovereign can default only once. However, looking at longer periods Reinhart & Rogoff (2009) find that sovereigns tend to default periodically.

growth rate of the default boundary by itself, both drift components are set to zero without loss of generality.

2.2 CDS Valuation

A credit default swap (CDS) is a contract providing protection against default of a reference obligation. The protection buyer of a CDS makes periodic premium payments to the protection seller until the contract matures or a credit event occurs. In return, the protection seller compensates the protection buyer for any losses on the notional principal in case a credit event occurs. The CDS spread is defined as the annual sum of premium payments as a percentage of the notional principal.

As shown by Musiela & Rutkowski (1998), an approximate closed-form solution for the risk-neutral survival probability $P(T)$ of the sovereign from time t up to time T is given by:

$$P(T) = \Phi\left(-\frac{A_T}{2} + \frac{\log(d)}{A_T}\right) - d \cdot \Phi\left(-\frac{A_T}{2} - \frac{\log(d)}{A_T}\right), \tag{11}$$

$$d = \frac{V_t e^{\lambda^2}}{\overline{E}D_t}, \tag{12}$$

$$A_T^2 = \sigma^2 T + \lambda^2. \tag{13}$$

As shown by Finger et al. (2002), the fair CDS spread that equates the expected discounted value of the protection buyer's premium payments and the protection seller's compensation payment in case of a credit event is given by:

$$CDS_t^T = r(1-R)\frac{1-\zeta+e^{r\xi}(G(T+\xi)-G(\xi))}{\zeta-P(T)e^{-rT}-e^{r\xi}(G(T+\xi)-G(\xi))}, \tag{14}$$

where $\xi = \frac{\lambda^2}{\sigma^2}$, R denotes the recovery rate, and the function G is given by:

$$G(u) = d^{z+\frac{1}{2}}\Phi\left(-\frac{\log(d)}{\sigma\sqrt{u}} - z\sigma\sqrt{u}\right) + d^{-z+\frac{1}{2}}\Phi\left(-\frac{\log(d)}{\sigma\sqrt{u}} + z\sigma\sqrt{u}\right), \tag{15}$$

with $z = \sqrt{\frac{1}{4} + \frac{2r}{\sigma^2}}$ and $\zeta = \Phi\left(-\frac{\sigma^2 t+\lambda^2}{2} + \frac{\log(d)}{\sigma^2 t+\lambda^2}\right) - d\Phi\left(-\frac{\sigma^2 t+\lambda^2}{2} - \frac{\log(d)}{\sigma^2 t+\lambda^2}\right)$.

3 Empirical Implementation

3.1 Methodology

As shown by equation (15), the sovereign's CDS spread depends on a measure of the distance to default given by $d = \frac{V_t e^{\lambda^2}}{\overline{E}D_t}$. Using equation (4) d can be rewritten as:

$$d = \frac{V_0 \frac{V_t}{V_0} e^{\lambda^2}}{\overline{E}D_0 \frac{D_t}{D_0}} = \frac{V_0 \frac{S_t}{S_0} e^{\lambda^2}}{\overline{E}D_0 \frac{D_t}{D_0}}, \tag{16}$$

To estimate the model equity of the representative firm, S_t is proxied by the sovereign country's stock market index S^m:[4]

$$d = \frac{V_0}{\overline{E}D_0} \frac{\frac{S_t^m}{S_0^m} e^{\lambda^2}}{\frac{D_t}{D_0}}. \tag{17}$$

The expression $\frac{V_0}{\overline{E}D_0}$ (the reciprocal, $\frac{\overline{E}D_0}{V_0}$, is henceforth referred to as the default barrier), is estimated by minimizing the sum of squared errors between observed market CDS spreads $CDS_t^{T,market}$ and model CDS spreads CDS_t^T:

$$\left\{\frac{V_0}{\overline{E}D_0}\right\} = \arg\min_{\frac{V_0}{\overline{E}D_0}} \sum_t^N (CDS_t^{T,market} - CDS_t^T)^2 \quad s.t. \quad \frac{V_0}{\overline{E}D_0} > 0. \tag{18}$$

3.2 Dataset & Model Parameters

The dataset used to estimate the model is summarized in tables (1) and (2). It consists of daily data for the period from July 2007 to July 2013 and covers all euro-area countries where CDS data was available. CDS spreads were obtained from Datastream and Bloomberg and correspond to 5-year maturity EUR denominated contracts. Stock index data was obtained from Bloomberg. The face value of debt D is proxied by general government net debt reported in national currency, which was obtained from the IMF World Economic Outlook Database. Yearly observations are linearly interpolated on a daily frequency. Stock market volatility σ is obtained from Bloomberg and is set to the average 12M historical stock index volatility over

[4] Note that as the size of the asset value relative to the sovereign country's debt level is being estimated, the market-implied default barrier depends only on the relative performance of the stock market index but not on its scale.

the respective estimation period. The first ranging from July 2007 to June 2009 and the second ranging from July 2010 to July 2013 (as described below). Default barrier uncertainty λ is set to 0.3 as suggested by Finger et al. (2002). The recovery rate R is set to 0.53 in line with Moody's (2011). The riskless rate r is based on the German 5-year zero yield obtained from Bloomberg.

3.3 Estimation Results

This section presents the estimation results for the default barriers. The sample period is split into two subperiods. The first subperiod ranges from July 2007 to June 2009, covering the first part of the latest financial crisis including the subprime mortgage crisis and the default of Lehman Brothers in September 2008. The starting point of the European debt crisis that followed this period is typically set between late 2009 and the first half of 2010. In November 2009 Greece revealed that its fiscal deficit was twice as large as previously believed. In April 2010 the Greek government requested the EU/IMF lending mechanism to be activated and shortly after Greek debt was downgraded to junk status by Standard & Poor's. In May 2010 the European Financial Stability Facility (EFSF) was created. The second subperiod ranges from July 2010 to July 2013 and covers the European debt crisis since the creation of the EFSF. To ensure two sufficiently distinct subperiods the time between July 2009 and June 2010 is assigned to neither subperiod 1 nor subperiod 2.

Table (3) reports the results of estimating the default boundaries over the first subperiod. Columns four to nine give the resulting mean error, mean absolute error, and root mean square error between observed CDS spreads ($CDS_t^{T,market}$) and model CDS spreads (CDS_t^T). For the first subperiod the mean absolute error ranges from 3.9 basis points for Germany to 28.1 basis points for Greece. Looking at columns seven to nine shows that given the default barriers estimated over subperiod one pricing errors increase substantially for subperiod two. In particular, mean pricing errors show different signs, indicating that the direction of average pricing errors varies over the country set. Figures (1) to (10) present model and market CDS spreads for the full sample period when the default barrier is estimated for the first subperiod as in table (3).

Estimating the default barrier over the second subperiod yields the results reported in table (4). Column four gives the relative difference (in percent) between the default barrier estimated over period two and the default barrier estimated over period one, while columns five to ten give the corresponding pricing errors. Compared to period one, the estimation results suggest an upward shift of the default barrier for Germany, France, Belgium, and Netherlands during the European debt crisis. At the same time the results suggest a downward shift for Greece, Ireland, Italy, Spain, Portugal, and Austria. The table below summarizes the change in default barriers from period one to period two:

Shift in Default Barrier			
Belgium	+31.33%	**Greece**	−31.26%
France	+14.54%	**Ireland**	−34.18%
Germany	+25.93%	**Italy**	−14.72%
Netherlands	+29.34%	**Portugal**	−5.82%
Austria	−10.69%	**Spain**	−41.61%

One possible explanation for the diverging shifts of default barriers for core and peripheral euro-area countries is that with the beginning of the European debt crisis and the creation of the EFSF, market participants price in implicit or explicit government guarantees between core and peripheral countries. In the same sense the upward shift of default boundaries for core euro-area countries would be consistent with government guarantees of core countries in favor of their domestic banks that are exposed to debt of peripheral countries.

As shown in the table above, the results for Austria are perhaps unexpected in that they suggest a downward shift of the default boundary. This result is based on the fact that Austria's stock market performance was relatively low compared to other core euro-area countries. At this point it should be stressed that this paper uses stock market data to generate a sovereign country's theoretical CDS spread. Hence, the results depend on how well a country's stock market index can represent its domestic economy.

4 Conclusion

This paper explores the impact of the European debt crisis on default thresholds of European sovereigns. We develop a structural model that utilizes data from the stock market, the CDS market, and from countries' national finances. Thereby we provide a framework which can be used to estimate the market valuation of the cross-country effects of rescue facilities. In particular, the methodology can be used to identify those euro-area countries that are perceived by market participants as net-providers of guarantees for debt of other euro member countries and those countries that are perceived as being net recipients of these guarantees.

Estimating the model for a set of euro-area countries over the sample period from July 2007 to July 2013 reveals an upward shift of default boundaries for most core euro-area countries and a downward shift of default boundaries for all peripheral countries since the beginning of the European debt crisis. These results are consistent with markets pricing in implicit or explicit guarantees between stronger core and troubled peripheral euro-area countries. Furthermore, measured by the size of the shift in default barriers we identify Spain, Ireland, and Greece as the main beneficiaries and Belgium, the Netherlands, and Germany as the main providers of guarantees. The results indicate that since the creation of the EFSF in May 2010 market-implied default barriers of the main guarantors increased by around 30% of their pre-crisis levels whereas the default barriers of the main recipients of guarantees dropped by a similar magnitude.

5 Appendix

5.1 Time Series Properties of CDS Spreads

This section discusses the time series properties of model and observed market CDS spreads. Here all time series for model CDS spreads are generated by estimating the default barrier for subperiod one. Tables (5) and (6) report the results of unit-root and cointegration tests for model and market CDS spreads. The second column gives the p-value of an augmented Dickey-Fuller test under the null that market and model CDS spreads have a unit-root over the respective sample period. A trend component as well as an intercept were included in the test equation and the lag length was chosen based on the Schwarz Criterion (SC). At a five percent significance level the null of a unit-root can be rejected for all times series.

Columns three and four of tables (5) and (6) report the results of an Engle-Granger and Johansen cointegration test. Column three shows the test statistic of the Engle-Granger test under the null that the model CDS spread of a country is not cointegrated with its corresponding market CDS spread. The symbol $*$ denotes significance at the 5% level. Column four gives the number of cointegration relations suggested by the Johansen approach when the model specification regarding constant and trend terms is based on SC and AIC, respectively. The lag length p is chosen such that a VAR($p+1$) model has minimum SC. For subperiod one ranging from July 2007 to June 2009 the Engle-Granger test suggests cointegration between model and market CDS spreads for Austria, Belgium, Germany Greece, and Netherlands while the Johansen approach points to one cointegration relation for all countries except Portugal. For the second subperiod ranging from July 2010 to July 2013 the Engle-Granger test finds a cointegration relation only for Germany while the Johansen approach suggests cointegration relations for Austria, Germany, and Greece.

Table (7) gives the R^2 of regressing market CDS spreads on a constant and model CDS spreads for both subperiods. For subperiod one, the R^2 ranges from 0.74 for Italy to 0.95 for Austria and for subperiod two the R^2 lies between 0.09 for Portugal and 0.72 for Italy.

Since model CDS spreads are based on stock market data, a natural question is whether the CDS or stock market leads in price discovery. To look into this matter tables (8) and (9) report the p-value of a Granger-causality test for model and market CDS spreads where the lag selection is based on SC. Looking at subperiod one we find that for nine out of ten countries model CDS spreads Granger-cause market CDS spreads, whereas for all countries market CDS spreads Granger-cause model CDS spreads. For subperiod two model CDS spreads Granger-cause market CDS spreads for five out of ten countries whereas market CDS spreass Granger-cause model CDS spreads for three countries. Hence, there is no strong evidence that one market leads the other.

5.2 Tables & Figures

Table 1: Dataset

Dataset – Type, Data Source, and Sample Period

	Type & Data Source		Sample Period	
Country	**CDS**	**Stock Index**	**Period**	**Observations**
Austria	CDS EUR 5Y (Bloomberg & Datastream)	ATX Prime (Bloomberg)	07/2007 – 07/2013	1585
Belgium	CDS EUR 5Y (Bloomberg & Datastream)	BEL20 (Bloomberg)	07/2007 – 07/2013	1585
France	CDS EUR 5Y (Bloomberg & Datastream)	CAC40 (Bloomberg)	07/2007 – 07/2013	1585
Germany	CDS EUR 5Y (Bloomberg & Datastream)	DAX (Bloomberg)	07/2007 – 07/2013	1585
Greece	CDS EUR 5Y (Bloomberg & Datastream)	ASE (Bloomberg)	07/2007 – 02/2012	1212
Ireland	CDS EUR 5Y (Bloomberg & Datastream)	ISEQ (Bloomberg)	10/2007 – 07/2013	1181
Italy	CDS EUR 5Y (Bloomberg & Datastream)	FTSEMIB (Bloomberg)	07/2007 – 07/2013	1585
Netherlands	CDS EUR 5Y (Bloomberg & Datastream)	AEX (Bloomberg)	09/2008 – 07/2013	1276
Portugal	CDS EUR 5Y (Bloomberg & Datastream)	PSI20 (Bloomberg)	07/2007 – 07/2013	1585
Spain	CDS EUR 5Y (Bloomberg & Datastream)	IBEX (Bloomberg)	07/2007 – 07/2013	1585

Table (1) presents a summary of the dataset discussed in section (3.2). The sample period ranges from July 2007 to July 2013. Data is available for a shorter period for Ireland, Greece, and Netherlands.

Table 2: Descriptive Statistics

CDS 5Y EUR (bp) & 12M Historical Stock Volatilities – Descriptive Statistics

	Total			Period 1			Period 2		
Country	**N**	**CDS**	**Vol**	**N**	**CDS**	**Vol**	**N**	**CDS**	**Vol**
Austria	1585	59.56	0.31	524	51.06	0.31	802	65.32	0.26
Belgium	1585	84.86	0.24	524	39.95	0.24	802	123.19	0.21
France	1585	75.25	0.26	524	24.17	0.25	802	119.40	0.25
Germany	1585	28.62	0.25	524	21.35	0.24	802	33.83	0.23
Greece	1212	1222.81	0.33	524	111.25	0.25	429	2818.13	0.35
Ireland	1181	285.91	0.28	450	95.27	0.31	802	437.05	0.23
Italy	1585	162.41	0.28	524	64.00	0.23	802	247.93	0.29
Netherlands	1276	45.57	0.25	215	63.79	0.25	802	45.88	0.20
Portugal	1585	355.55	0.22	524	48.43	0.20	802	630.17	0.22
Spain	1585	165.00	0.28	524	52.31	0.25	802	258.68	0.28

Table (2) provides the mean of 5Y EUR denominated CDS contracts in basis points denoted by “CDS” and the mean of the 12M historical stock index volatilities denoted by “Vol”. “Total” refers to the sample period from July 2007 to July 2013, “Period 1” denotes the period from July 2007 to June 2009, and “Period 2” denotes the period from July 2010 to July 2013.

Table 3: Default Barrier Estimation (1)

Default Barrier Estimation: July 2007 – June 2009

			Period 1			Period 2		
Country	**N**	$\frac{\overline{ED}_0}{V_0}$	**ME**	**MAE**	**RMSE**	**ME**	**MAE**	**RMSE**
Austria	524	9.73	0.48	8.80	14.86	7.55	35.48	44.90
Belgium	524	13.11	5.62	11.49	14.56	120.75	82.27	102.67
France	524	12.34	1.69	5.69	8.06	61.03	46.44	57.20
Germany	524	15.35	0.53	3.90	6.15	27.56	21.76	24.17
Greece	524	12.96	16.87	28.13	33.98	(*)	(*)	(*)
Ireland	450	4.22	5.61	21.89	33.21	-2561	2377	4044
Italy	524	15.22	16.03	26.48	35.94	-61.76	119.39	142.39
Netherlands	524	12.77	-2.37	8.76	12.96	38.16	31.90	37.09
Portugal	524	16.17	9.34	15.63	18.62	376.11	402.52	445.21
Spain	524	16.03	9.09	17.48	21.52	-203.94	716.49	992.51

Table (3) reports the results of estimating the default barrier over the period from July 2007 to June 2009. The variable N denotes the number of observations used to estimate the default barrier $\frac{\overline{ED}_0}{V_0}$. The variables ME, MAE, and $RMSE$ denote the mean error, mean absolute error, and root mean square error between observed and model CDS spreads. "Period 1" refers to the time period from July 2007 to June 2009 while "Period 2" denotes the period from July 2010 to July 2013.

Table 4: Default Barrier Estimation (2)

Default Barrier Estimation: July 2010 – July 2013

				Period 1			Period 2		
Country	**N**	$\frac{\overline{E}D_0}{V_0}$	**Shift**	**ME**	**MAE**	**RMSE**	**ME**	**MAE**	**RMSE**
Austria	802	8.69	−10.69%	14.42	15.71	25.87	29.90	32.24	34.75
Belgium	802	17.22	+31.33%	-47.29	50.69	78.82	48.37	54.25	60.82
France	802	14.13	+14.54%	-12.61	13.38	21.27	23.73	29.42	35.54
Germany	802	19.33	+25.93%	-27.41	27.41	37.28	4.75	7.56	9.51
Greece	428	8.91	−31.26%	66.43	66.43	86.21	1067	1190	1847
Ireland	802	2.78	−34.18%	65.72	65.74	98.71	169.13	183.79	220.45
Italy	802	12.98	−14.72%	37.17	37.38	48.61	36.05	45.33	57.94
Netherlands	802	16.51	+29.34%	-42.03	42.03	58.64	7.90	12.69	16.27
Portugal	802	15.23	−5.82%	17.93	18.42	22.31	437.80	366.91	416.36
Spain	802	9.36	−41.61%	46.94	46.94	58.97	141.94	117.72	128.52

Table (4) reports the results of estimating the default barrier over the period from July 2010 to July 2013. The variable N denotes the number of observations used to estimate the default barrier $\frac{\overline{E}D_0}{V_0}$ and "Shift" denotes the relative difference (in percent) between the default barrier estimated over period 2 and the default barrier estimated over period 1 as given in table (3). The variables ME, MAE, and $RMSE$ denote the mean error, mean absolute error, and root mean square error between observed and model CDS spreads. "Period 1" refers to the time period from July 2007 to June 2009 while "Period 2" denotes the period from July 2010 to July 2013.

Table 5: Unit-Root and Cointegration Tests (1)

Unit-Root and Cointegration Tests – Period 1: July 2007 – June 2009

Country	**ADF**	**Engle-Granger**	**Johansen**
Austria	0.47/0.67	−5.90*	1/1
Belgium	0.86/0.63	−3.47*	1/1
France	0.80/0.37	−2.95	1/1
Germany	0.84/0.19	−6.45*	1/1
Greece	0.60/0.84	−3.99*	1/1
Ireland	0.54/0.71	−2.96	1/1
Italy	0.93/0.20	−2.15	1/1
Netherlands	0.89/0.59	−4.37*	1/1
Portugal	0.76/0.49	−3.09	0/0
Spain	0.48/0.40	−2.49	1/1

Table (5) presents the results of unit-root and cointegration tests for the period from July 2007 to June 2009. Column two reports the p-values of an augmented Dickey-Fuller test under the null that the market/model CDS spread has a unit-root. The lag length was chosen according to the Schwarz Criterion (SC) and a trend component as well as an intercept were included in the test equation. Column three presents the test statistic of an Engle-Granger cointegration test under the null that the respective country's model CDS spread is not cointegrated with the market CDS spread. The symbol * denotes significance at the 5% level. Column four reports the number of cointegration relations suggested by a Johansen cointegration test, where the model specification (constant and trend terms) is based on AIC/SC and the optimal number of lags p is chosen such that a VAR(p+1) model has minimum SC.

Table 6: Unit-Root and Cointegration Tests (2)

Unit-Root and Cointegration Tests – Period 2: July 2010 – July 2013

Country	**ADF**	**Engle-Granger**	**Johansen**
Austria	0.67/0.49	−0.73	0/1
Belgium	0.58/0.61	−1.35	0/0
France	0.90/0.41	−1.70	0/0
Germany	0.64/0.41	−3.39*	1/1
Greece	0.40/1.00	−1.24	1/1
Ireland	0.43/0.68	−1.26	0/0
Italy	0.79/0.36	−2.42	0/0
Netherlands	0.81/0.36	−2.22	0/0
Portugal	0.80/0.70	−1.43	0/0
Spain	0.59/0.48	−2.34	0/0

Table (6) presents the results of unit-root and cointegration tests for the period from July 2010 to July 2013. Column two reports the p-values of an augmented Dickey-Fuller test under the null that the market/model CDS spread has a unit-root. The lag length was chosen according to the Schwarz Criterion (SC) and a trend component as well as an intercept were included in the test equation. Column three presents the test statistic of an Engle-Granger cointegration test under the null that the respective country's model CDS spread is not cointegrated with the market CDS spread. The symbol * denotes significance at the 5% level. Column four reports the number of cointegration relations suggested by a Johansen cointegration test, where the model specification (constant and trend terms) is based on AIC/SC and the optimal number of lags p is chosen such that a VAR(p+1) model has minimum SC.

Table 7: Explanatory Power of Model CDS Spreads

Explanatory Power of Model CDS Spreads

	Period 1			Period 2		
Country	β_0	β_1	R^2	β_0	β_1	R^2
Austria	0.63	1.00*	0.95	29.41*	0.60*	0.24
Belgium	9.73*	0.88*	0.90	27.71*	0.80*	0.27
France	3.33*	0.92*	0.89	13.87*	0.90*	0.55
Germany	1.08*	0.97*	0.91	7.32*	0.81*	0.60
Greece	27.88*	0.84*	0.90	106.57*	2.10*	0.65
Ireland	9.92*	0.95*	0.91	185.16*	0.61*	0.18
Italy	27.37*	0.76*	0.74	20.24*	0.93*	0.72
Netherlands	−3.69*	1.04*	0.88	1.46*	0.97*	0.48
Portugal	17.72*	0.78*	0.87	479.99*	0.32*	0.09
Spain	17.77*	0.80*	0.83	197.44*	0.30*	0.25

Table (7) reports the OLS estimates of regressing market CDS spreads on model CDS spreads: $\text{CDS}_t^{T,market} = \beta_0 + \beta_1 \text{CDS}_t^T + \epsilon_t$. "Period 1" ranges from July 2007 to June 2009 and "Period 2" ranges from July 2010 to July 2013. The symbol * denotes significance at the 5% level.

Table 8: Granger-causality Test (1)

Granger-causality Test – Period 1: July 2007 – June 2009

	H1: model spread does not Granger-cause market spread	H2: market spread does not Granger-cause model spread
Austria	0.00	0.00
Belgium	0.00	0.00
France	0.33	0.00
Germany	0.00	0.00
Greece	0.01	0.00
Ireland	0.00	0.00
Italy	0.00	0.00
Netherlands	0.00	0.00
Portugal	0.00	0.00
Spain	0.00	0.00

Table (8) reports the p-values of a Granger-causality test for model and market CDS spreads over the period from July 2007 to June 2009. Lag selection is based on the Schwarz Criterion (SC).

Table 9: Granger-causality Test (2)

Granger-causality Test – Period 2: July 2010 – July 2013

	H1: model spread does not Granger-cause market spread	H2: market spread does not Granger-cause model spread
Austria	0.00	0.00
Belgium	0.05	0.71
France	0.23	0.16
Germany	0.00	0.06
Greece	0.18	0.57
Ireland	0.05	0.13
Italy	0.07	0.47
Netherlands	0.00	0.50
Portugal	0.15	0.01
Spain	0.66	0.14

Table (8) reports the p-values of a Granger-causality test for model and market CDS spreads over the period from July 2010 to July 2013. Lag selection is based on the Schwarz Criterion (SC).

Table 10: Global Factors (1)

Core euro-area countries: $\Delta(CDS_t^{market} - CDS_t) = \beta_0 + \beta_1\ \Delta(EUR/USD) + \epsilon_t$

Peripheral euro-area countries: $\Delta(CDS_t - CDS_t^{market}) = \beta_0 + \beta_1\ \Delta(EUR/USD) + \epsilon_t$

Country	β_0	β_1	R^2
Austria	−0.1055	43.276	0.00
	(0.06)	(0.09)	
Belgium	−0.0911	−197.47	0.07
	(0.63)	(0.00)	
France	−0.0306	−28.056	0.00
	(0.80)	(0.25)	
Germany	−0.0114	−7.7607	0.00
	(0.81)	(0.46)	
Greece	17.552	−1274.1	0.01
	(0.13)	(0.17)	
Ireland	5.2654	−1052.5	0.04
	(0.09)	(0.00)	
Italy	0.1788	−344.97	0.04
	(0.65)	(0.00)	
Netherlands	0.1225	−29.887	0.01
	(0.30)	(0.20)	
Portugal	0.6469	−165.08	0.00
	(0.63)	(0.55)	
Spain	1.9499	−2617.6	0.04
	(0.37)	(0.04)	

Table (10) reports the OLS estimates of regressing daily changes in the spread between market and model CDS spreads on daily changes of the EUR/USD exchange rate. Model CDS spreads are generated by estimating the default boundary over subperiod one ranging from July 2007 to June 2009. Numbers in parenthesis represent p-values based on HAC (Newey-West) standard errors. For Greece and Ireland sample periods are cut off after November 2011 and July 2011, respectively.

Table 11: Global Factors (2)

Core euro-area countries: $\Delta(CDS_t^{market} - CDS_t) = \beta_0 + \beta_1\ \Delta(Stoxx600) + \epsilon_t$

Peripheral euro-area countries: $\Delta(CDS_t - CDS_t^{market}) = \beta_0 + \beta_1\ \Delta(Stoxx600) + \epsilon_t$

Country	β_0	β_1	R^2
Austria	−0.1651	1.9628	0.18
	(0.15)	(0.00)	
Belgium	−0.0794	−0.9339	0.03
	(0.73)	(0.00)	
France	−0.0670	1.0426	0.09
	(0.61)	(0.00)	
Germany	−0.0207	0.2638	0.03
	(0.69)	(0.00)	
Greece	15.471	−63.261	0.18
	(0.12)	(0.06)	
Ireland	6.0050	−34.363	0.41
	(0.01)	(0.00)	
Italy	0.4035	−7.9298	0.37
	(0.25)	(0.00)	
Netherlands	0.1140	−0.2772	0.01
	(0.26)	(0.33)	
Portugal	0.9884	−11.015	0.09
	(0.47)	(0.00)	
Spain	2.9860	−39.546	0.16
	(0.26)	(0.00)	

Table (10) reports the OLS estimates of regressing daily changes in the spread between market and model CDS spreads on daily changes of the Stoxx600. Model CDS spreads are generated by estimating the default boundary over subperiod one ranging from July 2007 to June 2009. Numbers in parenthesis represent p-values based on HAC (Newey-West) standard errors. For Greece and Ireland sample periods are cut off after November 2011 and July 2011, respectively.

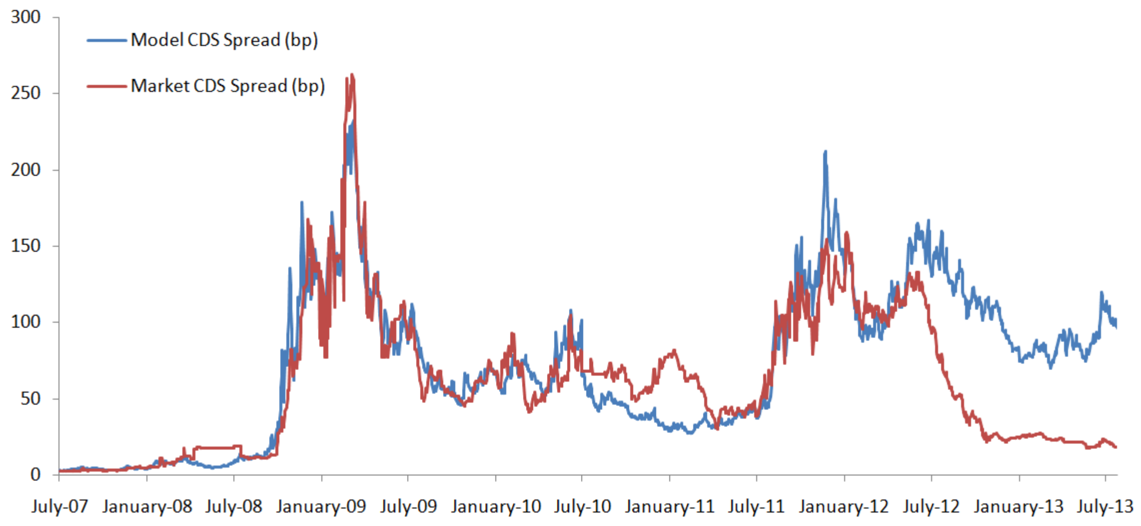

Figure 1: Austria

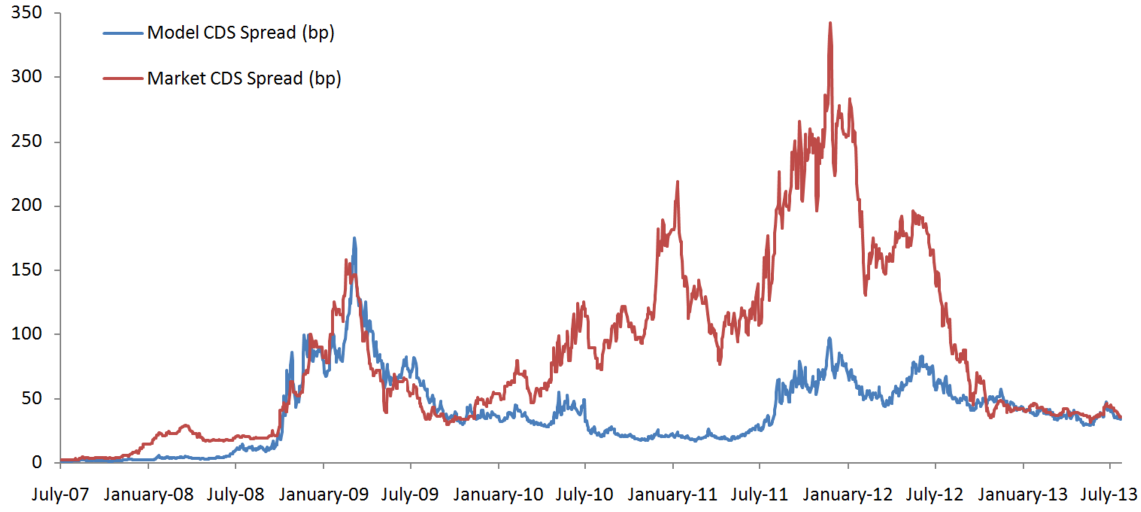

Figure 2: Belgium

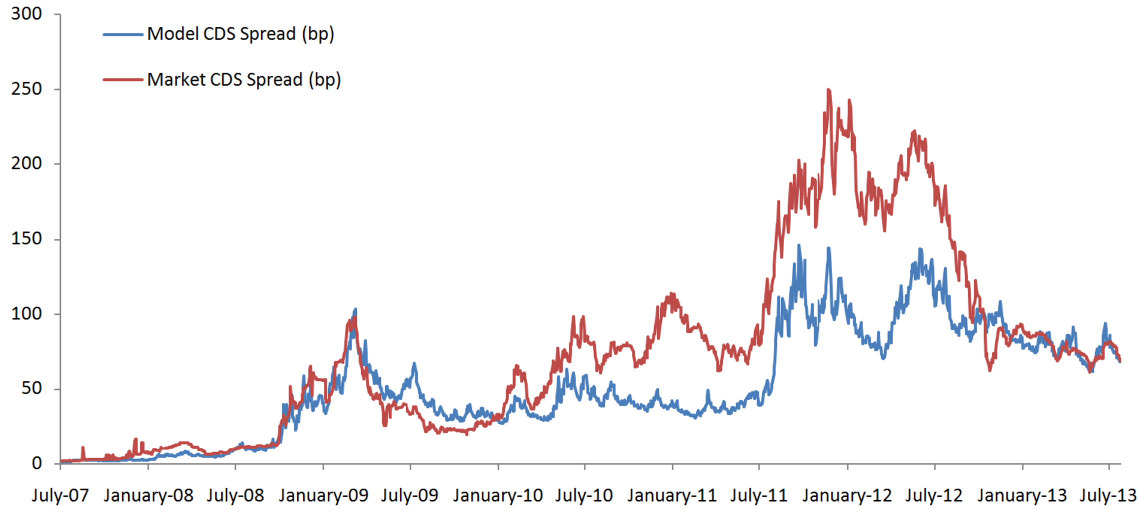

Figure 3: France

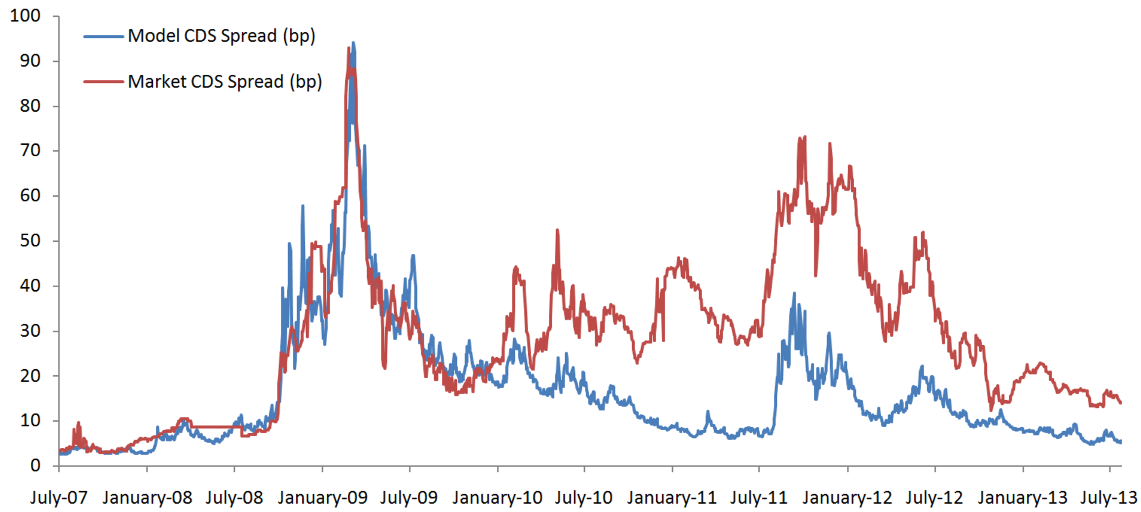

Figure 4: Germany

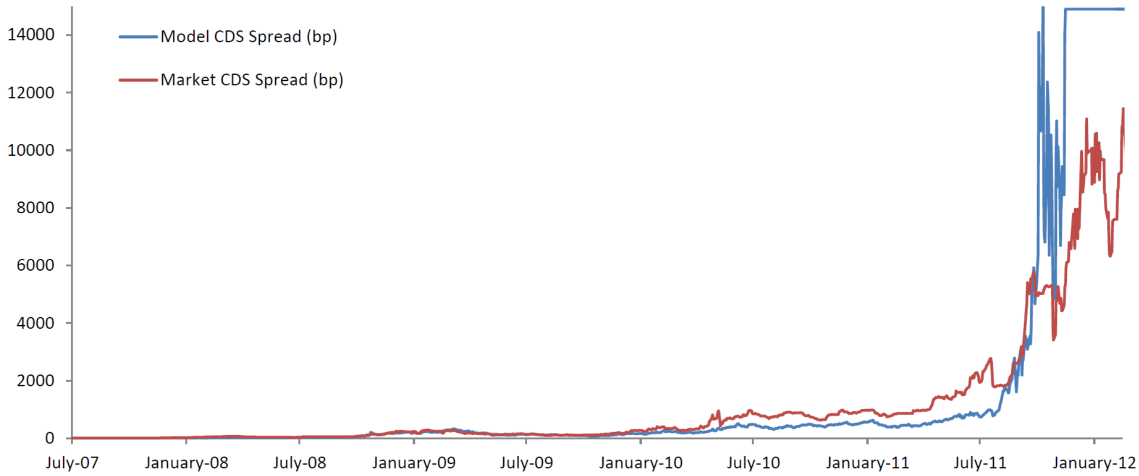

Figure 5: Greece[5]

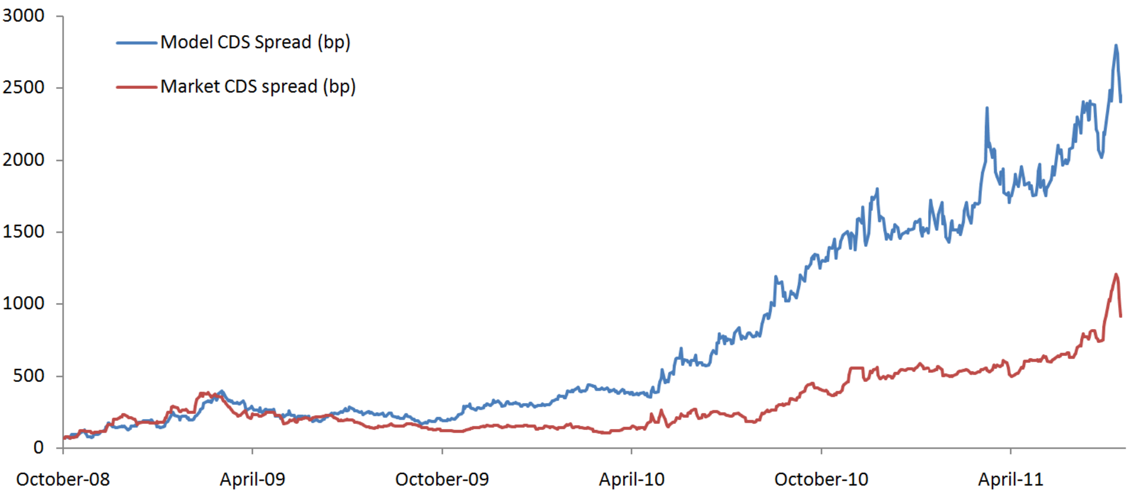

Figure 6: Ireland[6]

[5]The model CDS spread becomes negative at the end of November 2011.

[6]For scaling reasons the graph is cut off at the end of July 2011.

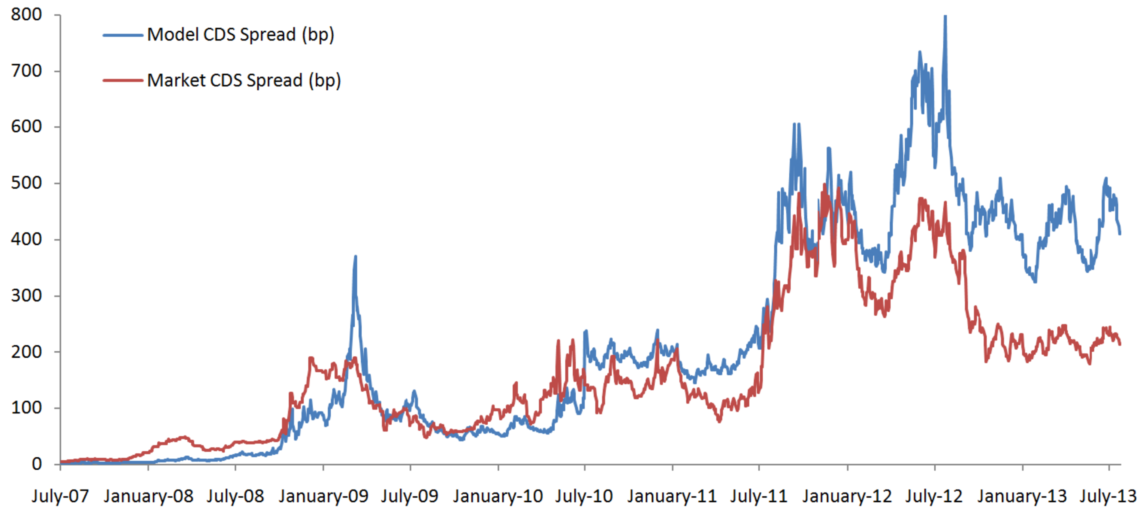

Figure 7: Italy

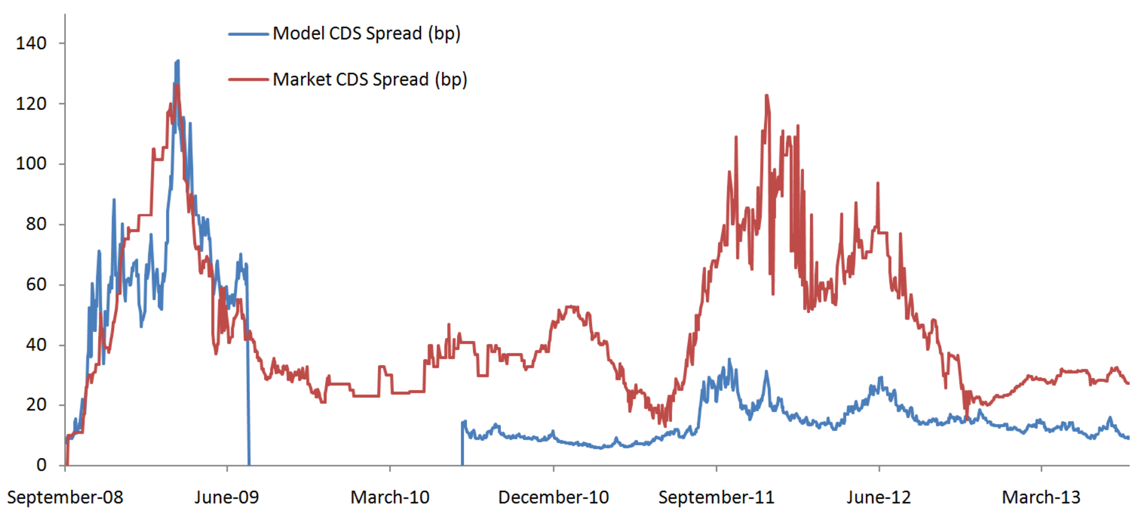

Figure 8: Netherlands

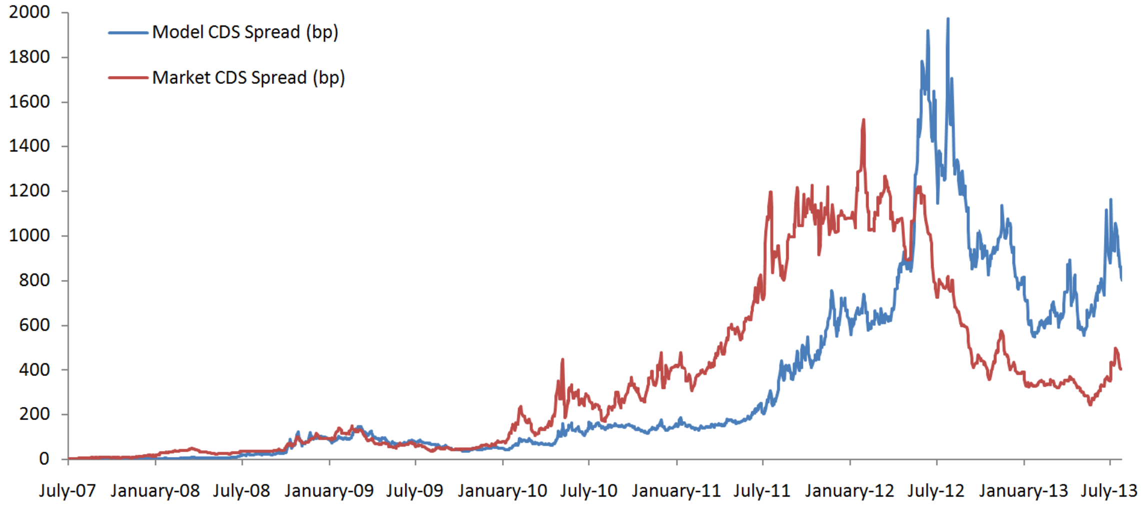

Figure 9: Portugal

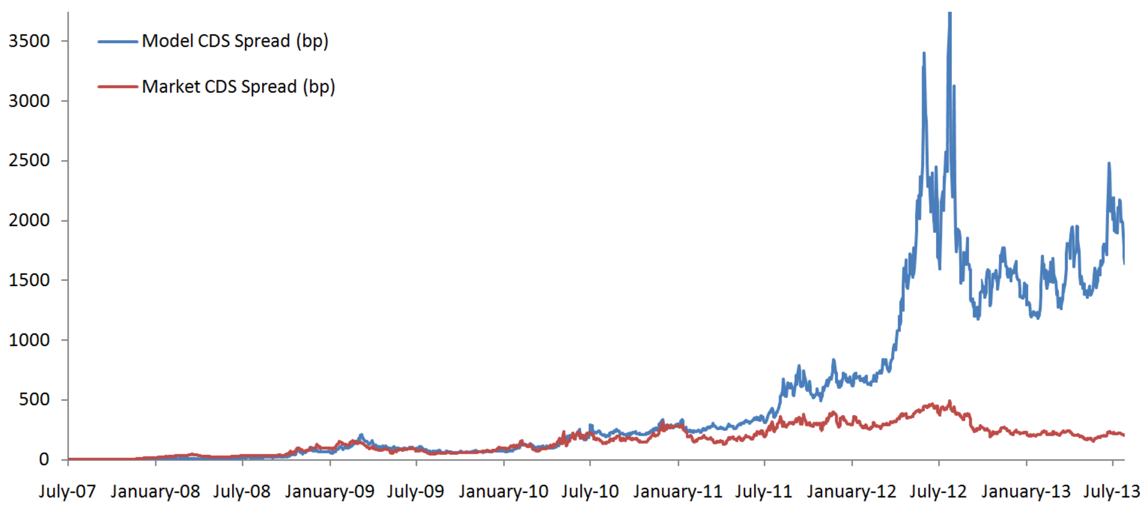

Figure 10: Spain

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