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Sovereign Default Probabilities within the European Crisis

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To my father José M. Coutinho

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Abstract

In this thesis we assess the real default probabilities of three groups of European sovereigns - *peripheral, central and safe haven* - in order to get a forward looking measure of the market sentiment about their default, as well as their evolution within the current European crisis. We follow Moody's *CDS-implied EDF Credit Measures and Fair-Value Spreads* methodology by extracting risk-neutral probabilities of default, assumed to be Weibull distributed, from CDS spreads and convert them into real probabilities of default, using an adaptation of the Merton model to remove the risk premium. We use CDS spreads data from 2008 to 2011 and country dependent market prices of risk as proxy for the risk premium based on the equity benchmark indices of each country. The obtained real default probabilities proved to be a suitable indicator to predict defaults according to the credit events. They have increased severely since 2009/2010, in particular for the peripheral economies - Greece, Ireland and Portugal. The Greece's 1-year probability of default reached 55% at the end of 2011 and a default took place in March 2012. These three countries had to request a bailout from the EU/IMF authorities, Greece and Ireland in 2010 and Portugal in April 2011. Spain and Italy, the central economies, have been a concern for investors, which is reflected in their real probabilities of default that increased substantially during the second half of 2011. The *safe haven* sovereigns - Germany and France - were also not immune to the economic slowdown in Eurozone and its GDP started to shrink, however, the rise in the default probabilities was more limited.

Keywords: Crisis, Risk-neutral probability, Real probability, Market price of risk, CDS spreads, Sovereign, Weibull distribution.

JEL Classification: G01, G12, G15, E58.

Resumo

Nesta tese apresentamos as probabilidades de incumprimento objectivas de três grupos de soberanos Europeus -*periféricos, centrais e seguros* - com o objectivo de captar antecipadamente o sentimento de mercado acerca dos mesmos, bem como analisar a evolução dessas probabilidades no contexto de crise europeia. Foi seguida a metodologia descrita em *CDS-implied EDF Credit Measures and Fair-Value Spreads* da Moody's, extraindo as probabilidades de incumprimento risco-neutrais, que se assume seguirem a distribuição Weibull, a partir dos preços dos CDS e convertendo-as em probabilidades de incumprimento objectivas, usando uma adaptação do modelo de Merton para expurgar o prémio de risco. Foram usados os preços dos CDS de 2008 a 2011 e os índices de Sharpe, variáveis com o país como proxy para o prémio de risco, baseados nos índices accionistas de referência de cada país.

As probabilidades de incumprimento objectivas obtidas parecem ser indicadas para prever os incumprimentos de acordo com os acontecimentos reais. As probabilidades têm aumentado drasticamente desde 2009/2010, especialmente para os países periféricos - Grécia, Irlanda e Portugal. A probabilidade de incumprimento a um ano da Grécia era de 55% no final de 2011 e o incumprimento ocorreu efectivamente em Março de 2012. Estes três países tiveram de recorrer a ajuda financeira das autoridades União Europeia e Fundo Monetário Internacional, a Grécia e a Irlanda em 2010 e Portugal em Abril de 2011. Espanha e Itália, as economias centrais, têm sido uma preocupação para os investidores, reflectida no aumento substancial das probabilidades de incumprimento no segundo semestre de 2011. Os soberanos seguros - Alemanha e França - também não ficaram imunes ao abrandamento económico na zona Euro e o seu PIB diminuiu, no entanto, o aumento das suas probabilidades de incumprimento foi mais limitado.

Palavras-Chave: Crise, Probabilidade risco-neutral, Probabilidade real, Índice de Sharpe, Preços dos CDS, Soberano, Distribuição Weibull.

Classificação JEL: G01, G12, G15, E58.

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List of Abbreviations

CAPM	Capital Asset Pricing Model
CDS	Credit Default Swap
CPI	Consumer Price Index
CR	Credit (Full) Restructuring
ECB	European Central Bank
ECOFIN	Economic and Financial Affairs Council
EDF	Expected Default Frequency
EU	European Union
GDP	Gross Domestic Product
IMF	International Monetary Fund
ISDA	International Swaps and Derivatives Association
LGD	Loss Given Default
MPR	Market Price of Risk
OTC	Over-the-counter
SMA	Simple Moving Average
SR	Sharpe Ratio
USA	United States of America

Chapter 1

Introduction

Europe is experiencing an unprecedented financial and economic crisis associated to a sovereign debt crisis, with deep implications on the economy and society. Uncertainty emerged among investors around the world as private and public indebtedness levels rose and rating[1] agencies downgraded the ratings of several European countries' debt, making it difficult or even impossible for some countries to refinance their government debt without the support from supranational entities such as the European Union (EU) and the International Monetary Fund (IMF).

The origins of this crisis date back to 2006 in the United States of America (USA), when the property market started to experience some problems. The levels of household indebtedness due to easy granting of credit rose to historical highs, creating a property bubble, which represents a situation of fast increase in real property valuations until they reach unsustainable levels. When this bubble burst and house prices declined, many households faced a severe depreciation of their debt collateral. Mortgage delinquencies and foreclosures took place and several financial institutions had to deal with huge losses. In the USA the principal financial institutions affected by property market losses were Fannie Mae, Freddie Mac, AIG and Lehman Brothers, this last one went bankrupt in September 2008. These losses hit many financial institutions around the world as the result of mortgage related investments and con-

[1] Ratings are assessments of the debtor's creditworthiness made by credit rating agencies. The largest rating agencies are Moody's Investors Services, Standard & Poor's Ratings Services and Fitch Ratings. Please see A.5.

fidence in the financial markets vanished. Governments were called to intervene in order to establish confidence and to provide liquidity to banks which no longer had access to the credit markets.

In early 2010, in the middle of a global financial crisis, the speculation about national debt increased with lenders demanding higher interest rates from some European countries' debt which, in turn, caused even more difficulties for those countries to finance their budget and service existing debt. This was the case of Greece, a country with an expansionary policy in a context of global crisis. In April 2010, the Greek government requested financial support from the EU and the IMF and a month later approved a series of austerity measures. A second bailout was delivered only in February 2012 with a debt restructure, a default event which triggered the payment of Credit Default Swaps (CDS). A credit default swap is a financial instrument which provides insurance against default. Since May 2012, due to political problems and the fragile economic and financial situation in Greece, speculation about the country leaving the Eurozone has increased.

In Ireland, the sovereign debt crisis had different features. The government guaranties to the main six Irish banks, which had been deeply affected by the property bubble burst, led to an EU/IMF financial support request from the Irish government in November 2010. In July 2012, as the result of the good progress in dealing with its financial crisis, Ireland was able to return to the financial markets. Governments are seen as indirectly responsible for banks, therefore, doubts about the solvency of banking systems has a negative impact on sovereign debt, since European banks own a significant amount of sovereign debt, this in turn has a negative impact on the banking system.

Portugal requested an EU/IMF financial package on the first half of 2011 to alleviate its public finances and several austerity measures were implemented. In July that year, Moody's cut the country's credit rating to speculative grade and suggested that Portugal could go for a second bailout. Nevertheless, the Portuguese government is committed to achieve the targets set by the EU and the IMF to return to the credit markets in late 2013.

As one of the largest economies in the Eurozone, Spain is under close scrutiny from investors. The government has implemented several austerity measures to cut the public spending and deficit. Despite those efforts, the property bubble burst has weakened the banks, leading to government intervention. Since June 2012, Spain has become a concern in the Eurozone. The long-term interest rates reached 7% and the access to the credit markets became unsustainable. In order to reinforce the banking system, Spain accepted a 100 billion aid package for its banks. More recently Spain is facing financial requests also from its regional governments.

In Italy, debt has increased significantly during the crisis, reaching 120,3% of GDP, while the economic growth has been lower than the Eurozone average. This led the market to be concerned about this sovereign, requesting higher bond yields.

Eurozone sovereign debt was seen by both regulators and banks as safe, at least until 2008. In the past, banks bought substantial amounts of sovereign bonds from weak economies which paid a higher interest rate and were seemingly equally sound as the other Eurozone countries. As the crisis surged it became clear that Greece and other countries' debt offered considerably more risk than the *safe haven* countries, Germany and France. The loss of confidence in the sustainability of these economies is reflected by the increase in the prices of the sovereign credit default swaps, which are an indicator of market expectations about countries' creditworthiness and the intrinsic probability of default[2]. While investors use risk-neutral probabilities of default to price their securities, in this thesis we are interested in assessing the real probabilities of default in order to get a forward looking measure of the market sentiment about these economies and their evolution.

We compute the real probabilities of default for the countries that requested financial support from EU/IMF - Greece, Ireland and Portugal -, and for the fourth-largest economies in the Eurozone - Spain, Italy, France and Germany -, using their sovereign credit default swaps spreads to extract risk-neutral probabilities of default, assumed to follow a Weibull distribution, which are then used to compute real probabilities of default according to Merton (1974) model. The framework is based

[2]For further information please see European Central Bank's annual reports from 2008 to 2011 .

on Moody's CDS-implied EDF model (Zhang et al., 2010) and was applied to data collected from 2008 to 2011. We observe that probabilities of default have increased significantly in the Eurozone, especially in Greece and in shorter tenors. Greece became an outlier during 2011, with CDS spreads suggesting a certain default. Ireland and Portugal experienced a significant increase in the default probabilities at the end of 2011, as well as Italy and Spain, especially in the 1-year tenor. Germany and France are still considered the safest economies in the Eurozone, even so, their probabilities of default increased slightly, in particular in France. The risk-neutral probabilities can be lower than the real probabilities of default, when investors prefer to transfer their funds to safer securities and, consequently, the market price of risk is negative.

In the next chapter, we introduce the theoretical framework. The third chapter describes the data used to calibrate the model and analyses the results, interpreting them within the economic framework. A sensitivity analysis is performed in the fourth chapter. Finally the fifth chapter presents the conclusions achieved.

Chapter 2

Theoretical framework

2.1 Background

Assets are risky once we cannot be certain of their future payoff. Investors are not indifferent to risk and demand a risk premium to be compensated for it. Risky cash flows have to be discounted at the proper discount rate, which in turn takes into account the outcome uncertainty. The discount rate depends on the investor's expectation about the future, as well as the risk aversion, therefore computing a proper discount rate to price a security can prove to be a very difficult task. Academic models related to credit spreads and pricing usually assume a risk-neutral world, where investors are indifferent to risk and cash flows are discounted at the risk-free rate (Berg, 2009; Bessis, 2011). However, a probability (risk-neutral) have to be assigned to these cash flows in order to use the risk-free rate. These probabilities are risk adjusted probabilities that take into account the uncertainty of future cash flows (Gisiger, 2009). The risk-neutral probabilities of default are those that take into account a default scenario in a context of assets with default risk, as in the credit market. The risk-neutral and the real or physical probabilities of default are related by the risk premium: the risk-neutral probabilities of default (Q_t) take into account the price of default risk, while the physical probabilities of default (P_t) only care about the likelihood of future cash flows and are the ones relevant for interpretation purposes.

This thesis is based on the Moody's CDS-implied EDF model (Zhang et al., 2010) which "translates credit spreads into comparable physical default probabilities as measured by EDF[3] credit measures". The model extracts the risk-neutral probabilities from CDS spreads available in the market.

A CDS contract is an insurance tool that protects the buyer from loss of principal on a bond in case of an issuer's default; it is particulary used as a hedge product against credit risk. These contracts are regulated by International Swaps and Derivatives Association (ISDA). As many other risky assets, CDS prices or spreads are computed using risk-neutral probabilities associated to the future cash flows and a risk-free discount rate (Hull, 2009; Hull and White, 2000).

The first Credit Default Swap contract was launched by J.P.Morgan in 1995. It was an over-the-counter (OTC) contract between the seller and the buyer of protection, against the risk of default on a set of debt obligations issued by a specific entity (JP-Morgan, 1999). However, the buyer of protection still faces counterparty risk in the case of a default event of the entity (in this example the seller of the protection, J.P.Morgan, might also default).

In the backdrop of the current financial crisis, where CDS had a main role due to the fear of more defaults, world regulators agreed on a more restrictive policy and standardization in the financial markets, especially regarding these contracts. After the collapse of Lehman Brothers and Bear Stearns many CDS holders were affected by counterparty default. In order to minimise this risk and many other faults of these contracts, the CDS market moved to standardisation. The convention changes took effect on June 20^{th}, 2009 in Europe and the over-the-counter contracts were replaced by standard contracts with fixed coupons of 25, 100, 500 or 1000 basis points[4] plus an upfront fee. Thus, the spread that will occur in dealer runs represents neither the annual coupon (price of protection) nor the amount paid upfront at the time of the trade. That spread represents the conversion of the fixed coupon and upfront payment into a single number that can be used to compare across dealers, as it was

[3]For further information about EDF (Expected Default Frequency) please see Crosbie and Bohn (2003) "Modelling Default Risk".

[4]100 basis points correspond to 1%.

used before the standardisation of these contracts (Markit, 2009).

The CDS contract can be settled to cover several kinds of default events, from restructuring to bankruptcy, failure to pay, repudiation, moratorium, obligation acceleration, obligation default. Several default clauses can be considered, some of them more restrictive than others. The market convention for sovereigns is the Full Restructuring (CR), the most comprehensive and expensive default clause, meaning that the buyer is protected from restructuring as well as the standard bankruptcy and failure to pay.

CDS Spreads are useful metrics to compare credit risk among issuers, but they are imprecise measures of an entity's real risk of default, because they include other premium that investors take into account to reflect their risk aversion. The default information (risk neutral) that is obtained from the CDS has to be adjusted in order to be an intuitive default metric (physical default probabilities).

Following the Moody's model, the conversion of risk neutral (Q_t) into physical default probabilities (P_t) is based on Sharpe (1994) ratios (market price of risk), according to the following framework:

$$Q_t = 1 - \exp[-(h_0 t)^{h_1}] \tag{2.1}$$

$$P_t = \mathcal{N}\Big(\mathcal{N}^{-1}(Q_t) - \frac{\mu - r}{\sigma}\sqrt{t}\Big) \tag{2.2}$$

Q_t : cumulative risk-neutral default probability

h_0 : scale parameter

t : time horizon

h_1 : slope parameter

P_t : cumulative real or physical default probability

$\mathcal{N}$ and $\mathcal{N}^{-1}$: the cumulative Normal distribution function and its inverse function

$\frac{\mu - r}{\sigma}$: the market price of risk or the Sharpe ratio

μ : risky-assets rate of return

r : risk-free rate of return

σ : volatility of the rate of return μ

According to equations 2.1 and 2.2, the model computes the risk-neutral probabilities of default by estimating the parameters of a distribution function using CDS spreads. Then the risk-neutral probabilities of default are converted into real default probabilities by adjusting them for the implied risk.

2.1.1 Weibull Distribution

We follow Moody's hypothesis by assuming that the risk-neutral probability of the default term structure is characterised by a Weibull distribution (Weibull, 1951), estimated from the CDS prices term structure of the countries to be considered.
The standard Weibull distribution function (two-parameter model)[5] is given by:

$$F(t, h_0, h_1) = Q_t = 1 - \exp[-(h_0 t)^{h_1}] \tag{2.3}$$

which characterises the default cumulative distribution at a given time t.
Conversely, the expression $1 - Q_t = \exp[-(h_0 t)^{h_1}]$ describes the survival function (no default).
The hazard function represents the likeliness of an instantaneous default at time t, given that a default has not occurred before that point in time, and is expressed by:

$$h(t) = \frac{f(t)}{1 - F(t)} = h_1 h_0^{h_1} t^{(h_1 - 1)} \tag{2.4}$$

while the cumulative hazard function is given by:

$$H(t) = \int_0^t h(x)dx = (h_0 t)^{h_1} \tag{2.5}$$

h_1 is the shape or slope parameter of the default term structure. If it is lower than 1 indicates that the hazard rate function decreases over time, i.e., the default is less likely in the near term than in the future.

[5]For further information please see Rinne (2009) and Murthy et al. (2003).

If h_1 is greater than 1, the hazard function increases with time, which means that the default in the near term is less likely than in the future.

Finally, if h_1 is equal to 1, the hazard rate is constant over time, corresponding to the particular case of an exponential distribution.

h_0 is the scale or level parameter, decreasing h_0 stretches out the default density function which is given by:

$$f(t) = \frac{dF(t)}{dt} = h_0^{h_1} h_1 t^{h_1 - 1} \exp\Big[- (h_0 t)^{h_1} \Big] \tag{2.6}$$

The chosen distribution function for the default times, the Weibull function, presents the best way to control the hazard function given the parameters level or scale (h_0) and slope or shape (h_1). These two degrees of freedom seem to be enough to fit most spread data quite well.

2.1.2 Conversion of the risk-neutral into real default probabilities

Using the Merton framework (Berg, 2009), the real default probabilities and the risk-neutral probabilities can be calculated, respectively, as:

$$P_T = P\left[V_T < NV\right] = \mathcal{N}\left[\frac{ln(\frac{NV}{V_0}) - (\mu - \frac{\sigma^2}{2})T}{\sigma\sqrt{T}}\right] \tag{2.7}$$

$$Q_T = Q\left[V_T < NV\right] = \mathcal{N}\left[\frac{ln(\frac{NV}{V_0}) - (r - \frac{\sigma^2}{2})T}{\sigma\sqrt{T}}\right] \tag{2.8}$$

considering the time interval $t = [0, T]$, and:

V_T, V_0 = asset market value at $t = T$ and $t = 0$ (initial value)

NV = nominal value of a zero bond

T = maturity

$\mathcal{N}$ = Normal cumulative distribution function

Combining both expressions we have:

$$Q_T(P_T) = \mathcal{N}\left[\mathcal{N}^{-1}(P_T) + \frac{\mu - r}{\sigma}\sqrt{T}\right] \tag{2.9}$$

$$P_T(Q_T) = \mathcal{N}\left[\mathcal{N}^{-1}(Q_T) - \frac{\mu - r}{\sigma}\sqrt{T}\right] \tag{2.10}$$

which implies that once we know one probability measure, the other only depends on the Sharpe Ratio ($\frac{\mu-r}{\sigma}$) and on the maturity.

2.2 Model Estimation

2.2.1 *First Step*

The first challenge is to estimate[6] the Weibull scale and slope parameters in order to characterise the risk-neutral default probability distribution function for each country CDS curve. This goal is achieved by solving the following optimisation problem:

$$(h_0^s, h_1^s) = argmin \sum \Big[\log(spreads) - \log(\phi(T, h_0, h_1, t)LGD)\Big]^2 \tag{2.11}$$

h_0 : scale parameter

h_1 : slope parameter

$spreads$: real CDS spreads

$\phi(T, h_0, h_1, t)LGD$: estimated spreads

LGD : Loss Given Default is the loss expected by the investor if a default occurs.

Assumptions:

1. LGD (Loss Given Default) = 75%, the same hypothesis used by Moody's model, once the average recovery rate is 25% among the sixteen countries

[6] All the estimation procedures were done using the MATLAB software. The codes are available upon request (cris.f.coutinho@gmail.com).

that experienced default in the past[7];

2. h_0 and h_1 initial values = 0,5. The obtained results are robust to different initial conditions.

This optimisation problem is solved for each country and a time series of $h = (h_0, h_1)$ is obtained for each observed day and for each sovereign. In other words, we obtain the term structure evolution of the risk-neutral default probabilities for all maturities.

After the estimation of the Weibull parameters we are able to calculate risk-neutral probabilities according to equation 2.1.

CDS Spreads and Risk-Neutral Default Probabilities

Given a CDS contract (€1 notional) with spread $s_{t,T}$ in the time interval $(t, t+dt)$ before maturity T, the present value of the potential cash flows of the paying/premium and the default legs is dependent on the risk-neutral probabilities of default before time t or $t + dt$, Q_t and Q_{t+dt}, respectively, on the discount factor δ_t and on the expected loss given default (LGD)[8].

Assuming that coupons are paid continuously, the probability of receiving a premium leg payment of $s_{t,T}dt$ is $(1 - Q_t)$, the probability of surviving up to time t. Thus, the present value of this payment is given by: $\delta_t(1 - Q_t)s_{t,T}dt$.

Otherwise, if the company defaults during this small time interval, the CDS counterparty pays the default leg, an amount of LGD, with probability of $Q_{t+dt} - Q_t$. Therefore, the present value of this payment is: $\delta_t(Q_{t+dt} - Q_t)LGD = \delta_t q_t LGDdt$, where $q_t = \frac{dQ_t}{dt}$ is the default density function, such that the probability of default during the time interval $(t, t + dt)$ is equal to $q_t dt$[9].

To have the contract fairly priced, its net present value should be zero at the pricing time t. Therefore, the spread and the risk-neutral default probabilities have to

[7] That assumption proved to be particularly suitable given that the Greek recovery rate was also around 25%, according to Moody's research *Sovereign Default and Recovery Rates, 1983-2012H1*, page 14 (Tudela et al., 2012).

[8] For further details please see Zhang et al. (2010), appendix B, 5.1.

[9] Remember that the hazard rate is the ratio of the default density (q_t) and the probability of survival until time t $(1 - Q_t)$.

satisfy:

$$\delta_t(1-Q_t)s_{t,T}dt = \delta_t q_t LGD dt \Rightarrow s_{t,T} = \frac{LGD\int_0^T \delta_t q_t dt}{\int_0^T \delta_t(1-Q_t)dt}, \text{ given a constant } LGD \tag{2.12}$$

Assuming that the spreads follow a Weibull distribution, the survival probability function is given by: $Q_t = 1 - e^{(-h_0 t)^{h_1}}$. Then, we can define the pricing equation implicitly as: $s_{t,T} = \phi(T, h_0, h_1, \delta_t)LGD$, that corresponds to the term structure of CDS calculated from the risk-neutral probabilities by using the Weibull distribution with estimated parameters h_0 and h_1 and the given LGD.

2.2.2 *Second Step*

In order to compute the real probabilities of default it is necessary to assess the market price of risk $\frac{\mu - r}{\sigma}$ for each country under analysis, which expresses the amount of excess return paid to the investor by incurring in one extra unit of risk or, in other words, can be interpreted has the investors' trade-off between risk and return. Once this measure becomes negative, the investor has no incentive to invest in risky-asset, so he transfers his funds to safer securities. The equity market seems to be appropriate to assess this measure but, as the equity data is not available for sovereigns, the market price of risk is computed using the equity benchmark index of each country as the risky-asset and the 3-month Eurozone spot rate[10], calculated using the parametric Svensson (1994) model, as the risk-free rate (r_T). The expression of Svensson model is as follows:

$$r_T = \beta_0 + \beta_1\left[\frac{1-e^{-\frac{T}{\tau_1}}}{\frac{T}{\tau_1}}\right] + \beta_2\left[\frac{1-e^{-\frac{T}{\tau_1}}}{\frac{T}{\tau_1}} - e^{-\frac{T}{\tau_1}}\right] + \beta_3\left[\frac{1-e^{-\frac{T}{\tau_2}}}{\frac{T}{\tau_2}} - e^{-\frac{T}{\tau_2}}\right] \tag{2.13}$$

with T=term to maturity (in years)

β_i and τ_j are the estimated parameters retrieved from ECB website.

The rate of return on risky assets for each day is the simple moving average (SMA) of annualised daily logarithmic returns over the last 25 days. A 25-days window is

[10]For further details please see: http://www.ecb.europa.eu/stats/money/yc/html/technical_notes.pdf.

used in order to capture short-term motion. The volatility is the standard deviation of those returns.

2.2.3 *Third Step*

The real probabilities are calculated from risk-neutral probabilities assuming a Normal probability distribution as described by expression 2.2.
Since the risk-neutral probabilities take into account the risk premium, they are expected to be higher than the real probabilities unless the risk premium is negative.

Chapter 3

Data and Empirical results

3.1 Data

The analysed period covers 4 years (2008 to 2011) of data for seven countries: Portugal, Ireland, Spain, Greece, Italy, France and Germany. The senior sovereign Debt CDS spreads were retrieved from Markit[11], for 9 maturities ranging from 1 year to 30 years. The default clause considered was Full Restructuring (CR), the most comprehensive and expensive, the market convention for sovereigns.

The benchmark equity indices[12] for each country were used to calculate the return on risky assets: PSI20 Index for Portugal, FTSE MIB Index for Italy, ISEQ Index for Ireland, ASE Index for Greece, IBEX Index for Spain, DAX Index for Germany and CAC Index for France. The use of country specific equity data introduces a variation to the Moody's model, which uses "the market Sharpe ratio estimated from the north American corporate sample across all sovereign issuers".

In general, the equity market is considered to be an efficient market in the semi-strong form given that it incorporates all the available and public information and reflects new information very quickly, so no investor is able to consistently obtain returns in excess of average market returns (outperform the market) unless he has

[11] Markit is a financial information services company providing independent data, valuations, trade processing and loan portfolio management platform (www.markit.com).

[12] It was also used the debt market to calculate the Sharpe ratios, specifically the countries' Sovereign IBOXX indices, which proved to be impossible for the bailed-out countries once the index became constant at the closing level of the bailout's day.

access to inside information (Elton et al., 2009).

3.2 Empirical results

Solving the optimisation problem in 2.11 we obtain the Weibull distribution function's parameters h_0 and h_1 for each day of the analysed period and for each country. Until August 2008, h_0 remained very stable and close to zero for all the considered countries. However, it started to increase that year, in September, when the collapse of Lehman Brothers in the USA wiped away confidence in the financial markets. The increase in h_0 reflects the surge in the CDS spreads and therefore higher probabilities of default.

The parameter h_1 remained very close to 1 for Germany and France during the 4 years under analysis, but decreased severely for Portugal, Ireland and Greece, reflecting the increase in the instantaneous probability of default. Please see table A.1 for a summary of parameters and obtained results. Additional figures can be found in A.2.

3.2.1 Greece

Greece was the first country asking for financial help. In the fall of 2009, with the change of the government, Greece made a significant upward revision of its deficit ratio for 2008 to 7,7% of GDP and its planned deficit for 2009 to 12,5% of GDP, revealing a very serious fiscal imbalance. The drop in economic activity, the increasing deficits and the state intervention in response to the financial crisis, contributed to the rapid growth of public debt ratios. In April 2009 the ECOFIN concluded that there was an excessive deficit in some countries of the Eurozone, particularly in Greece, and recommended its correction, but the Greek government failed to take effective action.

The situation continued to deteriorate, reflected on the rise of the 5-year probability of default P_t at the end of 2009 to about 10%, and to 26% in 2010.

In early 2010 it was revealed that the Greek government had misreported the gov-

ernment's finance statistics for many years, with the conclusion that Greece's revised statistics had exceeded the EU's Stability and Growth Pact deficit limit (3%) over the last decade. The revised level of government deficit reported in early 2010 showed that Greece's 2009 deficit was 15,4% of GDP[13], the highest in the Eurozone. In April 2010, a financial aid programme to Greece was approved but some days after, with the rating downgrades of the Greek and Portuguese government bonds - to a speculative rating for Greece - contributed to the emergence of a confidence crisis in the sustainability of the Greek fiscal position. The probability of default (both Q_t and P_t) climbed to historically high values reaching almost 100% in the 5-year tenor.

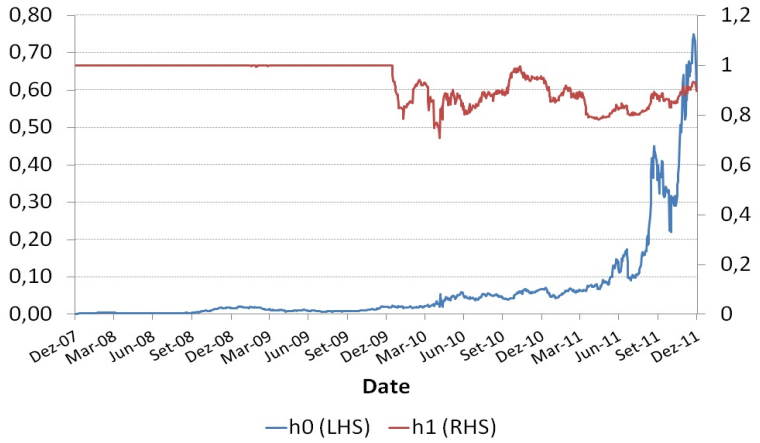
The persistence of budget deficits and high debt in Greece associated to incorrect reporting statistics, as well as the postponement of needed economic and social reforms, seriously compromised the credibility of the authorities. Consequently, this country has been increasingly confronted with high borrowing costs and severe funding difficulties. In late 2010, the debt ratio was still well above 100% of GDP (142,8%).

According to Figure 3.1, the parameter h_0 recorded its first rise in May 2010 concerning the sovereign debt crisis and remained stable around 0,05 during the next year. In May 2011 the increase of h_0 was quick and aggressive, when the country's debt restructure became a likely scenario. In turn, h_1 was near 1 until the end of 2009 but started to decrease in early 2010, reaching the lowest value in May (0,71). The decrease in this parameter reflected an imminent default, which was expected after the disclosure of the revised statistics. Greece's 5-year CDS Spreads increased from about 800 basis points during 2010 to more than 10.000[14] basis points at the end of 2011, reflecting a certain default scenario. Consequently, the probabilities of default Q_t and P_t reached 100% from 7 to 30 years maturities, with the 1-year probabilities recording values around 54%.

[13]All economic data referred in the thesis was collected from Moody's Investors Services. For complete data please see A.3.

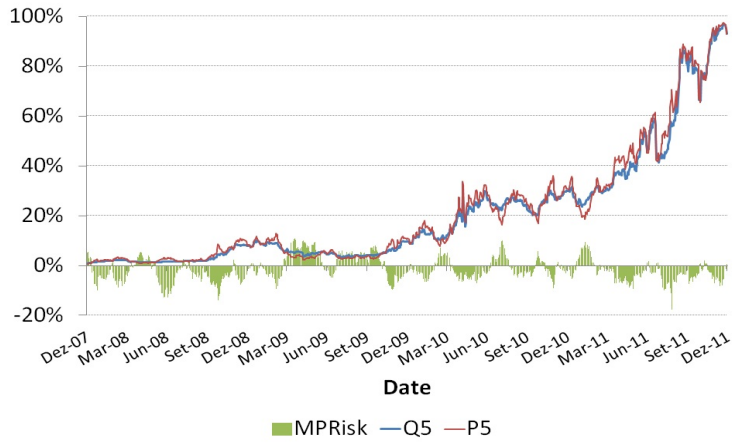
[14]Spreads above 10.000 basis points (100%) have no meaning once they reflect a probability of default higher than 100%.

Figure 3.1: Greece's Weibull parameters: h_0 and h_1



The 5-year default probabilities have presented an upward trend, especially after the first EU/IMF programme in April 2010, reaching a maximum of 96,8% for Q_t and 97,5% for P_t. The market price of risk was computed using the equity benchmark ASE Index and ranged from -17,6% (August 2011) to 10,8% (April 2009), as can be observed in Figure 3.2.

Figure 3.2: Greece's 5-year Probabilities of Default

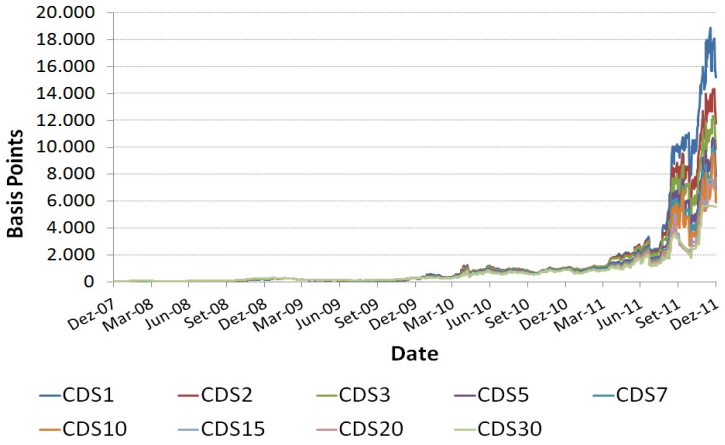


From March 2011 until the end of that year the market price of risk was positive only in 18 days, meaning that safer securities like risk-free deposits were a better choice than to invest in the Greek index. Regarding the real CDS spread curves, there are some level differences among the different tenors, being the shortest maturities the ones with the highest spreads, especially during the second half of 2011. 1-year

and 30-year CDS spreads reached a maximum of 18.890 basis points and 5.640 basis points, respectively, at the end of 2011 (Figure 3.3).

In what concerns the estimated CDS spreads, the differences among different maturities are not so significant and all maturities reached spreads near 10.000 basis points for the same period.

Figure 3.3: Greece's Credit Default Swap Spreads (Real)



In March 2012, the ISDA declared that, upon the conclusion of an exchange of 177 billion Euros of Greece's sovereign's debt, the exchange was a credit event under the terms of its CDS.

3.2.2 Ireland

Ireland was the second country to ask for financial help. In the second half of 2007, housing prices began to fall significantly in Ireland, then stabilised and only decreased sharply again in the first half of 2009. Consequently, the economic situation deteriorated in the context of weak consumer confidence, tight financing conditions worldwide and negative wealth effects due to the devaluation of the houses. In October 2008, the situation was critical, the major banks collapsed and the level of uncertainty was enormous. On the other hand, the implementation of fiscal stimulus measures and state support to the financial sector led to the deterioration of the financial position of some countries in the Eurozone during 2009, particularly in Ireland. The worsening economic situation led to an unsustainable public deficit

that reached 32,4% in 2010. Thus, in November that year, the International Monetary Fund (IMF), the European Commission (EC) and the European Central Bank (ECB) (commonly called "Troika" or triumvirate) agreed on a financial aid package to Ireland.

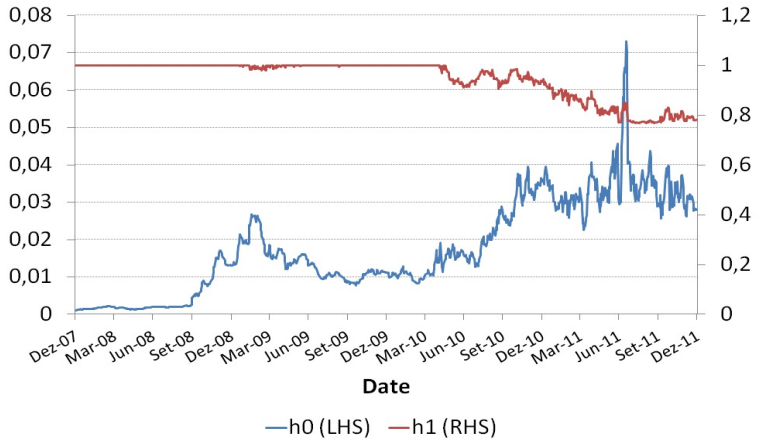
Among the considered countries, Ireland was the one with the most severe economic contraction in 2009, with a real GDP annual change of -7,6% that year, but was able to recover to -1% in 2010 and to 0,6% in 2011, mainly due to the increase in exports, domestic consumption and investment. Unemployment rate reached 14,2% in 2010, improving to 13,5% in 2011 (and is expected to decrease during 2012). In turn, the debt ratio increased during the 4 years under analysis, from 25% to 112%. The successful implementation of the austerity programme and structural reforms brought confidence to the investors, allowing the country to get funding from the credit market, by issuing 5 billion euros of bonds in July 2012.

h_0 began to increase in September 2008, when its value raised from 0,002 to 0,026 in early 2009. This parameter increased again from late 2009 to 2011, reaching its peak in July 2011 (0,073) as a result of the intensification of tensions in financial markets and the extension of sovereign debt crisis to some of the largest economies of the Eurozone (Italy and Spain).

As can be seen in Figure 3.4, the parameter h_1, which in 2008 and 2009 remained very close to one, fell sharply in May 2010, when the sovereign debt crisis in Europe was recognized. The drop of h_1 below one means the increase of imminent failure (default). The risk-neutral probabilities of default (Q_t) follows the same pattern as h_0, meaning that this parameter determines the probability curve shape. These probabilities of default increased after Lehman Brother's collapse (September 2008), as well as at the beginning of the sovereign debt crisis (May 2010), peaking in July 2011 with a value around 35% in the 5-year tenor. Ireland's market price of risk was estimated from ISEQ Index. A positive market price of risk represents a positive return by investing in risky assets as opposed to a risk free asset.Thus, from April (Greece's request for financial support) to November 2010 (Ireland's request for financial support) the "flight to safety" led investors to allocate funds in less

risky assets such as U.S. or European sovereign debt rated AAA, also known as *safe haven* instruments, resulting in negative market price of risk.

Figure 3.4: Ireland's Weibull parameters: h_0 and h_1

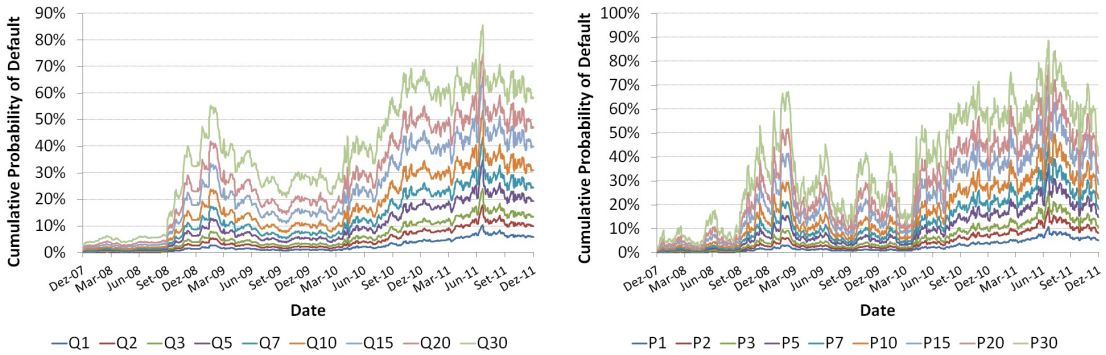


This indicator ranged from -13,6% (August 2011) to 10,6% (April 2010). The maximum value for the 5-year real probabilities of default (P_t) was 37%, reached in July 2011 when the uncertainty raised in Europe due to the rating downgrades of Portugal and Greece by Moody's. At the same time, this rating agency also suggested that Greece might need an additional financial injection.

Figure 3.5 presents the evolution of the default probabilities for several selected maturities from the complete term structure. The risk-neutral probabilities of default behave similarly to those of five years, usually the most liquid maturity, being only parallel shifts of this curve, with differences in level. The 30-year Q_t curve reaches the maximum of 85,7% in July 2011, while the value for the 1-year tenor is 10,4% at that same date. This is due to the maturity effect t in the calculation of probabilities, a longer term imply a more pronounced effect of the risk premium in the calculation of probabilities P_t, as defined in expression 2.2, and a higher risk-neutral probability of default Q_t, as defined in expression 2.1. The probabilities P_t have the same behaviour than Q_t but with a higher level due to the negative risk premium in this period as result of "flight to safety".

In what concerns the real CDS spreads, they basically do not differ from each other

Figure 3.5: Ireland's Probabilities of Default



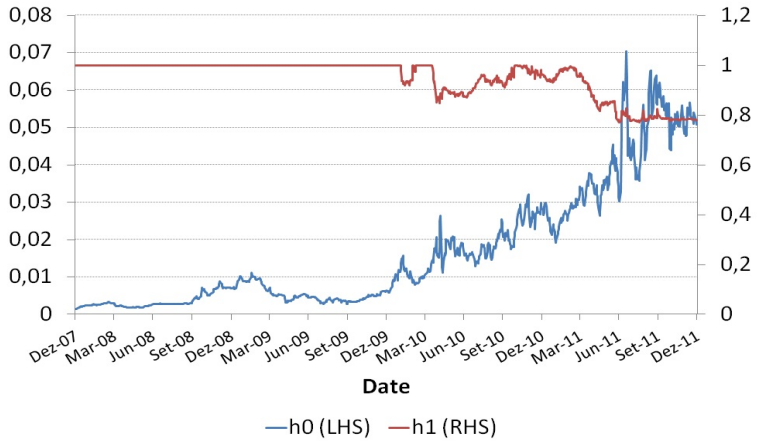
among the different maturities until the end of 2010. In 2011 the spreads for the shortest maturities (1, 2 and 3 years) are significantly higher than the ones of the longest maturities (from 10 to 30 years), suggesting that the default scenario is imminent in the short term since in the long term the economy would have been recovered. As expected, the estimated CDS spreads have the same behaviour, with higher values for the shortest maturities from May 2010 on.

3.2.3 Portugal

Portugal was the third country asking for a bailout. Portugal's real GDP decreased severely by 2,5% in 2009, the worst year for the country's economy during the period 2007-2011. During 2010, with an expansionary policy, the GDP recovered and had a positive change of 1,3%, especially due to the increase of public investment. However, the public debt increased from 83% in 2009 to 93% the following year. Despite the positive GDP growth, the ongoing economic crisis did not spare Portugal and in 2011 the GDP level contracted by 2,2% with the unemployment rate reaching 12,3%, an historical peak. The public deficit recorded the worst value in 2009 (-10,1%), recovering slightly in the following years (to -9,2% in 2010 and -5,9% in 2011). The public debt ratio increased every year under analysis and reached 101,7% in 2011. With the economic and sovereign debt crisis going on, this country has faced severe funding difficulties in the market and, in April 2011, a formal request for financial help to EU/IMF authorities occurred.

For Portugal, the first increase in h_0 happened during the last quarter of 2008 and the first quarter of 2009, when the turmoil in the financial markets, caused by the collapse of Lehman Brothers as well as several bailouts of other investment banks and of the biggest insurance company in the USA (AIG), affected the financial markets, especially in Europe. At the end of 2009, the uncertainty about countries' financial health is reflected on the increase of the likelihood of default at any time. It peaked after the request for financial support in April 2011.

Figure 3.6: Portugal's Weibull parameters: h_0 and h_1

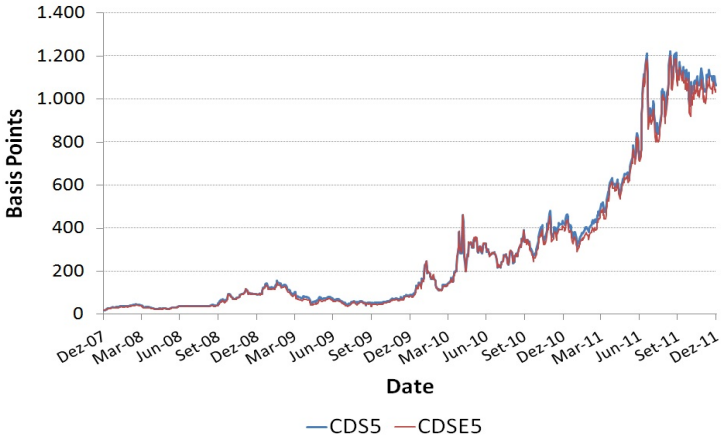


According to Figure 3.6, the h_1 parameter started to decrease at the beginning of 2010, reaching a minimum of 0,847 in May. The downward trend continued until the end of the period under analysis, around 0,787 during the last quarter of 2011. The decrease in the h_1 parameter, in particular after Greece request for financial support (April 2010), represents a higher likelihood for an imminent default.

Portugal had very low levels of CDS spreads until September 2008 (around 35 basis points in the 5-year tenor). The problems in the U.S. financial sector were felt in Europe causing the rise in spreads, which in Portugal almost doubled leaving the 5-year CDS spreads at 158 basis points in February 2009. Between February and November 2009, spreads have recovered to levels around 50 basis points, reflecting confidence in the policies adopted by the U.S. government to contain the effects of financial crisis.

However, the contagion of the crisis was felt in Europe at the end of 2009, leading

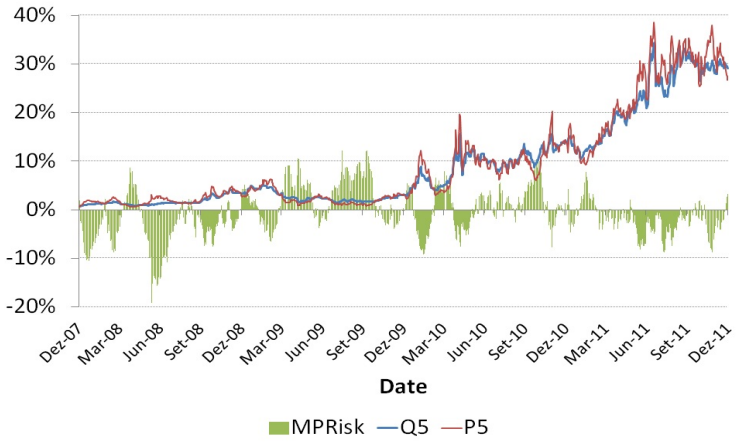
Figure 3.7: Portugal's Credit Default Swap Spreads



to the climb in spreads that reached 1.200 basis points in the summer of 2011 in the 5-year CDS (Figure 3.7).

The risk-neutral probabilities of default (Q_t) in the 5-year tenor, calculated with expression 2.1, reflect the behaviour of the CDS curve with the same tenor, increasing from 0,7% in early 2008 to nearly 35% in July 2011, to stabilise at around 30% at the end of the year.

Figure 3.8: Portugal's 5-year Probabilities of Default



The real probabilities of default (P_t) do not differ significantly from Q_t, although they are more volatile, ranging between 0,59% and 38,5% against 0,72% and 34,4% for Q_t, as can be seen in Figure 3.8. The maximum values were reached in July 2011. As said before, the real probabilities of default, computed from expression 2.2, are

probabilities that do not incorporate any risk premium and therefore are expected to be smaller than Q_t, when the market price of risk is positive.

In order to assess Portugal's market price of risk, the equity benchmark PSI20 Index was used. Computed values vary between -19% and 12%. Volatility peaked twice, the first time in September 2008 and the second time in April 2010, which reflects the equity market reaction to the collapse of Lehman and to the Greek request for financial aid, respectively.

During 2009 the market price of risk was positive with investors taking advantage of high yields in the debt market, but became negative in 2010 and 2011 due to the "flight to safety" phenomenon.

The default probability curves for the different maturities are parallel representations from each other. The real probabilities, P_t, show a downward trend at the end of 2011 in opposite to the Q_t probabilities, which stabilised.

The real CDS spreads exhibits some disparity among maturities especially towards the end of 2011, with the shortest maturities (1, 2 to 3 years) presenting the highest spreads, of about 1.500 basis points, whereas the longest maturities (10 to 30 years) show spreads around 840 basis points, representing lack of confidence in the short term. The intermediate maturities (5 and 7 years) ended 2011 with spreads around 1.050 basis points. The estimated CDS spreads also differ by maturity in late 2011 but more evenly, without evidence of any clusters.

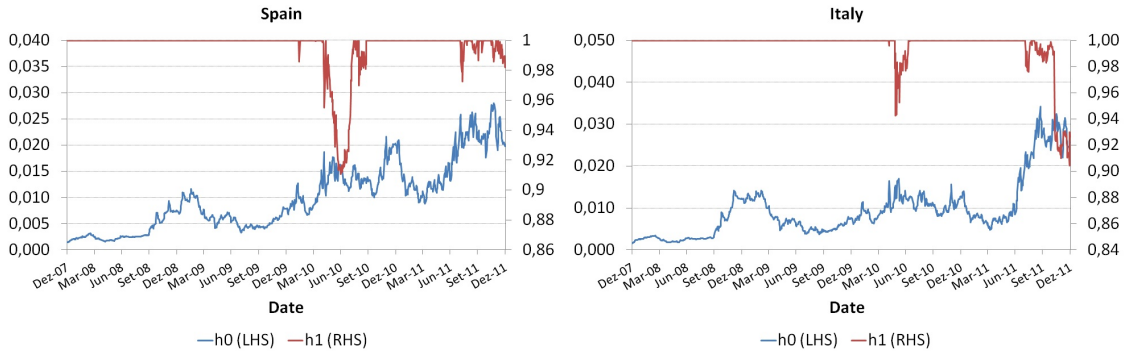
3.2.4 Spain & Italy

During 2008, these countries still enjoyed a favorable economic situation and could adopt expansionary fiscal measures. However, in 2009, Spain was hit by a significant drop in prices of residential and commercial buildings, as already have been observed in other European countries. In Italy prices rose slightly in the first half of the year. Both countries had, in late 2009, very high budget deficits and the debt ratio in Italy exceeded 100% of GDP (116,1% in 2009 and 119% in 2010). In early 2010, the Spanish and Italian public debt became to be mistrusted by investors, causing an increase in yields of government debt.

In the second half of 2011, significant deterioration in various segments of financial markets in the Eurozone led the ECB to implement several additional measures of monetary policy, namely, buying bonds of the countries with refinancing difficulties and expanding the collateral accepted in the monetary policy operations to help the financial system. Tensions in the government bond markets that, generally, had been confined to Greece, Ireland and Portugal, were extended to Italy and Spain and then to other Eurozone countries.

The Weibull parameters have a similar behaviour for Spain and Italy. The parameter h_1, always very close to one, decreased slightly in May 2010, due to the sovereign debt crisis (Figure 3.9). The parameter h_0 increased over time, especially at the end of 2011, where it reached a maximum of 0,028 (in November) for Spain and 0,034 (in September) for Italy.

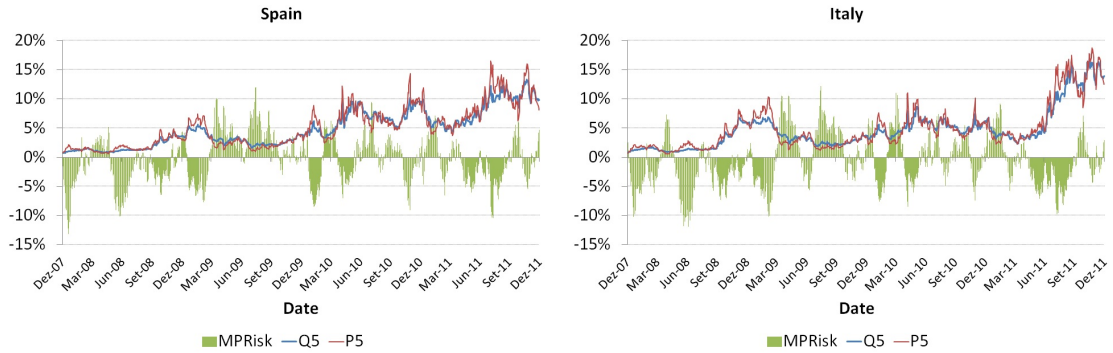
Figure 3.9: Weibull parameters h_0 and h_1: Spain & Italy



Therefore, the probability of default of these countries shows an upward trend, and three phases can be distinguished. According to Figure 3.10, the first phase of the increase in the default probabilities occurred in late 2008 with the collapse of Lehman Brothers which marked the beginning of the financial crisis. The second phase of rising probabilities of default occurred in 2010 with the beginning of the European sovereign debt crisis and the third phase occurred in the second half of 2011 with the deteriorating economic and financial situation of the countries.

In Spain, the 5-year risk-neutral probabilities, Q_t, reached a maximum of 14%, in

Figure 3.10: Probabilities of Default: Spain & Italy



late 2011. The 5-year real probabilities, P_t, are in general higher than Q_t, reaching 16,5%, in 2011. However, at the end of 2011, P_t dropped to 8%.

In Italy, Q_t peaked to 17% while P_t reached 18,8% in late 2011 for the 5-year tenor. In November 2011, default probabilities increased more than four times the end of June 2011 level.

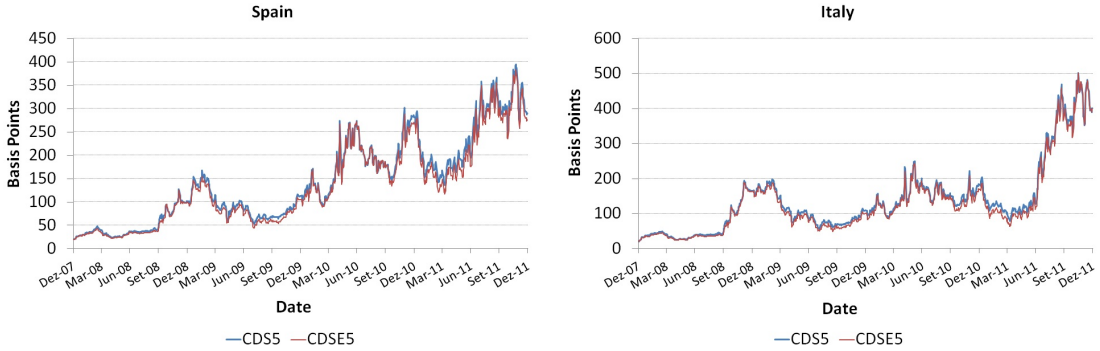
Equity benchmarks IBEX Index (Spain) and FTSE MIB Index (Italy) were used to calculate the market price of risk. Spanish values ranged from -13% to 12% and the Italian from -12% to 12%.

Despite the efforts of the ECB and central banks in solving the sovereign debt crisis, Spain had a deficit higher than expected (6,6%) in 2011. In June 2012, Spain ended up asking EU/IMF for financial aid to recapitalize the financial system. On the other hand, despite all the efforts of the Italian government towards fiscal convergence, Italy has a very fragile situation and the financial aid request has become a more likely scenario[15] (debt ratio reached 120,3% of GDP in 2011).

The CDS spreads of the two countries (represented in Figure 3.11) have increased, especially in the second half of 2011 with the worsening economic conditions in the Eurozone, as a result of the economic slowdown. The estimated CDS spreads are very similar to the real CDS spreads showing a good fitting of the Weibull distribution function.

[15]The European Central Bank is currently studying a new programme to buy sovereign bonds in the secondary markets in order to "safeguard the monetary policy transmission mechanism in all countries of the euro area" - Mario Draghi, President of the ECB, Frankfurt am Main, 6 September 2012. This programme is known by "Outright Monetary Transactions" and is expected to avoid further bailouts.

Figure 3.11: 5-year Real and Estimated CDS Spreads: Spain & Italy



As in the previous analysed countries, in Spain and Italy the Q_t probabilities also differ in scale by maturity, showing lower values for the shortest maturities (4% in 1-year tenor versus 64% in the 30-year tenor). P_t, have a similar shape, reaching higher values than Q_t in the second half of 2011, especially in the longest maturities (70% in the 30-year tenor).

Unlike the estimated CDS spreads that are basically the same among all maturities, the real CDS spreads show some differences, especially during the first half of 2011.

3.2.5 France & Germany

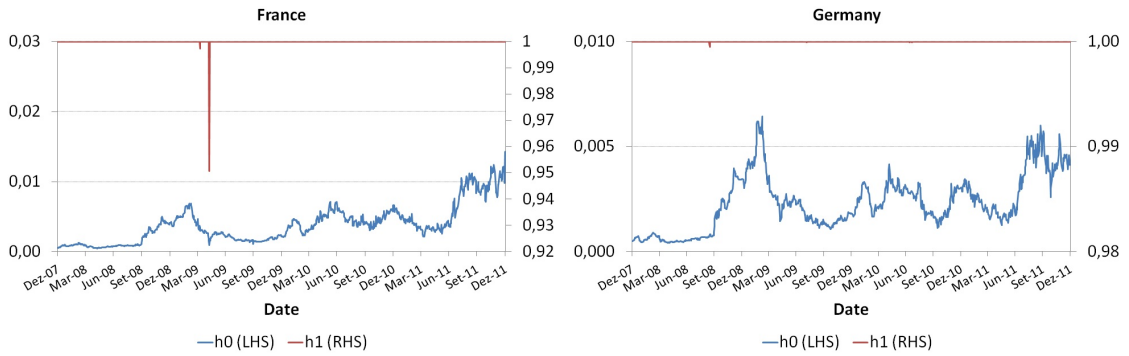
In France, the increases in house prices slowed in 2008 compared with 2006 and 2007. The deficit exceeded the reference value of 3% of GDP in 2008. In 2009, the price of houses decreased significantly and the deficit, 7.5%, has become excessive. The German budget deficit was kept around the reference value of 3% of GDP in 2009 and 2010 and the house prices only have decreased slightly since 2009.

The economy contracted for both countries during 2009, with a real GDP negative growth of 2,6% for France and 4,7% for Germany, as a result of the USA economic crisis contagion. The average unemployment rate in France was 9,4% from 2009 to 2011, while in Germany was 7,1%. The French budget deficit exceeded slightly the reference value of 3% of GDP in 2008, but in 2009 and 2010 the deficit overcame 7%. Finally, during 2011, it recovered to 5,8%. The evolution of the debt ratio was similar in both countries, ranging from around 64% at the end of 2007 to 83,4% at

the end of 2011.

The Weibull parameters, as shown in Figure 3.12, are less volatile compared with the other analysed countries. h_1 is always equal to 1 in Germany. In France this figure had a unique drop (to 0,95), in May 2009.

Figure 3.12: Weibull parameters h_0 and h_1: France & Germany



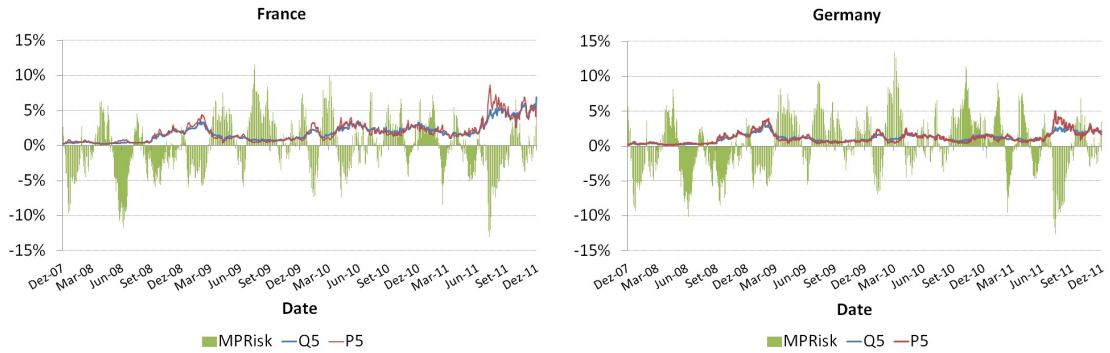
Thus, the likelihood of defaulting today remained the same as in some point in the future, for these two countries. In turn, h_0 increased slightly in early 2009 and again at the end of 2011. In France h_0 reached a maximum of 0,0143 (December 2011) while in Germany the peak was 0,0064 (March 2009).

The estimated 5-year CDS spreads for Germany only approached 100 basis points even in the toughest moments of the crisis (collapse of Lehman and the 2^{nd} half of 2011). The default probabilities remained low as evidenced by Figure 3.13, with 5-year Q_t reaching a maximum of 3,2% at the beginning of 2009 and 5-year P_t reaching the 5% peak in August 2011. In France the probabilities of default for the 5-year tenor were slightly higher, Q_t reached a non-negligible maximum of 6,9% and 8,6% for P_t.

DAX Index was the equity benchmark used to assess Germany's market price of risk and CAC Index was the one used for France. The values ranged from -12,6% to 13,6% in Germany and from -13% to 11,6% in France.

Germany's 5-year CDS spreads reached its maximum value at the beginning of 2009 and have risen since September 2008 from 9 basis points to more than 80 basis points in February 2009 but rebounded at the end of 2011.

Figure 3.13: Probabilities of Default: France & Germany



France enjoyed low spreads around 11 basis points until September 2008, which then peaked three times around 100 basis points: March 2009, June 2010 and January 2011. At the end of the year spreads almost doubled approaching 200 basis points. Regardless of the deterioration in the risk indicators, Germany has been a *safe haven* for investors during the financial crisis, comparing to the other European sovereigns. Regarding these two countries, it is important to note that the real CDS spreads differ by maturity showing lower spreads for the shortest maturities (1, 2 and 3 years), while estimated CDS spreads are roughly the same for all the considered maturities.

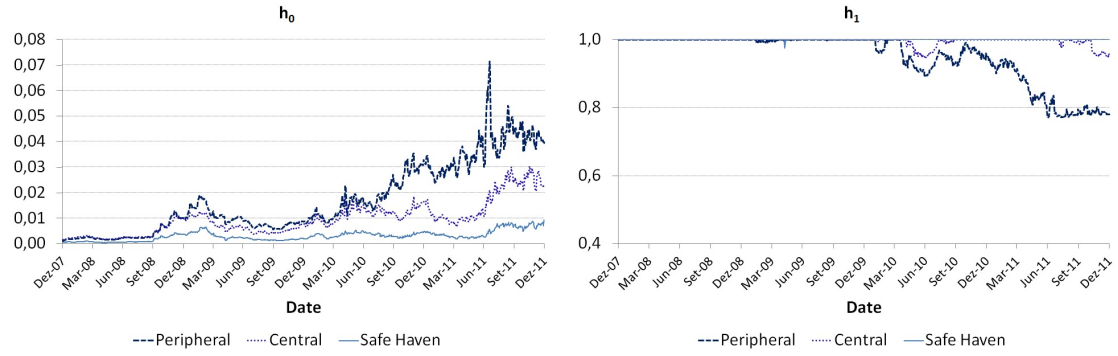
3.2.6 Peripheral, central and *safe haven* economies

With the exception of Greece, that proved to be an outlier, we can group the countries under scrutiny into 3 groups: peripheral economies representing the countries under EU/IMF programme until 2011 (Ireland and Portugal), central economies representing the countries which might need a bailout (Spain and Italy) and, finally, *safe haven*/core economies representing the safest investment choice in the Eurozone (France and Germany).

In what concerns the parameter h_0, the peripheral block has the highest values, with a rising trend, which peaks in July 2011 (0,072) when the Portuguese credit rating was downgraded by Moody's to the speculative grade/junk and suggested that the country might need a second bailout. On the other hand, Ireland experienced a

lowering in the interests rates paid in the EU/IMF programme, easing slightly its financial situation. Then, as depicted in Figure 3.14, h_0 dropped substantially (to around 0,04). As this parameter defines the shape of the default probability, the behavior of Q_t is very similar, peaking in July 2011 at 34,6% and then dropping to 25% at the end of the year, for the 5-year tenor. The results for the central block stand in the middle between the peripheral and the *safe haven* blocks, with the highest values for h_0 being reached at the end of 2011 ranging between 0,02 and 0,03 and risk-neutral probabilities Q_t between 10% and 15%. These economies are very large in the Eurozone and represent a source of concern for the investors, especially Spain where the banking system has shown particular weaknesses. The *safe haven* block's h_0 approached 0,01 at the end of 2011 with Q_t reaching almost 5%, which is not negligible for these countries. Even though considered a refuge for the investors' funds, these economies are not immune to the crisis effects and contagion and they are also slowing down.

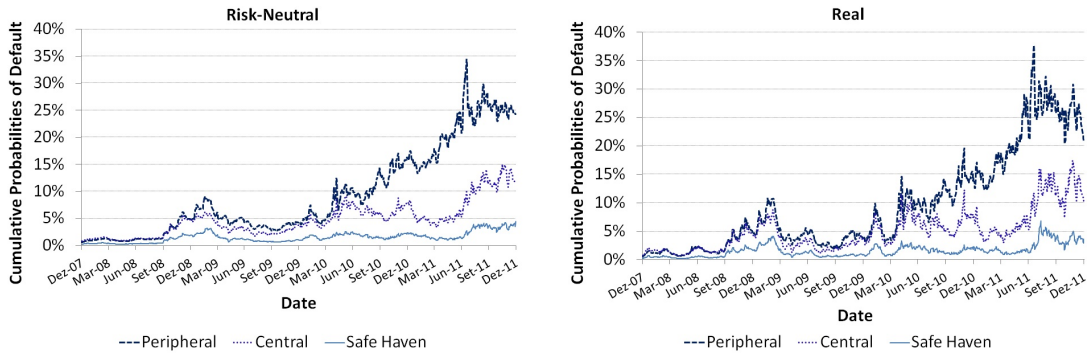
Figure 3.14: Weibull parameters h_0 and h_1



The probability of an imminent default, reflected on h_1, increased substantially for the peripheral economies in the last couple of years (h_1 decreased from 1 to 0,77 at the end of 2011). In the central economies h_1 decreased in May 2010 with the recognition of the sovereign crisis in Europe and again from August 2011 until year-end with the speculation about the future of the Eurozone. The *safe haven* economies do not show any concerns about imminent default, with h_1 always very close to 1. The market price of risk for these three blocks presents the same behavior, ranging

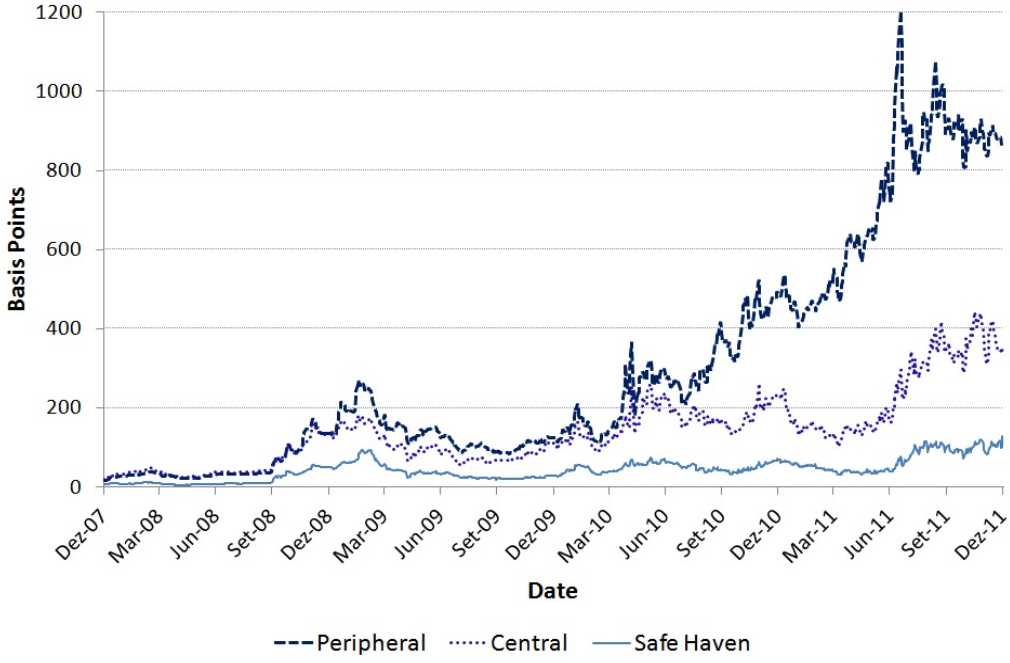
between -14,6% (peripheral block in June 2008) and 12% (central block in August 2009). Consequently, the real probabilities of default P_5 differ from Q_5 especially on those dates, being higher than Q_5 when the market price of risk is positive and lower when the market price of risk is negative (Figure 3.15).

Figure 3.15: 5-Year Probabilities of Default



The CDS spreads' graph shows the obvious difference between the considered blocks (Figure 3.16). The peripheral economies stand out for very high spreads, particularly after August 2010, reaching almost 1200 basis points. The difference between CDS spreads of peripheral and central economies is almost 910 basis points, ending with a difference around 500 basis points at the end of 2011. Looking at the *safe haven* economies, this difference increases to 713 basis points. In turn, the difference between *safe haven* economies and central ones reaches 215 basis points, with spreads at the end of 2011 around 345 basis points and 129 basis points for central and *safe haven* economies, respectively.

Figure 3.16: 5-Year Credit Default Swap Spreads (Real)



Chapter 4

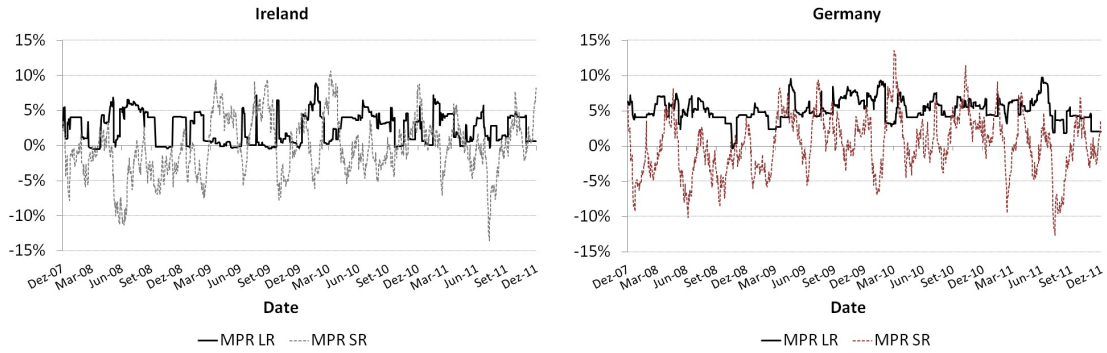
Sensitivity Analysis

4.1 The Sharpe ratio/market price of risk ($\rho\lambda$)

Moody's uses the Capital Asset Pricing Model (Jensen et al., 1972) framework to re-write the Sharpe ratio in an equivalent expression: $\frac{\mu - r}{\sigma} = \lambda\rho$, where ρ is the correlation between asset returns and market returns and λ is the market Sharpe ratio.

In this case, to compute the market price of risk, the EuroStoxx 50 Index was assumed as proxy for the market and the asset returns were computed from the countries' equity market benchmark indices. The obtained market prices of risk, as shown in Figure 4.1, were always positive over the analysed period, generating Q_t always higher than P_t.

Figure 4.1: Market Price of Risk with Sharpe Ratio (SR) and $\lambda\rho$ (LR)



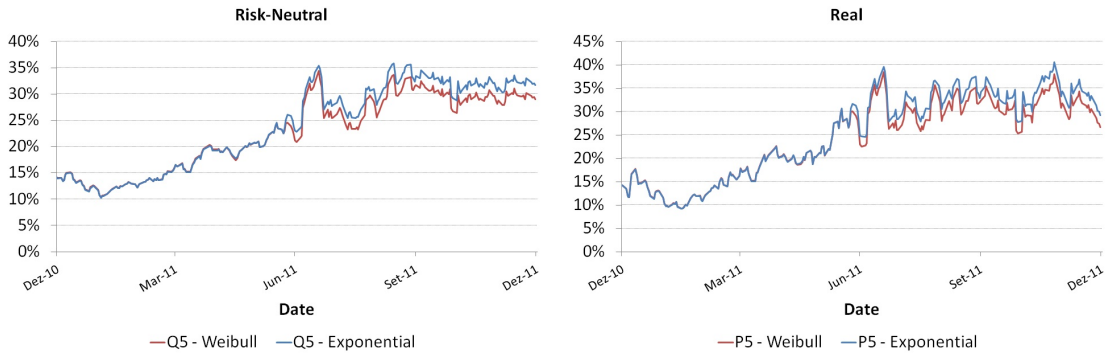
The real probabilities of default P_t are higher and more reactive under the Sharpe

ratio methodology rather than using $\lambda\rho$, in particular during the Lehman Brothers bankruptcy, the Greece's bailout and the beginning of the European sovereign debt crisis. Since the default probabilities reflect the market expectation about the credit worthiness of the entities, in those distressed times the probabilities tend to be higher and more volatile; therefore the results achieved in Chapter 3 seem more in line with the reality than using the CAPM model just described.

4.2 Exponential Distribution ($h_1 = 1$)

Since h_1 has proved to be very close to 1, during the period under analysis, for almost all countries, the particular case of the Exponential distribution (Weibull distribution with $h_1 = 1$) was also tested.

Figure 4.2: Portugal's Probabilities of Default: Weibull vs Exponential



The results obtained do not differ significantly from the ones described in Chapter 3, as well as for the estimated CDS spreads. Both probabilities of default, Q_t and P_t, for the 5-year tenor, are slightly higher than using the Weibull distribution, during the second half of 2011, for Ireland, Greece and Portugal (Figure 4.2). The other countries do not show any differences between Weibull and Exponential results for the probabilities of default (Figure 4.3).

The three countries that received financial aid show some negligible differences in the second half of 2011, while France and Germany illustrate exactly the same curve for both estimated CDS. Again, the estimated CDS spread are very similar to the real ones, reflecting the good fitting of the probability distribution function to the

data. Thus, the results obtained using the Exponential distribution support those obtained in the previous chapter.

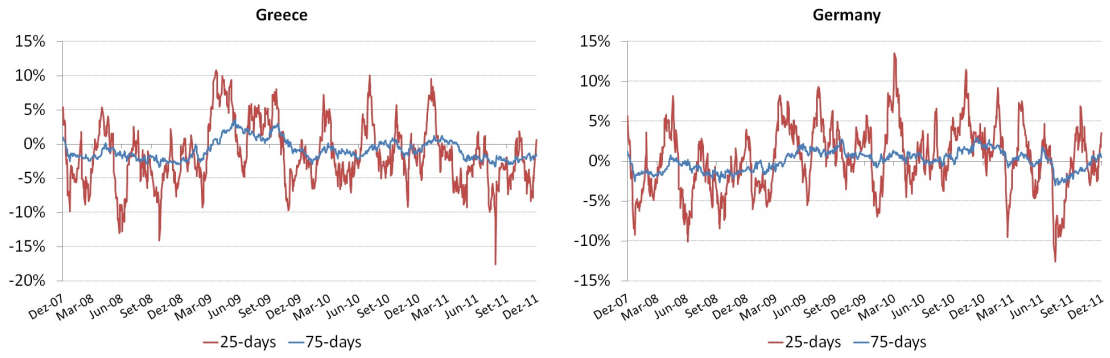
Figure 4.3: Germany's Probabilities of Default: Weibull vs Exponential

4.3 75-days window Simple Moving Average (SMA)

We obtain a smoother market price of risk by using a 75-days window in the SMA calculation, instead of 25-days, as can be seen in Figure 4.4. Short-term averages respond quickly to variations in the equity indices, while long-term averages are slow to react and therefore they are usually used to highlight trends.

The 75-days window's market price of risk ranges between -3,5% and 4,2% while the 25-days window's market price of risk goes from -19,2% to 12,2%, generating more distinct P_t and Q_t.

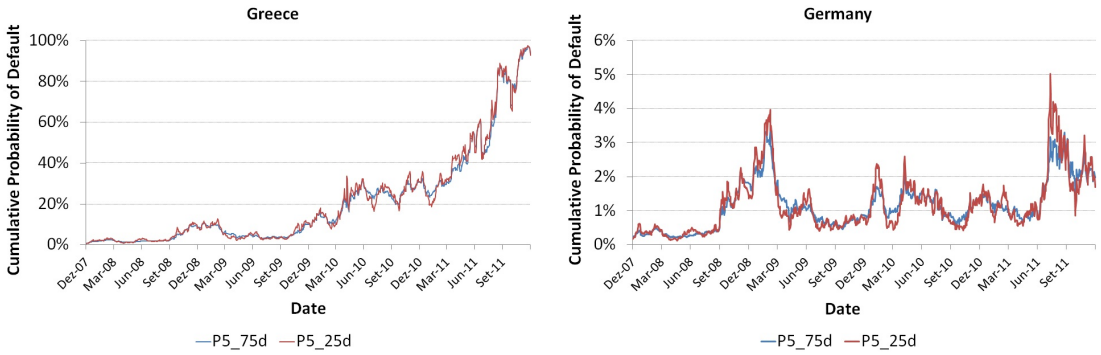
Figure 4.4: Market Price of Risk: Greece & Germany



Looking at Figure 4.5, we notice that the 25-days SMA real probability of default

is more reactive to market variations, reaching higher or lower values than the ones observed in the 75-days SMA probability. Within a crisis context, it is crucial to give more weight to recent market information in order to responde quickly to events. Thus, in our view, the 25-days SMA is more appropriated than the 75-days SMA to calculate the market price of risk.

Figure 4.5: 5-year Probabilities of Default with 25-days and 75-days SMA



Chapter 5

Conclusions

The aim of this thesis is to assess the real default probabilities of the European sovereigns in order to get a forward looking measure of the market sentiment about them, as well as their evolution within the current European crisis. For this purpose, we based on a framework which extracts risk-neutral probabilities of default (Q_t) from CDS spreads, assuming 25% of recovery rate[16], and converted them into real probabilities of default (P_t) by using an adaptation of the Merton model to remove the risk premium from the risk-neutral probabilities, assumed to follow a Weibull distribution. That premium is the market price of risk or Sharpe ratio, calculated from the equity market, and intends to reflect the investors' trade-off between risk and return. As the risk-neutral probabilities incorporate the risk premium of the market, they are expected to be higher than the real probabilities of default, unless there is a negative market price of risk ("flight to safety" phenomenon). In fact, this has happened often during the current crisis as the investors have preferred to allocate their funds to safer securities, even at negative yields, like bonds from France and Germany.

The obtained real default probabilities proved to be a good indicator to predict defaults according to the credit events. They have increased severely since 2009 and 2010, in particular for the peripheral economies - Greece, Ireland and Portugal. The Greece's 1-year probability of default reached 55% at the end of 2011 and a

[16]That assumption proved to be particularly suitable given that the Greek recovery rate was also around 25%.

default took place in March 2012. These countries had to request a bailout from the EU/IMF authorities, Greece and Ireland in 2010 and Portugal in April 2011, and at the end of 2011 the average CDS spread was 1.200 basis points, considering the three countries together. Spain and Italy, the central economies, have been a concern for investors, which is reflected in their real probabilities of default that increased substantially during the second half of 2011, from 5%-10% in 2010 to 10%-15% in 2011, and the two-countries' average CDS spread was 440 basis points. The *safe haven* economies - Germany and France - were also not immune to the economic slowdown in Eurozone and its GDP started to shrink. German 5-year CDS spreads were around 90 basis points at the end of 2011 and French spreads were around 200 basis points.

The effects of the crisis outside Eurozone can also be assessed by applying that methodology to other countries and financial institutions. Alternative approaches and data to calculate the market price of risk are left as a topic for future research, as they might impact substantially the real probabilities obtained. A complementary work could be to assess the impact of the monetary policy decisions on the banks and countries' CDS spreads as well as on their default probabilities.

Research about the European sovereign crises is very important in this context. As the individual Eurozone countries cannot adopt quantitative easing[17], all the possible solutions require multi-national cooperation and investors are still worried about the incapacity of the policy makers to quickly contain the crisis.

[17]One solution used in the past by countries in financial difficulties was to print money to pay debt holders. This practice is known as quantitative easing and might cause some problems, for instance, inflation. In the case of the Eurozone, the Euro currency is common; therefore, this measure cannot be implemented by each country on its own.

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Appendix A

A.1 Summary of the parameters and results

Figure A.1: Summary Table

				Q_t (in %)			P_t (in %)			Real CDS (basis points)			Estimated CDS (basis points)		
Ireland		**h0**	**h1**	**1y**	**5y**	**30y**	**1y**	**5y**	**30y**	**1y**	**5y**	**30y**	**1y**	**5y**	**30y**
Weibull	min	0,0010	0,7673	0,1%	0,5%	2,9%	0,1%	0,4%	1,9%	3	15	25	13	13	13
	max	0,0731	1,0000	10,4%	34,7%	85,7%	10,9%	37,0%	88,8%	1.399	1.194	1.009	1.486	1.184	992
Exponential	min	0,0010	-	0,1%	0,5%	2,9%	0,1%	0,4%	1,9%	3	15	25	13	13	13
	max	0,0872	-	8,4%	35,3%	92,7%	8,8%	37,6%	94,5%	1.399	1.194	1.009	1.163	1.163	1.163
Greece															
Weibull	min	0,0017	0,7081	0,2%	0,8%	4,9%	0,1%	0,6%	2,6%	9	21	40	22	22	22
	max	0,7502	1,0000	53,4%	96,8%	100,0%	55,4%	97,5%	100,0%	18.889	10.735	5.641	10.349	9.796	10.017
Exp	min	0,0017	-	0,2%	0,8%	4,9%	0,1%	0,6%	2,6%	9	21	40	22	22	22
	max	0,7514	-	52,8%	97,7%	100,0%	54,8%	98,2%	100,0%	18.889	10.735	5.641	10.019	10.019	10.019
Portugal															
Weibull	min	0,0015	0,7700	0,1%	0,7%	4,3%	0,1%	0,6%	2,1%	7	17	36	19	19	19
	max	0,0704	1,0000	10,8%	34,4%	84,4%	11,5%	38,5%	90,0%	1.501	1.224	968	1.598	1.201	993
Exp	min	0,0015	-	0,1%	0,7%	4,3%	0,1%	0,6%	2,1%	7	17	36	19	19	19
	max	0,0888	-	8,5%	35,9%	93,0%	9,1%	40,6%	96,6%	1.501	1.224	968	1.184	1.184	1.184
Spain															
Weibull	min	0,0014	0,9106	0,1%	0,7%	4,2%	0,1%	0,6%	2,8%	6	20	30	19	19	19
	max	0,0281	1,0000	2,9%	13,4%	57,0%	3,3%	16,5%	71,4%	377	395	372	392	383	375
Exp	min	0,0014	-	0,1%	0,7%	4,2%	0,1%	0,6%	2,8%	6	20	30	19	19	19
	max	0,0287	-	2,8%	13,3%	57,7%	3,2%	16,5%	71,6%	377	395	372	382	382	382
Italy															
Weibull	min	0,0016	0,9043	0,2%	0,8%	4,7%	0,1%	0,6%	2,3%	4	21	39	21	21	21
	max	0,0343	1,0000	4,1%	17,0%	64,2%	4,4%	18,8%	70,2%	556	502	451	565	501	457
Exp	min	0,0016	-	0,2%	0,8%	4,7%	0,1%	0,6%	2,3%	4	21	39	21	21	21
	max	0,0370	-	3,6%	16,9%	67,0%	3,8%	18,6%	73,6%	556	502	451	493	493	493
France															
Weibull	min	0,0005	0,9507	0,0%	0,2%	1,4%	0,0%	0,2%	0,6%	2	6	11	6	6	6
	max	0,0143	1,0000	1,4%	6,9%	34,8%	1,4%	8,6%	51,9%	123	199	231	190	190	190
Exp	min	0,0005	-	0,0%	0,2%	1,4%	0,0%	0,2%	0,6%	2	6	11	6	6	6
	max	0,0143	-	1,4%	6,9%	34,8%	1,4%	8,6%	51,9%	123	199	231	190	190	190
Germany															
Weibull	min	0,0004	0,9995	0,0%	0,2%	1,2%	0,0%	0,1%	0,4%	2	5	9	6	6	6
	max	0,0064	1,0000	0,6%	3,2%	17,5%	0,8%	5,0%	36,8%	77	91	101	86	86	86
Exp	min	0,0004	-	0,0%	0,2%	1,2%	0,0%	0,1%	0,4%	2	5	9	6	6	6
	max	0,0064	-	0,6%	3,2%	17,5%	0,8%	5,0%	36,8%	77	91	101	86	86	86

A.2 Additional graphs

Figure A.2: Greece's Probabilities of Default

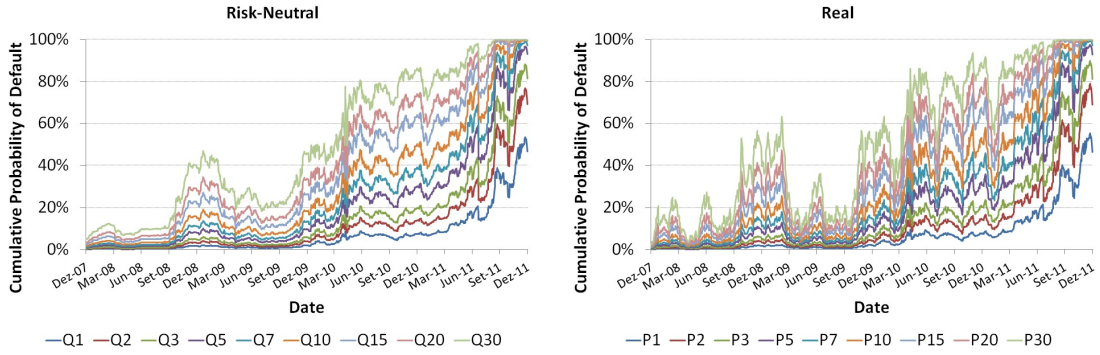


Figure A.3: Ireland's 5-year Probabilities of Default and Credit Default Spreads

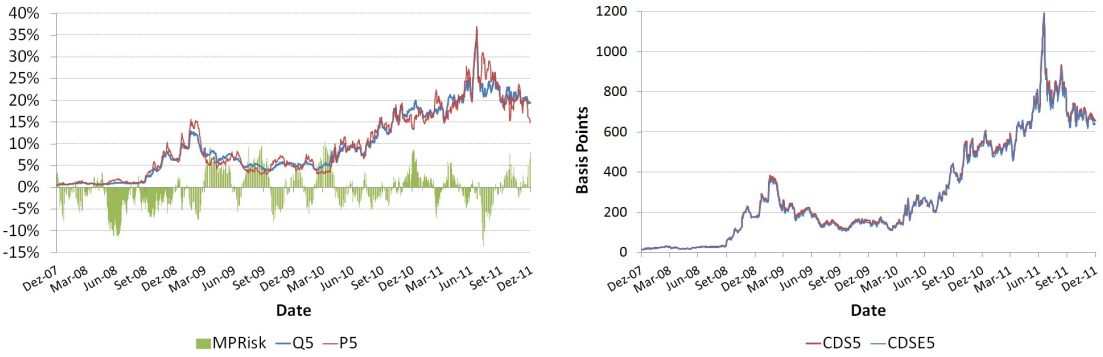


Figure A.4: Ireland's Credit Default Swap Spreads

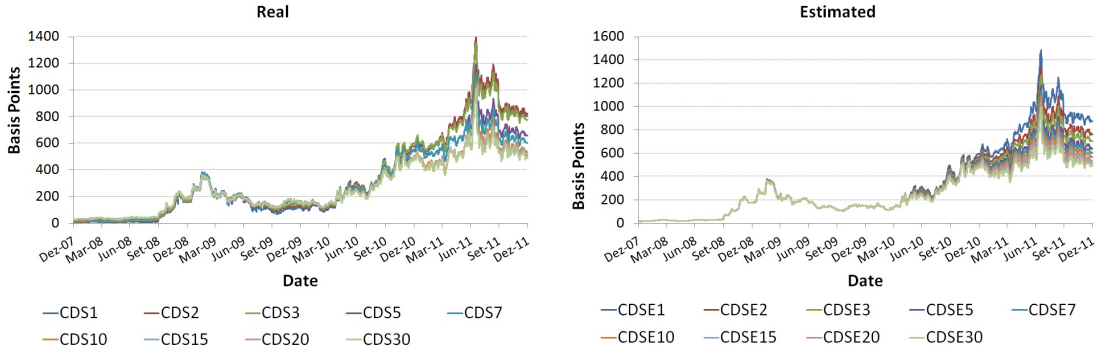


Figure A.5: Portugal's Probabilities of Default

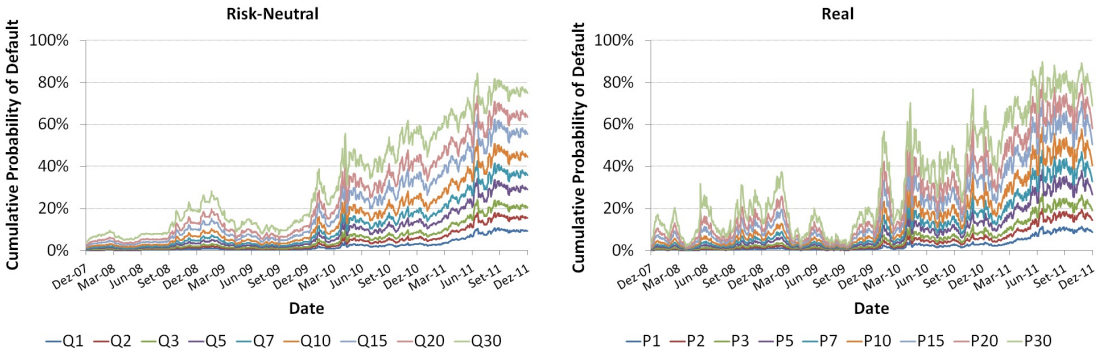


Figure A.6: Portugal's Credit Default Swap Spreads

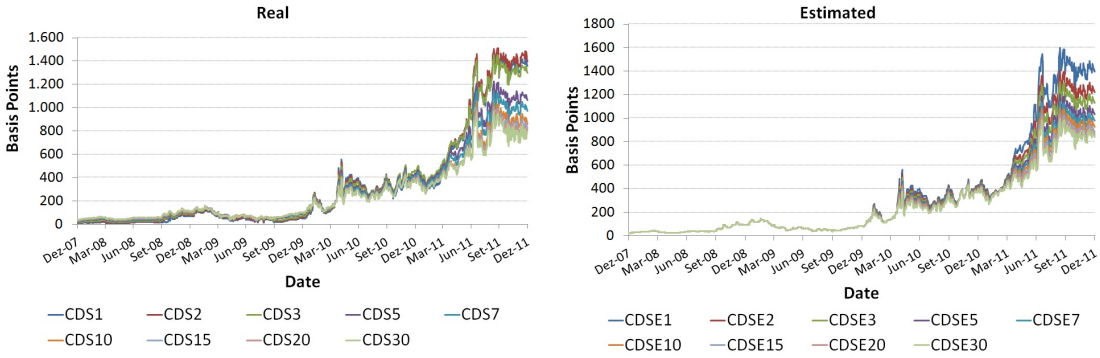


Figure A.7: Spain's Probabilities of Default

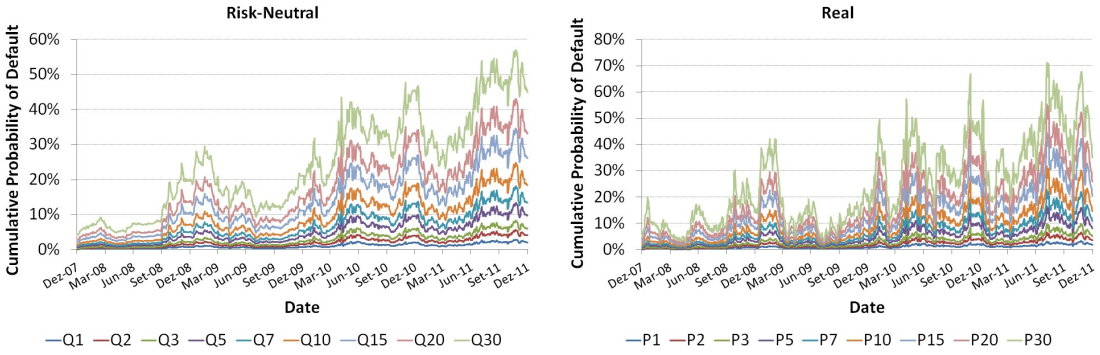


Figure A.8: Spain's Credit Default Swap Spreads

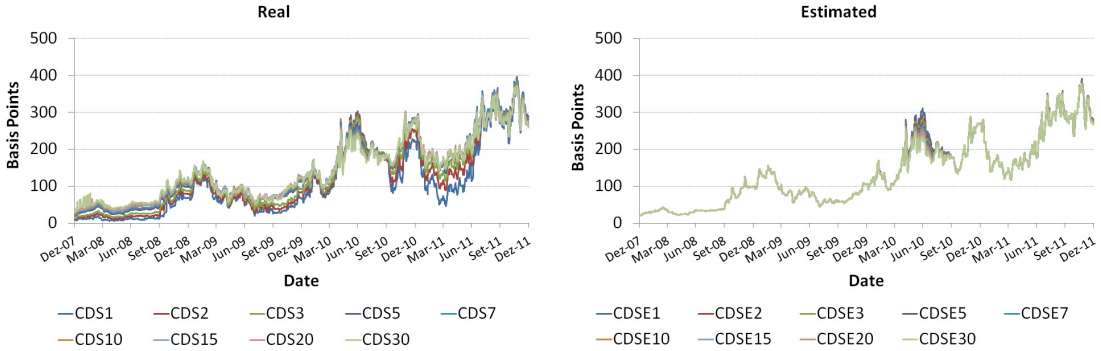


Figure A.9: Italy's Probabilities of Default

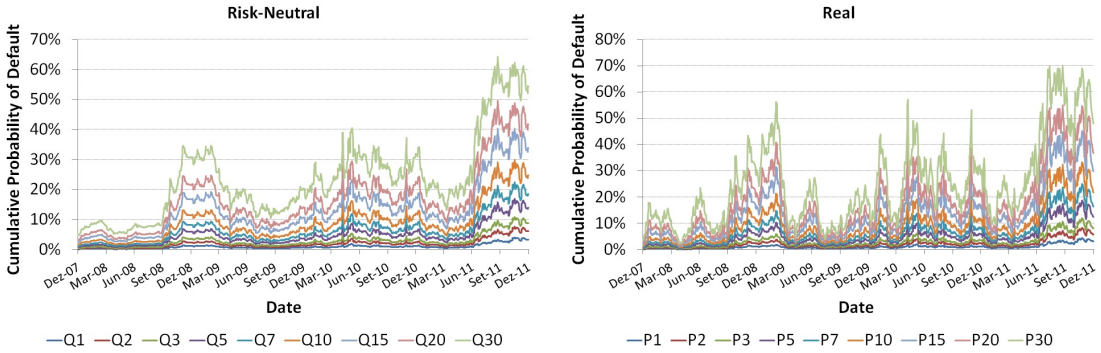


Figure A.10: Italy's Credit Default Swap Spreads

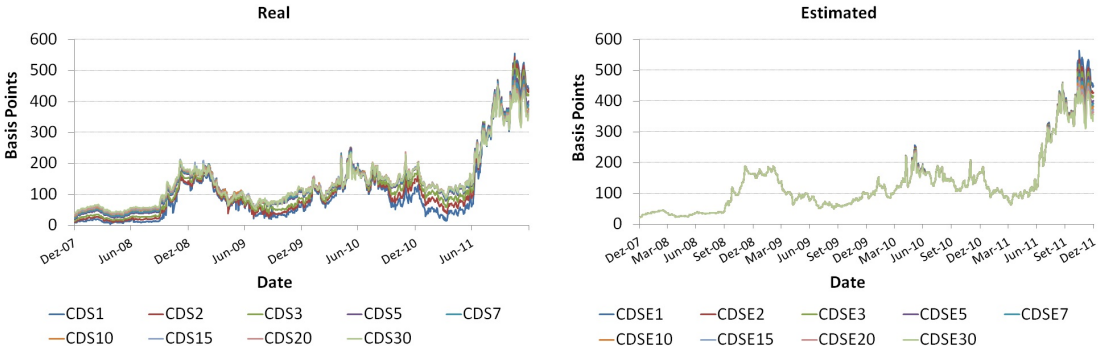


Figure A.11: France's Probabilities of Default

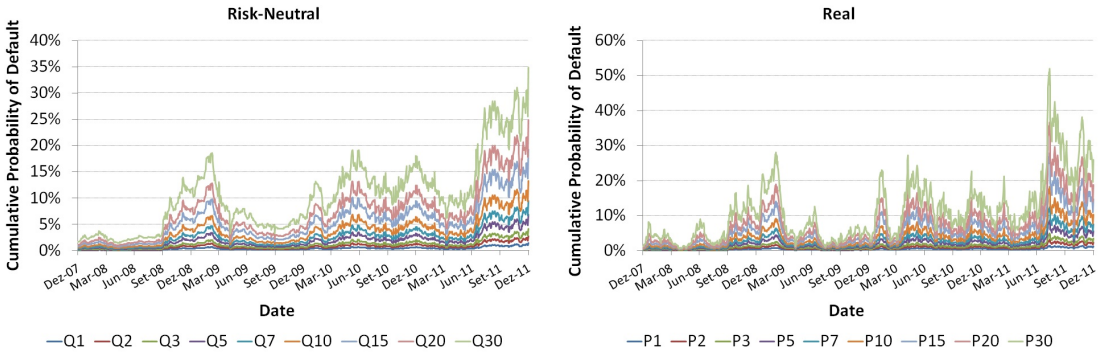


Figure A.12: France's Credit Default Swap Spreads

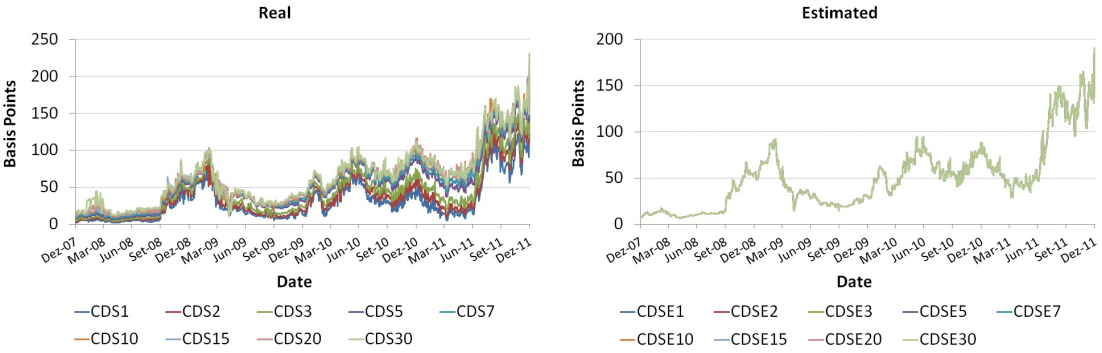


Figure A.13: Germany's Probabilities of Default

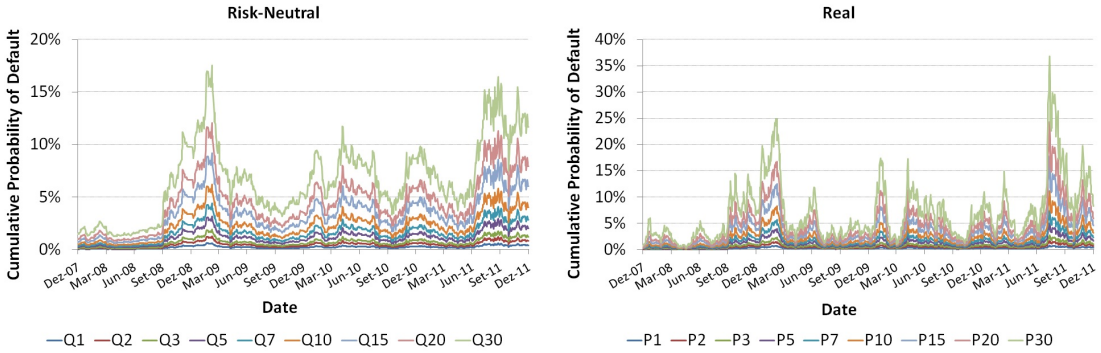
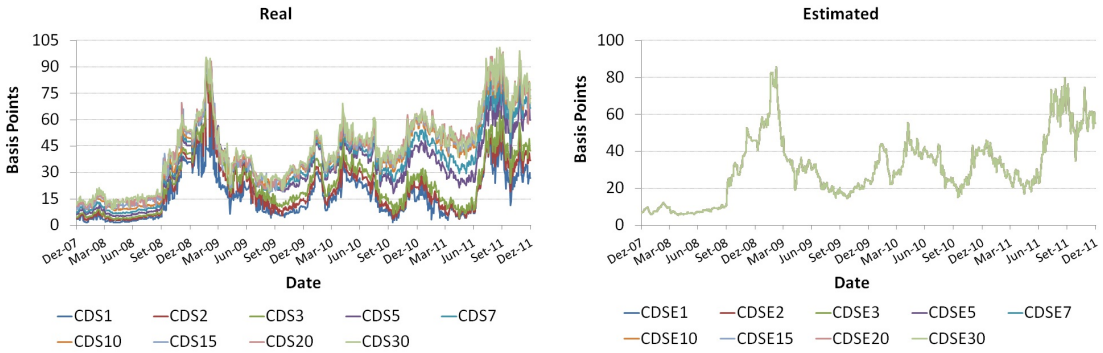


Figure A.14: Germany's Credit Default Swap Spreads



A.3 Economic Data (Moody's Investor Service)

Figure A.15: Real GDP (% change)

	2007	2008	2009	2010	2011
Eurozone	**2,8%**	**0,4%**	**-4,1%**	**1,8%**	**1,7%**
Ireland	**5,6%**	**-3,6%**	**-7,6%**	**-1,0%**	**0,6%**
Greece	**4,3%**	**1,0%**	**-2,0%**	**-4,5%**	**-3,5%**
Portugal	**2,4%**	**0,0%**	**-2,5%**	**1,3%**	**-2,2%**
Spain	**3,6%**	**0,9%**	**-3,7%**	**-0,1%**	**0,8%**
Italy	**1,5%**	**-1,3%**	**-5,2%**	**1,3%**	**1,0%**
France	**2,4%**	**0,2%**	**-2,6%**	**1,6%**	**1,6%**
Germany	**2,7%**	**1,0%**	**-4,7%**	**3,6%**	**2,6%**

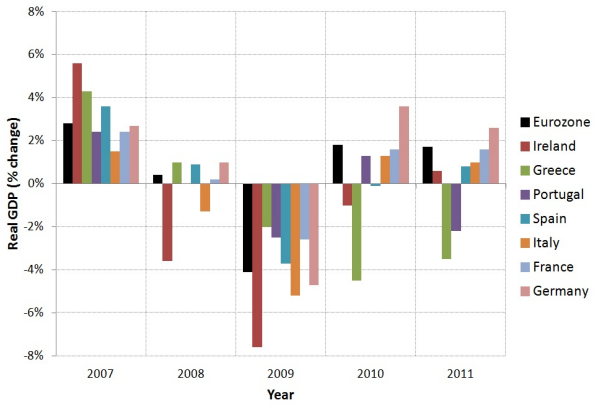


Figure A.16: Inflation (CPI, % change Dec/Dec)

	2007	2008	2009	2010	2011
Eurozone	**3,1%**	**1,6%**	**0,9%**	**2,3%**	**2,9%**
Ireland	**3,2%**	**1,3%**	**-2,6%**	**-1,0%**	**1,0%**
Greece	**3,9%**	**2,0%**	**2,6%**	**5,2%**	**1,4%**
Portugal	**2,7%**	**0,8%**	**-0,1%**	**2,5%**	**1,4%**
Spain	**4,2%**	**1,4%**	**0,8%**	**3,0%**	**2,0%**
Italy	**2,6%**	**2,3%**	**1,0%**	**1,5%**	**1,7%**
France	**2,8%**	**1,2%**	**0,1%**	**1,7%**	**2,0%**
Germany	**3,1%**	**1,1%**	**0,9%**	**1,0%**	**1,2%**

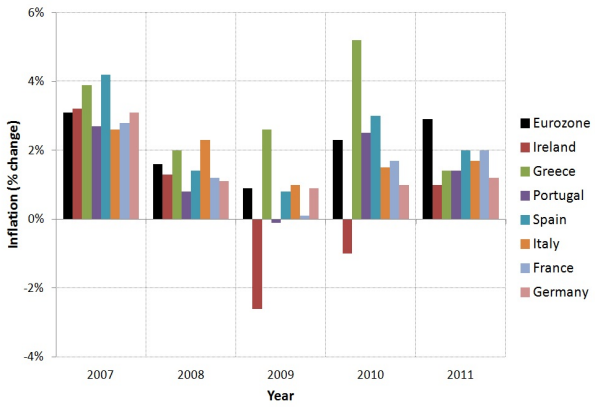


Figure A.17: Unemployment Rate (%)

	2007	2008	2009	2010	2011
Eurozone	**7,6%**	**7,6%**	**9,6%**	**10,1%**	**10,0%**
Ireland	**4,6%**	**6,3%**	**11,9%**	**14,2%**	**13,5%**
Greece	**8,3%**	**7,7%**	**9,5%**	**12,6%**	**14,8%**
Portugal	**8,1%**	**7,7%**	**9,6%**	**11,0%**	**12,3%**
Spain	**8,3%**	**11,3%**	**18,0%**	**20,1%**	**19,8%**
Italy	**6,1%**	**6,7%**	**7,8%**	**8,4%**	**8,5%**
France	**8,4%**	**7,8%**	**9,5%**	**9,7%**	**9,0%**
Germany	**8,7%**	**7,5%**	**7,8%**	**7,1%**	**6,4%**

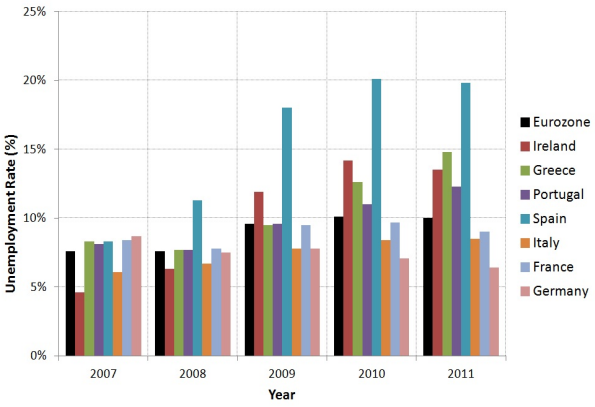


Figure A.18: Deficit/Surplus (%GDP)

	2007	2008	2009	2010	2011
Eurozone	**-0,7%**	**-2,0%**	**-6,3%**	**-6,0%**	**-4,3%**
Ireland	**0,1%**	**-7,3%**	**-14,3%**	**-32,4%**	**-10,5%**
Greece	**-6,4%**	**-9,8%**	**-15,4%**	**-10,5%**	**-8,5%**
Portugal	**-3,3%**	**-3,6%**	**-10,1%**	**-9,2%**	**-5,9%**
Spain	**1,9%**	**-4,2%**	**-11,1%**	**-9,2%**	**-6,6%**
Italy	**-1,5%**	**-2,7%**	**-5,3%**	**-4,5%**	**-3,9%**
France	**-2,7%**	**-3,3%**	**-7,5%**	**-7,0%**	**-5,8%**
Germany	**0,3%**	**0,1%**	**-3,0%**	**-3,3%**	**-2,0%**

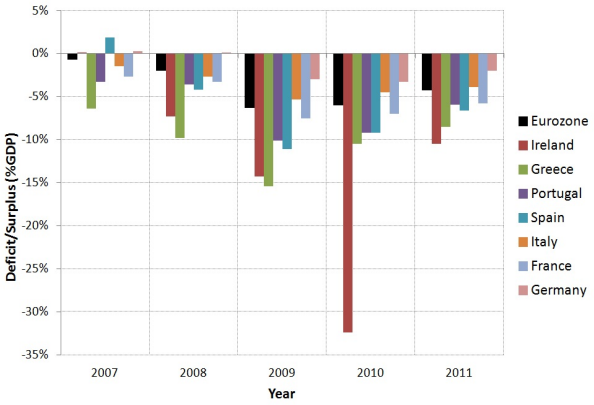
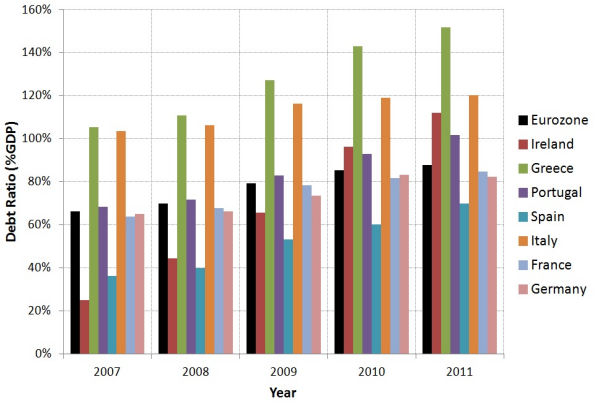


Figure A.19: Debt Ratio (%GDP)

	2007	2008	2009	2010	2011
Eurozone	**66,2%**	**69,9%**	**79,3%**	**85,4%**	**87,7%**
Ireland	**25,0%**	**44,3%**	**65,6%**	**96,2%**	**112,0%**
Greece	**105,4%**	**110,7%**	**127,1%**	**142,8%**	**151,8%**
Portugal	**68,3%**	**71,6%**	**83,0%**	**93,0%**	**101,7%**
Spain	**36,1%**	**39,8%**	**53,3%**	**60,1%**	**70,0%**
Italy	**103,6%**	**106,3%**	**116,1%**	**119,0%**	**120,3%**
France	**63,9%**	**67,7%**	**78,3%**	**81,7%**	**84,7%**
Germany	**64,9%**	**66,3%**	**73,5%**	**83,2%**	**82,4%**



A.4 Crisis timeline (2007 - Q1/2012)

9-Ago-07	Tensions related to US sub-prime mortgages start to cause shortages of liquidity in money markets around the world.
17-Fev-08	Northern Rock is taken into state ownership by the Treasury of the United Kingdom.
7-Set-08	The Federal Housing Finance Agency (FHFA) places Fannie Mae and Freddie Mac in government conservatorship.
15-Set-08	Lehman Brothers files for bankruptcy.
16-Set-08	The Federal Reserve Board authorizes the Federal Reserve Bank of New York to lend up to $85 billion to the American International Group (AIG) under Section 13(3) of the Federal Reserve Act.
30-Set-08	Ireland guarantees all deposits and most debt liabilities of its banks. Irish 10-year bonds yields 4,59%.
3-Out-08	Congress passes and President Bush signs into law the Emergency Economic Stabilization Act of 2008, which establishes the $700 billion Troubled Asset Relief Program.
8-Out-08	ECB decides on extraordinary liquidity measures.
26-Nov-08	The Federal Reserve Board announces approval of the notice of Bank of America Corporation to acquire Merrill Lynch and Company.
14-Jan-09	S&P cuts Greece to A- from A. The rating company cites the country's weakening finances as the global economy slowed. Greek 10-year bond yields rise to 5.43 percent the next day.
19-Jan-09	S&P cuts Spain to AA+ from AAA.
4-Jun-09	ECB launches first covered bonds programme - Eurosystem starts to purchase euro-denominated covered bonds issued in the euro area.
20-Out-09	New Greek Finance Minister Papaconstantinou says deficit will balloon to 12,5% of GDP this year, more than double the previous government's forecast. Yield on Greek 10-year bond 4,58%.
16-Dez-09	S&P Cuts Greece to BBB+ from A-, three steps above junk.
8-Mar-10	Portuguese government announces new budget cuts, more asset sales and a freeze on public wages.
21-Mar-10	EU offers support to Greece - Euro area leaders agree, together with the IMF, to offer financial support to Greece if the country should ask for it.
24-Mar-10	Fitch cuts Portugal's credit rating to AA-.
30-Mar-10	Ireland says country's banks need to raise an additional 31.8 billion euros of capital.
22-Abr-10	The EU revises Greece's 2009 budget deficit to 13,6% of GDP, higher than the government's previous forecast of 12,9%. Ireland overtakes Greece as the EU nation with the largest deficit. Moody's cuts Greece one level to A3.
23-Abr-10	Greece seeks financial support.
27-Abr-10	S&P become first rating company to cut Greece to junk and downgrades Portugal to A-.
27-Abr-10	S&P cuts Spain's credit rating for second time since January 2009, pushing the euro to a one-year low of $1.3115.
2-Mai-10	110 M€ Loan package for Greece agreed - The euro area countries and the IMF agree on a €110bn loan package to Greece.
6-Mai-10	Greek Parliament approves deficit cuts. Greek 10-year yields reach 12 percent the next day.
12-Mai-10	Spain announces public-wage cuts and a pension freeze while Portugal says it will lower the salaries of top government officials and increase taxes. Spain cuts deficit target to 6% in 2011 and trims growth outlook.
28-Mai-10	Fitch cuts Spain's AAA rating one level to AA+.
7-Jun-10	The European Financial Stability Facility is established.
14-Jun-10	Moody's cuts Greece to junk.
13-Jul-10	Greece returns to bond markets for first time since bailout, selling 1.62 billion euros of six-month bills.
13-Jul-10	Moody's Investors Service downgrades Portugal's government-bond rating to A1 from Aa2, with a stable outlook, pointing to the country's weak fiscal position and low growth propspects.

19-Jul-10	Moody's Investor Services cut Ireland's credit rating to Aa2 from Aa1. Moody cites a rising debt burdgen, a weak growth outlook and the high cost of rebuilding a shattered banking system.
24-Ago-10	Standard & Poor's cuts its rating on Ireland by one notch to AA- because of concern over the costs of shoring up the country's banking system.
30-Set-10	Ireland prepares to take majority control of Allied Irish Banks Plc and pump extra cash into Anglo Irish Bank Corp. Ireland says its banking collapse will cost it far more than expected. Moody's cuts Spain's AAA rating to Aa1.
21-Nov-10	Ireland seeks financial support.
23-Nov-10	S&P Cuts Ireland two steps to A from AA-.
7-Dez-10	EU-IMF package for Ireland agreed.
23-Dez-10	Fitch cuts Portugal to A+.
14-Jan-11	Fitch follows S&P and Moody's in cutting Greece to junk.
7-Mar-11	Moody's cuts Greece's credit rating to B1 from Ba1.
23-Mar-11	Portugal's Prime Minister Jose Socrates resigns after opposition rejects austerity package.
6-Abr-11	Portuguese Prime Minister Jose Socrates requests EU bailout, saying he "tried everything" to avoid seeking aid.
9-Mai-11	S&P cuts Greece two levels to B from BB- and threatens further cuts.
17-Mai-11	EU Council approves Portugal's 78 billion-euro bailout and sets conditions
13-Jun-11	S&P Cuts Greece to CCC, the lowest rating for any country it reviews in the world.
24-Jun-11	Draghi appointed to succeed Trichet as president of the ECB
30-Jun-11	Greek lawmakers approve the austerity plan after two votes in two days marred by violent protests outside parliament.
5-Jul-11	Moody's cuts Portugal to junk.
12-Jul-11	Moody's cuts Ireland to junk.
25-Jul-11	Moody's cuts Greek debt by three notches to Ca - The second bail-out of Greece will weaken the credit ratings of Italy and Spain as well as resulting in a default for Athens, Moody's says.
14-Set-11	Italian parliament gives final approval in a confidence vote to a 54 billion-euro austerity package to balance the budget in 2013.
19-Set-11	Standard & Poor's cuts Italy's credit rating for the first time in almost five years, downgrading it to A from A+.
30-Set-11	Spanish bank bailout fund takes over three more savings banks, valuing them between 0 and 12% of book value and saying the overhaul of the financial industry is complete. Portugal revises up 2010 budget deficit to 9,8%.
4-Out-11	Moody's cuts Italy for the first time in almost two decades, lowering the rating to A2 from Aa2.
7-Out-11	Fitch cuts Spain to AA- and Italy to A+.
26-Out-11	After talks in Brussels, the leaders say some private banks holding Greek debt have accepted a loss of 50%. Banks must also raise more capital to protect them gainst losses resulting from any future government defaults.
1-Nov-11	Draghi succeeds Trichet as ECB president.
3-Nov-11	Draghi unexpectedly cuts interest rates at his first meeting, from 1,5% to 1,25%.
6-Nov-11	Papandreou agrees to step aside to make way for a government of national unity. Greek 10-year bonds yield 25,52%. Spanish 10-year bonds yield 5,56%. Italian 10-year bonds yield 6,35%. German 10-year bonds yield 1,80%.
8-Dez-11	ECB lowers interest rates by 25 basis points, from 1,25% to 1%.
16-Jan-12	The credit ratings agency Standard & Poor's has downgraded the EU bailout fund to AA+ from AAA.
19-Jan-12	S&P's rating of Italy - currently at the epicentre of the crisis - has been cut two notches from A to BBB+. Spain was also cut two notches from AA- to A, as was Portugal, whose rating fell from BBB- to a "junk" rating of BB.
21-Fev-12	Eurogroup agrees on second financial aid package for Greece.
9-Mar-12	ISDA declares that, upon the conclusion of an exchange of 177 billion Euros of Greece's sovereign's debt, the exchange was a credit event under the terms of its CDS.

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A.5 Credit Ratings from the largest Rating Agencies

	Moody's	Standard & Poor's	Fitch
Investment Grade	Aaa	AAA	AAA
	Aa1	AA+	AA+
	Aa2	AA	AA
	Aa3	AA-	AA-
	A1	A+	A+
	A2	A	A
	A3	A-	A-
	Baa1	BBB+	BBB+
	Baa2	BBB	BBB
	Baa3	BBB-	BBB-
Speculative Grade/Junk	Ba1	BB+	BB+
	Ba2	BB	BB
	Ba3	BB-	BB-
	B1	B+	B+
	B2	B	B
	B3	B-	B-
	Caa1	CCC+	CCC
	Caa2	CCC	CC
	Caa3	CCC-	C
	Ca	CC	RD
	C	SD and D	D
	WR	NR	WD
			PIF
			NR