NTNU – Trondheim
Norwegian University of
Science and Technology

Drivers of Euro Area Yield Spreads: Economic Fundamentals or Psychology?

A study of long term government bond yield spreads from 1990 to 2014

Hanne Abrahamsen Selvik
Helene Ege Tørres

Industrial Economics and Technology Management
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Supervisor: Einar Belsom, IØT

Norwegian University of Science and Technology
Department of Industrial Economics and Technology Management

Problem Description

Purpose: Examine the drivers of government bond yield spreads in different time regimes.

Main content: Review and discuss literature on drivers of government bond yield spreads in the euro area (GIPSI).

Consider various drivers and their impact on yield spreads, with emphasis on market sentiments and spillover effects (psychology). Develop a panel data model for yield spreads, which distinguishes between countries.

Evaluate the model using theoretical and/or empirical analysis.

Preface

We have written this Master's thesis as the concluding part of our Master's degree program at the Department of Industrial Economics and Technology Management (IØT) at the Norwegian University of Science and Technology (NTNU).

We would like to thank our supervisor at the IØT department, Associate Professor Einar Belsom, for guiding us through the entire process of this thesis. He has also provided us with great experience within the fields of processing imperfect data sets and econometric modelling. Furthermore, we express gratitude towards PhD student Kari Krizak Halle at the Mathematics Department (IMF) at NTNU for providing us with knowledge of mixed effects panel data models. We also wish to thank PwC for support through the PwC Scholarship. We especially thank Manager Thor Christian Grosås and Manager Øystein Fossen Thorud at PwC for their assistance, and for sharing their professional expertise throughout the process.

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Hanne Abrahamsen Selvik and Helene Ege Tørres

Abstract

We analyze government bond yield spreads in Greece, Ireland, Portugal, Spain, and Italy from 1990 to 2014. Seeking to identify the effects of economic fundamentals and psychology, we split the time period into four regimes of relatively consistent risk perception. We fit moving average models for each regime, thus allowing relationships between explanatory variables to fundamentally differ across countries and time periods. To distinguish between common movements and country-specific deviations we also fit mixed effects panel data models. We combine the regressions with a spillover analysis to understand how the Greek government bond market affects the others, both with respect to interdependence and contagion. Our findings suggest that fundamentals drive the spreads in the long run, while psychology outweighs these factors in shorter time periods in response to economic events.

Sammendrag

Vi studerer rentedifferanser for statsobligasjoner i Hellas, Irland, Portugal, Spania og Italia fra 1990 til 2014. For å måle effekten av fundamentale økonomiske faktorer og psykologi deler vi tidsperspektivet inn i kortere perioder med relativt stabil risikooppfatning. Vi gir parametrene fleksibilitet på tvers av land og tid ved å tilpasse modeller med glidende gjennomsnitt til hvert land i hvert regime. For å skille mellom felleseffekter og landspesifikke avvik tilpasser vi en paneldatamodell med lineære kombinerte effekter til hvert regime. Regresjonsanalysene kombineres med en analyse av smitteffekter fra det Greske statsobligasjonsmarkedet til de fire andre. Vi skiller mellom spredning fra faktisk økonomisk avhengighet og psykologiske smitteeffekter. Funnene våre tyder på at fundamentale faktorer driver spreaden på lang sikt, mens psykologi overskygger disse på kortere sikt som reaksjon på økonomiske hendelser.

Contents

List of Figures

List of Tables

Chapter 1

INTRODUCTION

Fear of fear itself may have a self-fulfilling effect on financial markets. Indications of herding behavior among investors in the euro area suggests that the financial situation cannot adequately be explained with economic fundamentals. In 2009, the Greek debt was 125 percent of GDP. At the time, fear of a Greek debt crisis spread among investors, leading to a loss of confidence and increase in government bond yield spread. The severe spread since then has lead Greece into a downward spiral, and the debt level has now risen to 175 percent. Investors' aptitude to act on fear as well as hard numbers introduce psychology as a possible driver of yield spreads. The size of yield spreads is an especially interesting topic in the euro area, as it determines the financing costs of public debt in countries where the governments can issue bonds, but have no power to increase money supply or force inflation to cope with excessive debt.

The question of what drives euro area yield spreads over time has attracted considerable interest in the literature. Spreads on government bonds are traditionally assumed to reflect a country's default risk. Findings present conflicting views on whether the perceived default risk is driven by fiscal fundamentals, market sentiments or spillover effects. Aßmann and Boysen-Hogrefe (2012) study the time period from 2003 to 2010, and find that fiscal fundamentals and debt in particular are the most important determinants. Specifically, they find that variable significance changes over time, and therefore a flexible model is favorable. Ang and Longstaff (2013) add to the view that fiscal fundamentals are the main drivers of yield spreads. De Grauwe (2012), on the other hand, examines the spreads from 2000 to 2010 and finds that countries with substantially different economic fundamentals were charged with the same risk premiums. He defines this behavior as systematic mispricing and claims that market sentiments is the most important determinant of yield spreads. Caceres et al. (2010) and Beirne and Fratzscher (2013) argue that also cross-country relations and spillover effects must be considered to understand the drivers of yield spreads.

Our purpose with this thesis is to provide new insights into the drivers of yield spreads in the euro area by extending the current literature in six ways. First, our analysis stretches over a considerable time perspective, including the decade from 1990 to 1999 before the countries adopted the common currency. This provides a wider understanding of the yield spread drivers over time, as well as the advantage of describing the perceived default risks of each country while they still controlled their own currency, and likely were judged more individually by the market. Second, we split the time perspective into shorter time regimes, to understand the changes in risk perception over time. The regimes add an extensive flexibility to our analysis, in that we allow for the drivers to fundamentally change over time. Third, we define a moving average model for each country in each regime. This gives flexibility for the drivers to change both across time and countries, in terms of significance and magnitude. Fourth, we define a panel data model for each regime where we extract the common effects, and isolate each country's deviation from this common movement. This enables us to analyze the common movement compared to the country-specifics. Fifth, we introduce an analysis of spillover effects that includes both interdependence and contagion. This allows us to distinguish spillover effects originating from actual economic interaction from those caused by psychology. We are thus able to consider spillovers as an integrated part of our study of fundamentals versus psychology as yield spread drivers. Last, we consider spillovers among the most distressed euro area countries, and not from these to the rest of the euro area, as previous work does. Overall, we hope to contribute to a broad understanding of the role of fundamentals and psychology as drivers of yield spreads over time.

We analyze the government bond yield spreads for Greece, Ireland, Portugal, Spain, and Italy (GIPSI) with Germany as benchmark, as German yields are generally considered risk free (Codogno et al., 2003; Aßmann and Boysen-Hogrefe, 2012; Favero, 2013). The time period we consider spans from first quarter 1990 to last quarter 2014, see Figure 1.1.

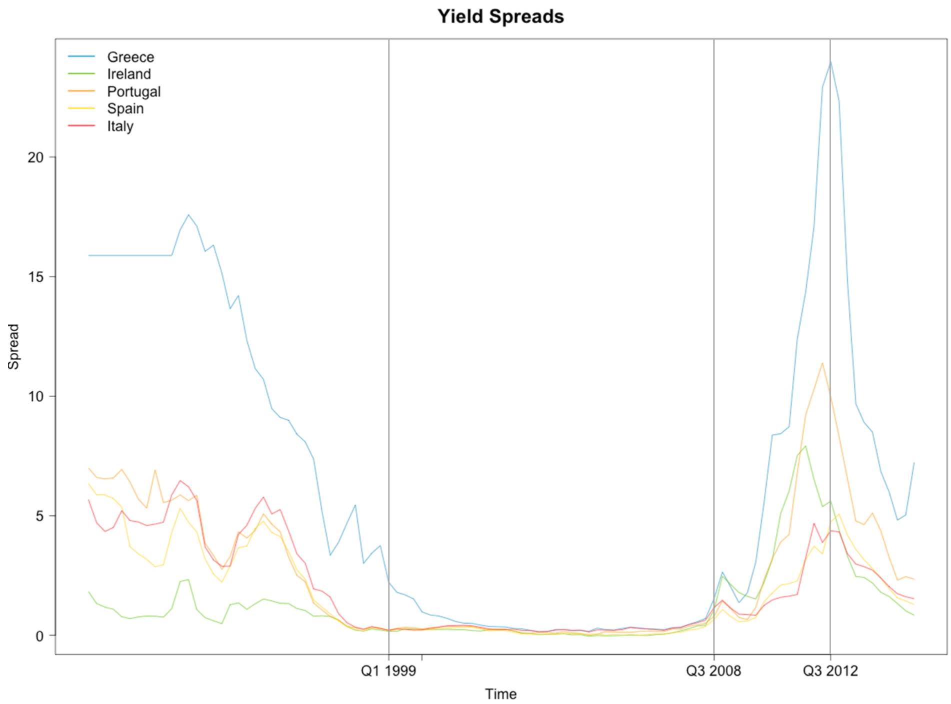


Figure 1.1: Yield spreads on government bonds in the GIPSI-countries

As Figure 1.1 suggests, we split the time perspective into four regimes. Each regime represents a time interval where the market's perception of risk is relatively consistent. The abrupt shifts in risk aversion seem to be triggered by economic events. For the time perspective considered, we observe three such events:

1. The countries' adoption of the euro on January 1st 1999 (except Greece, where the euro was introduced two years later)
2. Lehman Brother's file for bankruptcy on September 15th 2008
3. The European Central Bank's (ECB) announcement of the Outright Monetary Transactions program (OMT) on August 2nd 2012

The hypothesis which form the foundation for this thesis is that fiscal fundamentals drive the yield spreads in the long run, while psychology outweighs these factors on a short term. Investors' tendency to herd may lead to periods of either under- or over-estimation of a country's default risk. We believe that economic announcements change the market's appetite for risk. We also suspect that the common currency has lead the market to exaggerate the economic interdependence between the GIPSI-countries, and thus a pure psychological contagion effect contributes to a common movement of the yield spreads.

Over the long run, we believe that the spreads will be adjusted towards the "true" default risk, determined by the fundamentals.

Allow us to specify the hypothesis in conjunction with the regime framework. The first regime is defined as the time period before the countries adopted the common currency. It seems that the spreads in Regime I provide a sensible judgement of each country's individual default risk. However, during this regime the spreads are declining. De Grauwe and Ji (2012) argue that this decline occurs as a result of yield manipulation, motivated by the countries' ambition to reach the interest rate threshold demanded by the Maastrich Treaty. Regime II spans over the decade after the euro was introduced. It appears that the countries are judged holistically, in that they are assumed to possess a very similar default risk. The government bonds in this time period seem to be underpriced. Regime III is set off by the Lehman collapse. The spreads quickly escalate and the comovements between the countries decrease. The differences in sovereign risks between countries are again apparent. It seems that in Regime III the fiscal fundamentals are significant factors of the spreads, and likely so in an exaggerating manner, as the sovereign risks at the end of this regime seem to be overpriced. Regime IV is initiated by ECB's announcement of the OMT program, when the spreads again abruptly decline. We here expect the decline to represent an adjustment to the overpricing of risk in Regime III.

The thesis proceeds as follows. In Chapter 2 we analyze the movements of the yield spreads across regimes and countries. We apply our regime framework, and fit two regression models to measure the impact of fundamentals and psychology on the yield spreads. We apply a moving average model to give flexibility both across regimes and countries, and a panel data model to observe the common movements in each regime compared to the country-specific deviations. In Chapter 3 we consider spillover effects in the GIPSI-area. We study sources of spillovers and perform a cross-market correlation analysis, to understand how Greece affects the other countries' yield spreads. In Chapter 4 we explain the overall implications of our regression- and correlation results. We address the consequences of herding behavior, self-fulfilling prophecies, and policy announcements on the yield spreads. In Chapter 5 we comment on model limitations and draw an aggregate conclusion on fundamentals and psychology as drivers of yield spreads.

Chapter 2

SOVEREIGN EFFECTS

Spreads on government bonds are traditionally assumed to reflect a country's default risk. Given the size of government debt, even small variations in the yield may entail significant costs for the country in debt. Understanding what drives the yield spreads is thus crucial. In Figure 1.1 we observe how announcements suddenly change the characteristic of the spreads. This indicates that the yield spreads are influenced by psychology and cannot adequately be explained by economic fundamentals. In this chapter we introduce two regression models to examine the drivers of yield spreads in Greece, Ireland, Portugal, Spain, and Italy over time.

The chapter proceeds as follows. First, we consider the literature on modeling yield spreads, present our choice of explanatory variables and address the regime division. Second, we apply a moving average model. Third, we present a mixed effects panel data model to identify the common drivers in each regime. Last, we combine our results from the two models and discuss the findings in light of our hypothesis.

1 Modeling Spreads

In this section we form the basis for our regression analyses. First, we discuss literature on determinants of spreads, and present our choice of explanatory variables. Next, we consider the characteristics of the data, and explain how the data was acquired. Last, we define the regime division.

1.1 Literature on Determinants of Spreads

The literature adapts a large variety of explanatory variables to describe the euro area yield spreads. These can generally be divided into two groups; fiscal fundamentals and cross-country market sentiments (i.e. psychology).

Examples of fiscal fundamentals used to model spreads are debt to GDP, growth of debt to GDP, growth of real GDP, unemployment rate, growth of the consumer price index, accumulated net foreign debt, net current account, and sovereign market liquidity measured by bid-ask-spread (Aßmann and Boysen-Hogrefe, 2012; Dewachter et al., 2014; De Grauwe and Ji, 2014).

Factors used in the literature to measure market sentiments are the Chicago Board Options Exchange Market Volatility Index (VIX), the Eurex Stock Exchange's Market Volatility Index (VSTOXX), and the European Commission's Economic Sentiment Indicator (ESI) (Dewachter et al., 2014; Arghyrou and Kontonikas, 2012). The VIX communicates the implied volatility of the S&P500 stock market index, which is a measure of global uncertainty in the financial markets based on the American stock market. The VSTOXX is the European counterpart, based on options on European stocks. The ESI is based on qualitative measures, and expresses expected outlook for each country in the euro area. The ESI is not further assessed as it does not cover data for Ireland. Haugh et al. (2009) use corporate bond spreads for the psychological effects, and argue that one should prefer US data over European to avoid the risk of endogenous variables. Other psychological factors include fear that the monetary union will collapse (Ang and Longstaff, 2013; Dewachter et al., 2014; Favero, 2013).

A clear majority of the models includes both fundamentals and psychological factors. However, their explanatory powers differ. Ang and Longstaff find that yield spreads in the euro area are mainly driven by fiscal fundamentals, while De Grauwe (2012) argues that mispricing is present and thus emphasizes the role of market sentiments.

We saw in Figure 1.1 that the yield spreads suddenly change in response to economic events. As mentioned in our hypothesis, it is not likely that the underlying fiscal fundamentals behave in the same abrupt way. This assertion implies that the significances of the variables change over time.

1.2 Choice of Explanatory Variables

Spreads are traditionally assumed to reflect a country's default risk. In our attempt to model the movements of the yield spread, it is therefore natural to consider various fiscal fundamentals as explanatory variables. Additionally, we believe that psychology plays an important role in determining spreads. In this section we take a closer look at four possible explanatory variables for the yield spread.

1.2.1 Fiscal Fundamentals

The GDP is an estimate of economic performance as it measures a country's production. The change in GDP is therefore a proxy for economic health, indicating whether an economy is in growth or decline. We believe this is closely linked to the risk premium on government bonds in a country; we expect a growing economy to contribute to decreasing spreads.

Debt to GDP measures a country's solvency risk. A high debt ratio indicates that a country might be struggling to meet its obligations, which makes it riskier to invest in its government bonds. If the debt ratio increases, we expect investors to ask for a higher risk premium.

The unemployment rate is a symptom of economic health in a country. High unemployment is related to lowered production and social inequality. As a result, a higher unemployment rate is linked to a higher risk premium. We note that the direction of the causality between spread and unemployment rate is not clear, and unemployment rate is thus possibly an endogenous variable.

1.2.2 Psychology

VIX and VSTOXX are measures of global uncertainty in the equity markets. Conceptually they capture investors' herding behavior and market sentiments in the financial markets in general. If the indices increase, it means that the market is more volatile and we expect the spreads to increase as well. To decide which of the two we should apply in our model, we plot the sentiments indicators together:

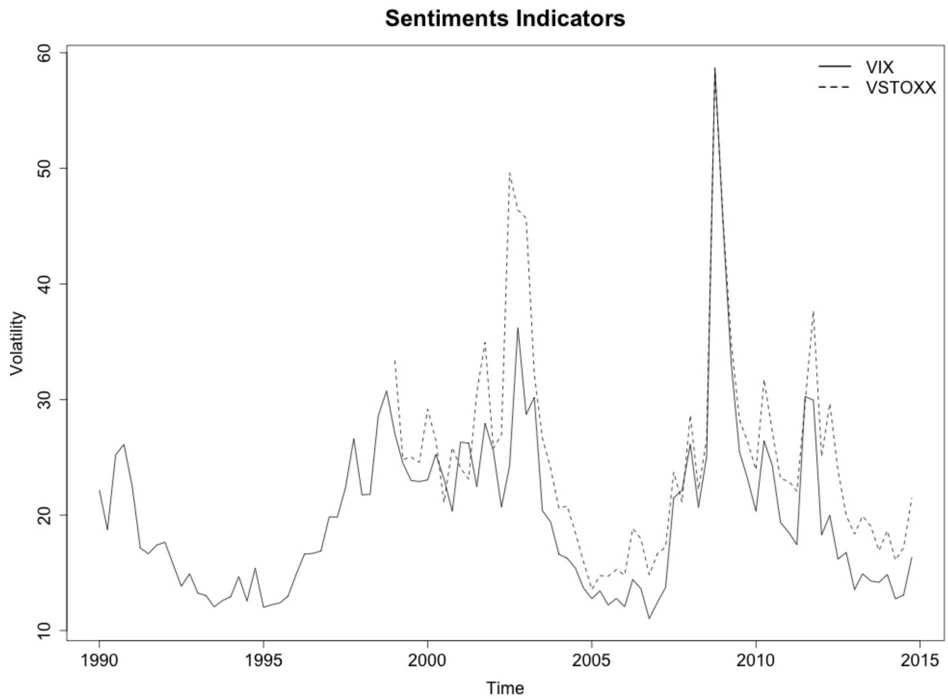


Figure 2.1: Comovement between VIX and VSTOXX

We observe strong comovement between the two variables. It is therefore natural to include only one of the two in our model, as including the other would not add much information and a problem of multicollinearity could arise. VSTOXX was created together with the euro in 1999, and as our time series analysis goes back to 1990 we choose VIX.

1.2.3 Explanatory Variables

In conclusion, we apply the following four explanatory variables to our model: Change in GDP, debt to GDP, unemployment rate, and VIX. Table 2.1 gives an overview of the variables and their explanatory powers.

Table 2.1: Variable descriptions

Variable	Notation	Explanatory Power
Change in GDP	ΔGDP	Economic growth
Debt to GDP	$\frac{\text{D}}{\text{GDP}}$	Solvency risk
Unemployment rate	UR	Economic health
VIX	VIX	Market sentiments in the US

1.3 Data Characteristics

The main purpose of our model is to describe the pattern of the yield spreads (ref. Figure 1.1). To get an illustrative overview we plot the data and observe individual characteristics as well as the relationship between variables (see Figure 2.2). Larger figures of each variable are presented in Appendix A.1.

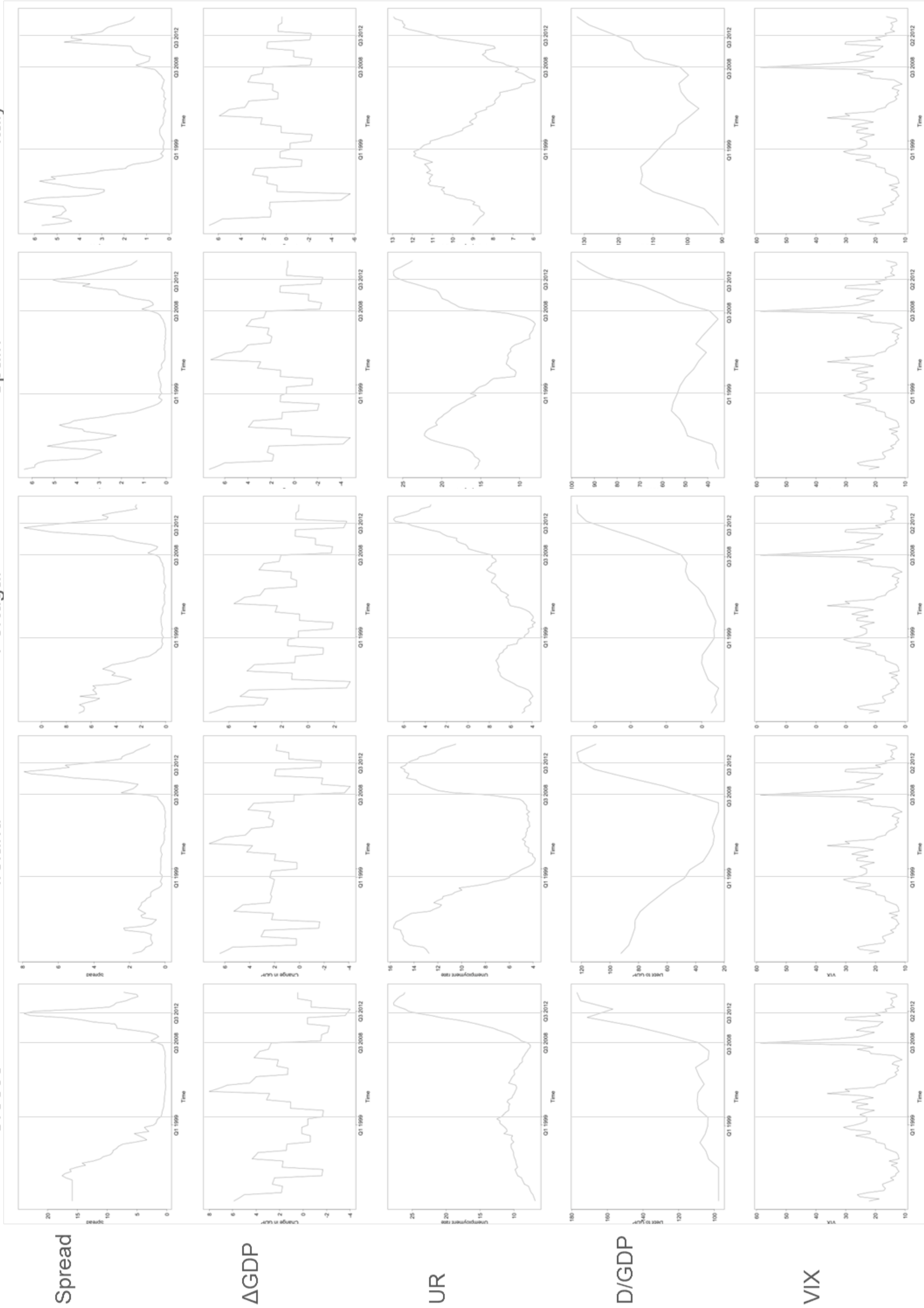


Figure 2.2: Data characteristics

1.3.1 Comovements Across Countries

An observation we draw from Figure 2.2 is the comovement between countries, which is especially visible in times of bull markets, like Regime II. This time-varying comovement is frequently discussed in the literature (Favero, 2013; Aßmann and Boysen-Hogrefe, 2012; Manganelli and Wolswijk, 2009; Haugh et al., 2009). Favero studies the response of euro area spreads after the Greek debt crisis. He compares the years before and after 2009, and find (as we expect from Figure 2.2) that the comovements have weakened during the financial crisis. We will get back to comovements across countries in Chapter 3 on spillover effects.

1.3.2 Multicollinearity

From Figure 2.2 we can also observe that some of the explanatory variables comove. This is especially visible for debt to GDP and unemployment rate. If two or more of the explanatory variables in a model strongly correlates, they most likely explain the same movement, and the problem of multicollinearity arises. In the presence of this phenomenon the estimate of one independent variable's impact on the dependent variable tends to be less precise than if predictors were uncorrelated with one another. As a result, t-tests may lead to type II errors where one fails to reject a false null hypothesis (Brooks, 2008). We will keep this in mind and test for multicollinearity in our models.

1.3.3 Stationarity

Furthermore, we observe that the variables are non-stationary. That is, the variables' mean, variance and/or autocovariance change over time (Brooks, 2008; Alexander, 2008). If data in a regression model is non-stationary, it can lead to invalid hypothesis tests, as the standard assumptions for asymptotic analysis are violated. This too can lead to type II errors.

The literature on spreads in the euro area discusses different approaches to handle non-stationarity. Favero (2013) models spreads as persistent processes reverting towards a time-varying long-run equilibrium, and uses the cointegrating relationship between the variables to capture the non-stationarity in the parameters. Aßmann and Boysen-Hogrefe (2012) use a time-varying coefficient model that allows for non-stationarity and volatility changes. Haugh et al. (2009) and De Grauwe and Ji (2014) use quadratic multivariate regression models to describe spreads, and are not concerned with stationarity.

In our case, the division of our time series into regimes is the most important measure to handle non-stationarity. Like Favero, we exploit the comovements within each regime to assume stationary statistical properties. The regime framework is therefore fundamental to obtain meaningful results.

The data characteristics form a basis for the two regression models. Before we attend to the model constructions, we show how we process the data and explain the regime division.

1.4 The Datasets

To obtain an accurate time series model we desire as many data points as possible. The quarterly reports of fiscal fundamentals therefore propose a challenge, as it makes our time series shorter than desired. However, estimating higher frequency data would create possible biases, hence create uncertainty. Therefore we choose not to expand the datasets. We extract our quarterly data from 1990 Q1 to 2014 Q4 from Thomson Reuters Eikon database, Eurostat, OECD, and CBOE. Complete datasets for the time period were not always available. In this section we explain the adjustments made to handle the missing data points.

1.4.1 Yield Spreads

Quarterly yield data from Thomson Reuters Eikon database is converted to yield spreads with Germany as benchmark. Greece is missing data points for the first two years. We average over the eight proceeding quarters, and add the number to the empty cells. Horton and Kleinman (2007) refer to this method as mean imputation. We choose this method due to large variances in the dataset, which would have made modeling approaches imprecise. Furthermore, the amount of data missing is relatively negligible, which suggests that a simple method will provide satisfactory predictions.

1.4.2 Economic Growth

We collect yearly GDP data from Eurostat and OECD, and calculate the yearly change. We assume linear growth within each year to calculate quarterly data.

1.4.3 Debt Ratio

The debt ratio is defined by outstanding debt over GDP. Quarterly debt to GDP is collected from OECD for the years 1990 to 2004, and from Eurostat for the next ten years. For Greece, data are missing for the first four years. We observe that over the proceeding five years the debt to GDP was either slowly increasing or decreasing. We therefore use the approach that Horton and Kleinman (2007) call longitudinal imputation, where the last (or first, in our case) data point replaces the missing points. Linear regression is an alternative, but since it is difficult to tell whether the data increased or decreased during the time period, we choose longitudinal imputation.

1.4.4 Unemployment Rate

The dataset containing the unemployment rate is a composition of monthly data from Eurostat and quarterly data from OECD. Separately, both contain missing data points, but together they form a complete dataset. We obtain quarterly data from Eurostat by averaging over the three respective months.

1.4.5 Sentiments Indicator

The VIX is the Chicago Board Options Exchange (CBOE) Market Volatility Index, and historical data is collected from CBOE's database. We average over the respective time periods to transform daily data from 1990 to 2003 and monthly data from 2003 to 2014 into quarterly data.

A last topic we address before we begin the model constructions is the division of our time perspective into regimes.

1.5 Regime Division

Econometric switching theory describes how models can be applied to capture changes in a series' behavior over time, in terms of mean value, volatility and to what extent the current value is related to the previous (Brooks, 2008; Hamilton, 1990). Hamilton describes how discontinuous changes may occur in financial environments. He argues that many of the major economic events that influence financial time series should be understood as time periods of identifiable duration. The behavior of the time series is expected to differ significantly between regimes. Several authors have pointed out how shocks in euro area yield spreads occur as a response to economic events, and seemingly unconnected to the countries' underlying fundamentals (Dewachter et al., 2014; De Grauwe and Ji, 2014).

Observing the yield spreads in Figure 1.1, we divide our dataset into four regimes between which the market behavior dramatically changes. The distinct shifts in risk perception follows from three events; the euro adoption, the Lehman collapse and the announcement of the OMT program. The division motivated us to study the possibility of applying a Markov regime-switching model. Unfortunately, analysis revealed that our time series of quarterly data from 1990 till today consist of too few observations for this purpose. However, our analyses are inspired by regime switching models in that we deterministically define each switch based on observations of the yield spreads and historical events. Through separate estimations of each regime we allow for flexible parameters. That is, we allow for the relations to be fundamentally different over time.

2 Moving Average Model

In this section we fit moving average models to understand the importance of fiscal fundamentals and market sentiments in each regime and country. We first consider the data characteristics (ref. Figure 2.2), and fit a basic multiple linear regression model to observe how well a simple model explains the spreads. Next, we apply an extension to a moving average model. We run tests on the residuals and control the robustness of the results, before we discuss implications. Last, we consider model limitations.

2.1 Constructing the Model

In this section we go through the steps of constructing a proper model for the spreads.

2.1.1 Multiple Linear Regression Model

The multiple linear regression (MLR) with the variables presented in Table 2.1 is defined as

$$\begin{aligned} \text{Spread}_{rit} = \beta_{0ri} + \beta_{1ri}\Delta\text{GDP}_{rit} + \beta_{2ri}\text{UR}_{rit} + \beta_{3ri}\frac{\text{D}}{\text{GDP}}_{rit} + \beta_{4ri}\text{VIX}_{it} + \epsilon_{rit}, \\ \epsilon_{rit} \sim \text{i.i.d } \mathcal{N}(0, \sigma^2), \end{aligned} \tag{2.1}$$

where r represents regimes, i represents countries, and t represents time. We obtain twenty models, one for each country and regime.

In a good model, the residuals should be normally distributed with mean zero and constant variation, and they should behave as white noise (Brooks, 2008). This implies no autocorrelation and no endogenous relations between the variables and the residuals. If the requirements are not fulfilled, there is something unexplained in the model which the residuals capture. This has three implications. First, the parameter estimates, the βs, may be false. Second, the associated standard errors may be wrong, and third, the assumption for the underlying distribution of the test statistic is not necessarily appropriate. By understanding the behavior of the residuals, model extensions may be applied to fit the specific dataset.

First of all, the models show good fit, with R-squared between 52 percent and 98 percent. For the MLR model the residuals look like white noise, and we cannot reject the nullhypothesis of normality. However, autocorrelation function (ACF) tests and partial autocorrelation function (PACF) tests find autocorrelation in some of the models (see Figure 2.3). A natural extension to cope with autocorrelation is to add an autoregressive (AR) term, a moving average (MA) term, or both (see Equations 2.2 and 2.3).

2.1.2 Extension to MA(1)

To cope with the autocorrelated residuals in the MLR model we propose the following extensions:

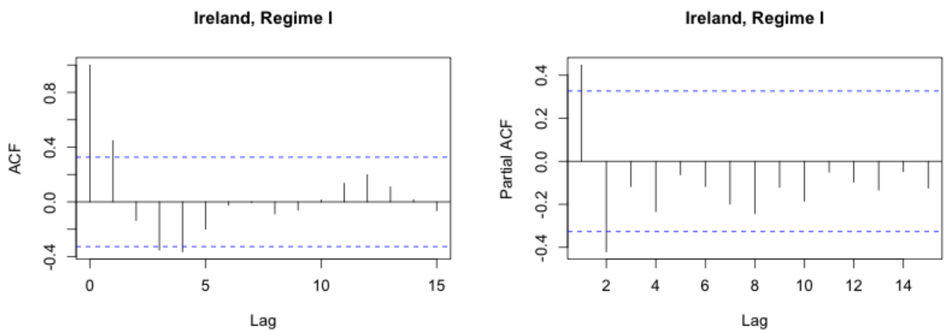
Extension to AR(1):

$$\text{Spread}_{rit} = \text{Spread}_{ri(t-1)} + \beta_{0ri} + \beta_{1ri}\Delta\text{GDP}_{rit} + \beta_{2ri}\text{UR}_{rit} + \beta_{3ri}\frac{\text{D}}{\text{GDP}}_{rit} + \beta_{4ri}\text{VIX}_{rit} + \epsilon_{rit}, \quad \epsilon_{rit} \sim \text{i.i.d } \mathcal{N}(0,\sigma^2). \tag{2.2}$$

Extension to MA(1):

$$\text{Spread}_{rit} = \beta_{0ri} + \beta_{1ri}\Delta\text{GDP}_{rit} + \beta_{2ri}\text{UR}_{rit} + \beta_{3ri}\frac{\text{D}}{\text{GDP}}_{rit} + \beta_{4ri}\text{VIX}_{rit} + \epsilon_{rit} + \phi_{rit}\epsilon_{ri(t-1)}, \quad \epsilon_{rit}, \epsilon_{ri(t-1)} \sim \text{i.i.d } \mathcal{N}(0,\sigma^2). \tag{2.3}$$

We determine whether to apply an AR or MA term to the multiple linear regression model by using ACF and PACF plots from the MLR models for all countries and regimes as decision criteria. If the ACF displays a sharp cut off while the PACF decays more slowly, the autocorrelation pattern is best explained by adding MA terms. If the opposite is true, the pattern is best explained by adding AR terms. Figure 2.3 shows one example of the twenty ACF and PACF plots we analyzed.



(a) ACF (b) PACF

Figure 2.3: ACF and PACF plots prefer MA over AR

Overall, the ACF and PACF plots suggest a preference for MA over AR. In the example above the ACF reveals that one lag is required to cope with autocorrelation if we choose MA, and two lags for AR. A majority of the plots confirms the same result. Supplementary to the plots, we perform residual tests in R for an extended MLR, first with one MA lag and then with one AR lag. The tests confirm that MA(1) solves the problem of autocorrelation while AR(1) does not. ARMA is also a possible extension, but as MA gives a good fit (see Figure 2.4) we prefer MA for its simplicity.

2.1.3 MLR versus MA(1)

In the previous section we saw that MA(1) is the preferred extension of the MLR to deal with autocorrelated residuals. However, autocorrelation is only present in nine of the twenty MLR models. A model extension is thus not necessarily a good idea, as it may be superfluous and lead to overfitting. In Figure 2.4 we evaluate to what degree the MA extension is necessary, by comparing the fit of the MLR and the MA to the real spread. The example illustrates that the MA extension manages the large jumps in the spread better than the MLR.

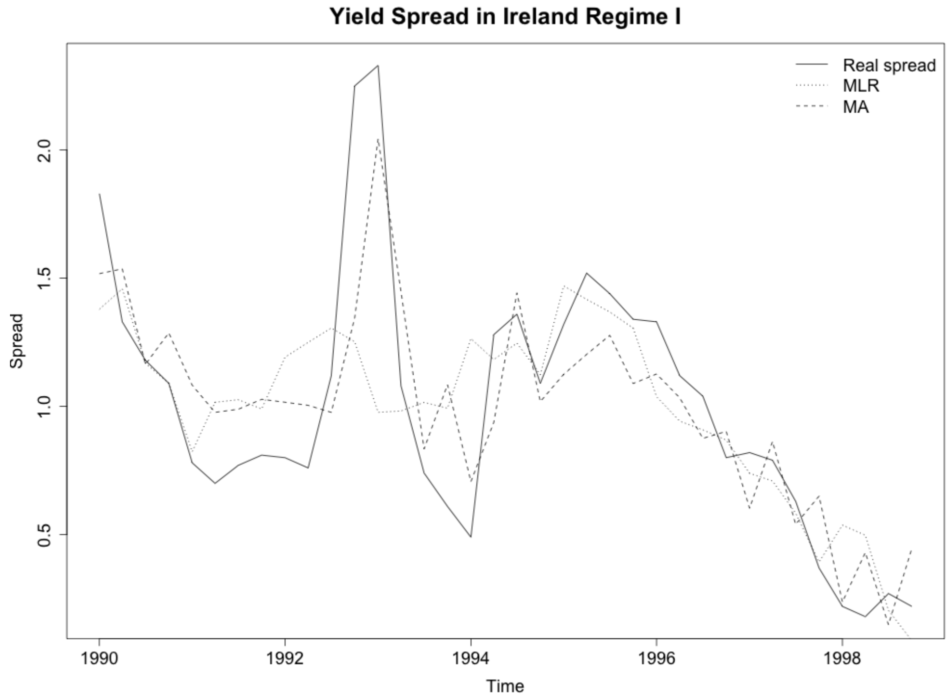


Figure 2.4: MA manages the large jumps in the spread better than MLR

2.1.4 Testing the Residuals

For the MA model, the residual plots seem to behave like stochastic white noise. Q-Q plots indicate normally distributed residuals, and the Jarque-Bera tests do not reject the null-hypothesis of normality. The ADF tests, however, cannot reject the null-hypothesis of non-stationary residuals for all models. Still, we obtain varying p-values, which implies that for the majority of the models we can reject the null-hypothesis at a 50 percent confidence level. In conclusion, the MA model provides good fit and residuals close to $\epsilon \sim$ i.i.d $\mathcal{N}(0, \sigma^2)$.

2.1.5 Scaling the Variables

As our predictors have different units, i.e. different scales, we standardize the variables to make the parameters comparable. The scaling is achieved by subtracting the mean and dividing by the standard deviation:

$$x_{scaled} = \frac{x_i - \bar{x}}{\sigma_x}. \tag{2.4}$$

By subtracting the mean we shift the origin of the coordinate system and dividing by the standard deviation we change the scale of the axes. When the predictors are scaled the parameters indicate how many standard deviations the dependent variable changes, with one standard deviation change in the independent variable. The movements of the regressors remain the same after scaling, and therefore we expect the same results from a standardized model as an absolute model.

2.2 Results

We estimate twenty regression models, one for each country and regime. We use the linear model function lm in R, which exploits ordinary least squares as fitting method. First, we run regressions with the general MA model and remove any insignificant variables, as they might disturb the significant parameter values and contribute to a poor fit (O'Halloran, 2005). Next, we run a new regression on the specific MA model consisting of the remaining variables. Tables 2.2 to 2.5 on page 22 report the regression results.

In the introduction we formed a hypothesis for the GIPSI yield spreads. It proposes that market sentiments change over time as a reaction to economic events. In some regimes they may even outweigh fiscal fundamentals in explaining the spreads. Additionally, it suggests that the market's perception of fiscal fundamentals changes over time. That is, the significance of the drivers changes.

Four general observations are explicit from the results. First, a considerable part of the shifts between regimes are captured in the intercept. This indicates that a large portion of the shifts cannot be described by the explanatory variables. We believe parts of the unexplained components are related to political risk and spillover effects, which we will get back to in proceeding chapters. Second, we note that because of multicollinearity, the significances of debt to GDP and unemployment rate are in some cases weaker than expected (see Section 2.4.1). A third observation is how market sentiments are significant in almost all models, except for Regime IV. This is in accordance with our presumption that market sentiments are vital in explaining the spreads. Fourth, we observe that the model structures vary across countries and regimes.

2.2.1 Regime I

A striking aspect of the first regime is that the dependencies of the spreads to the explanatory variables often are in the opposite direction of what one could expect. Using

Portugal as an example, we see that the change in GDP is positively correlated to the spread, while the unemployment rate and the VIX are negatively correlated to the spread. That is, an increase in economic growth leads to increasing spreads, and a decrease in unemployment rate or uncertainty lead to increasing spreads. These irrational relationships might be evidence of an artificial development in the spreads in Regime I. It is reasonable to explain the irrationale with the manipulation that took place in the time period before the adoption of the euro, to reach the interest rate threshold demanded by the Maastricht Treaty.

2.2.2 Regime II

A trend we observe in Regime II is how market sentiments are more significant compared to the variables expressing fiscal fundamentals. See for example Ireland and Spain, where only one of the three fiscal fundamentals are significant. This is in accordance with our expectations and the general view that the market underpriced the default risk of the GIPSI countries during the decade after the euro adoption. In Regime II, it seems that the market has considered the default risk of the euro area altogether, instead of evaluating each country's sovereign risk.

2.2.3 Regime III

In Regime III we find two interesting observations. First, the parameters in the models for Regime I and III are often similar, but reversed. This is the case for unemployment rate and VIX in Greece and Italy, change in GDP and VIX in Portugal, and debt to GDP in Spain. A reasoning for this is that the market in Regime I and III judge the euro area countries individually, contrary to the holistic approach we see in Regime II.

Second, in Regime III the fiscal fundamentals' significances increase slightly compared to the previous regime. See for example Greece, Portugal and Spain. However, we cannot confirm our expectation that the fiscal fundamentals would be exaggerated in this regime, where the risk in retrospect is assumed to be overpriced.

2.2.4 Regime IV

In Regime IV we observe that some of the explanatory variables have reverse dependency from what one could expect, as was the trend in Regime I. This is the case for debt to GDP in Portugal, Spain and Italy. A rationale is that the market in Regime III overpriced risk, so that the spreads in Regime IV are subject to a readjustment. This is in accordance to our expectations derived from the market's response to the announcement of the OMT program. Furthermore, we observe that VIX is less significant in this regime. An interpretation is that the market now prices the bonds more in accordance with the "true" default risk. In general we note that few variables are significant, which likely is due to the small dataset in this regime.

Overall, we find that VIX is more powerful in explaining the spreads than fiscal fundamentals, especially in Regime II. That is, psychology explains the remarkably stable spreads in a time period where the countries' actual solvency risk increased, as they gave up control over the currency of their debt. Furthermore, we find elements of irrational pricing, particularly in Regime I. Last, our results reveal a model structure that varies across countries and time, attesting to the regime framework as an advantageous contribution. The MA models support our hypothesis that economic fundamentals drive the long term movement of the spreads, while market sentiments are most significant on a short term.

Moving Average Results

Table 2.2: Moving average results, Regime I

Country	Intercept	ΔGDP	UR	$\frac{D}{GDP}$	VIX	ϕ
Greece	27.0179***[1]	-	−6.6878***	−20.1205***	−1.8136***	0.6285***
Ireland	1.0779***	-	-	0.6211***	-	0.9641***
Portugal	−2.0505*	0.7506***	−4.6654***	-	−0.9781***	0.5349***
Spain	−8.3342***	0.4600***	2.6296***	−5.9557***	0.4015*	0.7586***
Italy	2.6452***	-	−4.2900***	-	−0.7134***	0.6298***

Table 2.3: Moving average results, Regime II

Country	Intercept	ΔGDP	UR	$\frac{D}{GDP}$	VIX	ϕ
Greece	0.4383***	−0.0691***	−0.1226**	-	0.0615***	0.3633*
Ireland	0.4731***	-	-	0.2820***	0.0310***	0.8093***
Portugal	0.1855***	-	−0.4005***	0.9637***	0.0406***	0.9999***
Spain	0.1550***	−0.0438***	-	-	0.0486***	0.5692***
Italy	−0.3925*	-	−0.1336***	0.6267***	0.0509***	0.7555***

Table 2.4: Moving average results, Regime III

Country	Intercept	ΔGDP	UR	$\frac{D}{GDP}$	VIX	ϕ
Greece	7.2613***	−0.8450***	7.5026***	-	1.3225***	−1.0000***
Ireland	4.2543***	-	6.1180***	-	1.1776*	0.8719***
Portugal	3.4038***	−0.6588**	−6.1042*	15.2744***	1.0010***	1.0000***
Spain	4.2495**	-	1.1443*	3.2187***	0.6935***	0.2793[2]
Italy	9.0967***	0.3982***	6.8354***	-	0.4041***	1.0000***

Table 2.5: Moving average results, Regime IV

Country	Intercept	ΔGDP	UR	$\frac{D}{GDP}$	VIX	ϕ
Greece	6.5555***	−4.3593***	-	-	-	−1.0000***
Ireland	4.5979***	−0.5848***	2.4313***	-	-	−0.9999***
Portugal	4.9269***	-	-	−15.0326***	-	1.0000***
Spain	−5.1987***	-	-	−5.6974***	0.1143***	−1.0000***
Italy	2.6663***	-	-	−6.0995***	-	1.0000***

[1]Significance levels: * = 0.1, ** = 0.05, *** = 0.01
[2]p-value $\geq$ 0.2

2.3 Robustness Analyses

We perform two robustness tests on our MA model to examine its stability. In the first test we replace VIX with VSTOXX. In the second test we remove parts of the dataset for each regime. The results are displayed in Appendix A.2.

2.3.1 Robustness Test A: Replacing VIX with VSTOXX

By replacing VIX with a similar variable, we are able to examine the robustness of the parameters (Arghyrou and Kontonikas, 2012). Note that the robustness test is not applicable for Regime I as VSTOXX was created in 1999.

In all three regimes, the parameter values and significances remain stable, and most importantly, all signs remain the same after the substitution. We observe a few examples where the variables change significance, for example for Ireland in Regime II. This may indicate multicollinearity (ref. Section 1.3.2). VSTOXX is significant in Regime IV for Greece and Italy when VIX is not. This is not surprising, as Regime IV contains fewer data points and are thus likely less robust than the others. Overall, the results of this test suggest structural validity in our model.

2.3.2 Robustness Test B: Exclude Part of the Dataset

For the second robustness test we remove five to ten percent from each dataset. We remove data points at the ends, since the regime shifts are periods of change and instability. This may imply that the results from this robustness test could give a clearer picture of the yield spread drivers than the original model. The results show that the signs, values and significance levels remain almost identical, thus confirming the result from robustness test A. That is, our original models give a clear picture of the drivers.

2.4 Model Limitations

In this section we examine limitations in our MA-model and suggest improvements.

2.4.1 Multicollinearity

As some of the explanatory variables comove, we test for multicollinearity (ref. Section 1.3.2). By looking at the variables' correlation matrices and running VIF-tests in R, we conclude that in twelve out of twenty cases, two or more independent variables are multicollinear. This generally applies to debt to GDP and unemployment rate. As a result, the remaining parameter may be biased after we omit its multicollinear peer. We test for this by removing the dominant variable, leaving the insignificant of the two, to observe whether the other then became significant. For the majority of the models the parameter remain insignificant. This signals that multicollinearity is not a major problem in our model.

To illustrate the problem of multicollinearity, however, we present one of the few cases where the insignificant parameter became significant after the removal of its multicollinear peer. Table 2.6 illustrates the multicollinearity between unemployment rate and debt to GDP in Greece Regime III.

Table 2.6: Multicollinearity between unemployment rate and debt to GDP

	Intercept	ΔGDP	UR	$\frac{D}{GDP}$	VIX	MA	AIC
Parameter Value	6.54	-0.98	7.21	0.55	7.21	-1.00	48.22
P-value	$1.83 \cdot 10^{-3}$	$3.31 \cdot 10^{-2}$	0	0.73	$1.11 \cdot 10^{-3}$	$1.62 \cdot 10^{-7}$	
Parameter Value	7.26	-0.85	7.50	-	1.32	-1.00	46.34
P-value	0	$1.08 \cdot 10^{-3}$	0	-	0	$2.57 \cdot 10^{-7}$	
Parameter Value	-8.05	-2.19	-	12.44	2.69	1.00	69.87
P-Value	$2.62 \cdot 10^{-4}$	$6.58 \cdot 10^{-3}$	-	0	$8.83 \cdot 10^{-3}$	$2.37 \cdot 10^{-7}$	

The first model contains both variables, the second excludes debt to GDP, and the third excludes unemployment rate. We observe that for the first model unemployment rate is significant and the debt ratio is not. In the second and third model, when only one of the two multicollinear variables are included, we observe that the remaining variable is significant. The reason is that the multicollinear variables explain the same movement, and the model will thus need only one of the two. Furthermore, we observe that the parameter values for change in GDP and VIX remains relatively stable. They are thus not affected by the multicollinearity.

In our MA model we handle multicollinearity by omitting the insignificant variable and use the smallest AIC value as decision criteria for which variable to keep. In the case of Greece Regime III this means that we exclude debt to GDP. However, unemployment rate may be an endogenous variable and debt is likely more important for the spreads in the indebted GIPSI countries (ref. Section 1.2.1). We therefore choose to remove unemployment rate for our remaining analyses.

2.4.2 Distinguishing Country-Specific and Common Factors

The moving average results give interesting insights on changes across regimes. However, it is difficult to find a clear distinction between the common movements and the country-specifics in each regime. In the next section we therefore apply a panel data model that extracts the common factors from the country-specific deviations. Another benefit we gain with panel data is larger datasets relative to the number of variables.

2.4.3 Unexplained Components

It seems that our models have unexplained components (ref. Section 2.2). This is natural, as for instance political risk and cross-country spillover effects most likely affect the spreads, but are impractical to include in a regression model. In Chapter 3 we address the spillover effects among the GIPSI-countries in light of our hypothesis and regression results.

Before we attend to the spillover effects, we fit a panel data model to distinguish the common movements from the country-specific deviations.

3 Panel Data Model

In the preceeding section we used a moving average model to analyze the drivers of yield spreads. The results enabled us to discover the differences in determinants of yield spreads across the four regimes. Our objective in this section is to extend our understanding of yield spreads by distinguishing common factors from country-specifics. For this purpose, we fit a mixed effects panel data model that separates country-specific deviations from a cross-country mean. We scale the regressors to be able to make direct comparisons of the parameters.

3.1 Model Characteristics

Formally, our mixed effects model is defined as

$$\begin{aligned}\text{Spread}_{rit} = \beta_{0r} + \beta_{1r}\Delta\text{GDP}_{rit} + \beta_{2r}\frac{\text{D}}{\text{GDP}}_{rit} + \beta_{3r}\text{VIX}_{rit} \\ + \zeta_{0ri} + \zeta_{1ri}\Delta\text{GDP}_{rit} + \zeta_{2ri}\frac{\text{D}}{\text{GDP}}_{rit} + \zeta_{3ri}\text{VIX}_{rit} + \epsilon_{rit}, \quad \epsilon_{rit} \sim \text{i.i.d } \mathcal{N}(0, \sigma^2),\end{aligned} \tag{2.5}$$

where r represents the regimes, i represents the five GIPSI-countries, t represents time, the βs are fixed effects parameters and the ζs are random effects parameters. We will explain the interpretations further in the next section.

3.1.1 Fixed and Random Effects

The mixed effects model consists of fixed effects and random effects. The first four terms in Equation 2.5 represent the fixed effects. These are the model's common factors, meaning that the βs can be viewed as mean effects for the GIPSI-countries as a whole (e.g. a general dependence of debt to GDP). Conceptually, fixed effects methods focus only on the within-country deviations and ignore the between-country variations. Fixed effects are useful for studying the explanatory power of variables that differ within each country, as do all our variables. Another advantage from including fixed effects is that the between-country variations are likely to be polluted by unmeasured sovereign characteristics that are correlated with the spreads. Fixed effects help to narrow this bias (Rabe-Hesketh and Skrondal, 2012). The independent variables in our case, however, also differs across countries and this is our motivation for including random effects as well.

The proceeding four terms of Equation 2.5, the ζs, represent the model's random effects. The random effects are each country's individual deviation from the mean effects. ζ_{0ri} represents the deviation of country i's intercept from the mean intercept β_{0r} in regime r. That is, ζ_{0ri} contains all stable characteristics of country i. $\zeta_{1ri,2ri,3ri}$ represent the deviations of country i's slopes from the mean slopes $\beta_{1r,2r,3r}$. By including the random intercepts and random slopes we allow the effects of the independent variables to vary across countries. An important property of the random effect terms is that for each parameter, the sum of all countries' ζs is zero (see Equation 2.7). This property provides an essential advantage to our model, because it makes it easier to distinguish and compare the countries. Its interpretation is that we isolate the country-specific variations through extracting the mean effects of each covariate. The values of the ζs form the basis for our country-specific analysis.

3.1.2 Application Requirements for Fixed Effects

Certain conditions must be met before we can apply fixed effects. The SAS Institute (Allison, 2005) points out two such requirements. First, each country must have at least two observations on the same variable. Our datasets contain between ten and 35. Second, the independent variables must have different values for at least two points in time, and this must be true for at least two of the countries. In our case, this is true for all countries over all regimes. It is thus safe to assume that we fulfill the requirements and can apply fixed effects to extract common factors.

3.1.3 Model Assumptions for Random Effects

Rabe-Hesketh and Skrondal (2012) point out two necessary assumptions for including random effects in a model; a correct mean structure and no correlation between the covariates and the error terms. For our model this leads to the following four model assumptions:

1. The expected mean of the residuals given the covariates, X_{rit}, and the random effects, ζ_{ri}, is zero:

$$E(\epsilon_{rit} \mid X_{rit}\zeta_{ri}) = 0. \tag{2.6}$$

   This implies no correlation between the residuals and the covariates (no endogeneity)

2. The expected sum of each random effect over all countries is zero[3]

$$\mathrm{E}\Big(\sum_{i=1}^{5} \zeta_{jri} \mid X_{rit}\Big) = 0, \quad \forall\, j = 0, ..., 3. \tag{2.7}$$

   That is, there is no correlation between the random effects and the covariates either. The similarity between the residuals, ϵ, and the four random effects, ζ_j, stems from how we mathematically derive our model. We start with only fixed effects, and split the error term into a within-country variance component and a between-country variance component such that

$$u_{rit} = \epsilon_{rit} + \sum_{j=0}^{3} \zeta_{jri}$$

3. The within-country residual variance is homoscedastic:

$$\mathrm{Var}\Big(\epsilon_{rit} \mid X_{rit} \sum_{j=0}^{3} \zeta_{jri}\Big) = c_1.$$

   That is, $\mathrm{Var}(\epsilon_{rit})$ is constant over time

4. The connection between the residuals and the random effects in our model applies here as well, implying that the variance of each random effect term given the covariates is homoscedastic:

$$\mathrm{Var}\Big(\sum_{i=1}^{5} \zeta_{jri} \mid X_{rit}\Big) = c_2, \quad \forall\, j = 0, ..., 3.$$

   That is, $\mathrm{Var}(\zeta_{ri})$ is constant over time

It follows from the third and fourth assumption above that the original error term, u_{it}, is also homoscedastic:

$$\mathrm{Var}(u_{rit} \mid X_{rit}) = c_1 + c_2.$$

In our model, however, we combine the random effects error terms with heteroscedastic variables:

$$\zeta_{1ri}\Delta\mathrm{GDP}_{rit} + \zeta_{2ri}\frac{\mathrm{D}}{\mathrm{GDP}}_{rit} + \zeta_{3ri}\mathrm{VIX}_{rit}.$$

[3]We checked the sum of the ζs for all countries in all regimes, and found that each sum adds up to zero

This implies that the total residuals become heteroscedastic. An implication of heteroscedastic total residuals is that it is not straightforward to define R^2 for our model. We will get back to this and alternative determinants of model fit in Section 3.2.2, where we run tests on our mixed effects model.

We have now established the mixed effects model defined by Equation 2.5 as basis for our analysis of yield spread drivers. In the following section we explain the methodology.

3.2 Constructing the Model

In this section we explain the development of the mixed effects model defined by Equation 2.5. We begin with the actual model construction, including a control for multicollinearity, before we test model fit and validity.

We choose R as programming tool to construct our model, as R is known to be solid on mixed models estimation (Croissant and Millo, 2008). We use the panel data package lme4, and estimate our models through log-likelihood. As we did for the MA model, we use scaled values to get comparable parameters (ref. Equation 2.4).

3.2.1 Control for Multicollinearity

In previous sections we observed two cases of multicollinearity. Figure 2.1 shows the close relationship between VIX and VSTOXX. Figure 2.2 and Section 2.4.1 describe how unemployment rate and change in GDP comove. To prevent the problem of multicollinear data we exclude VSTOXX and unemployment rate from our datasets. These variables would not have added much value since their explanatory powers are already captured by VIX and change in GDP respectively.

For each regime, we run regressions with the remaining variables (ref. Equation 2.5), and construct correlation matrices. For all countries and regimes the matrices show low correlations between the variables. We are thus not further concerned about multicollinearity.

3.2.2 Model Fit

To test model fit we plot the modeled spread against the real spread for all regimes[4]:

[4]Note that the x-axes in Figure 2.5 are made up of five time series, one for each GIPSI-country

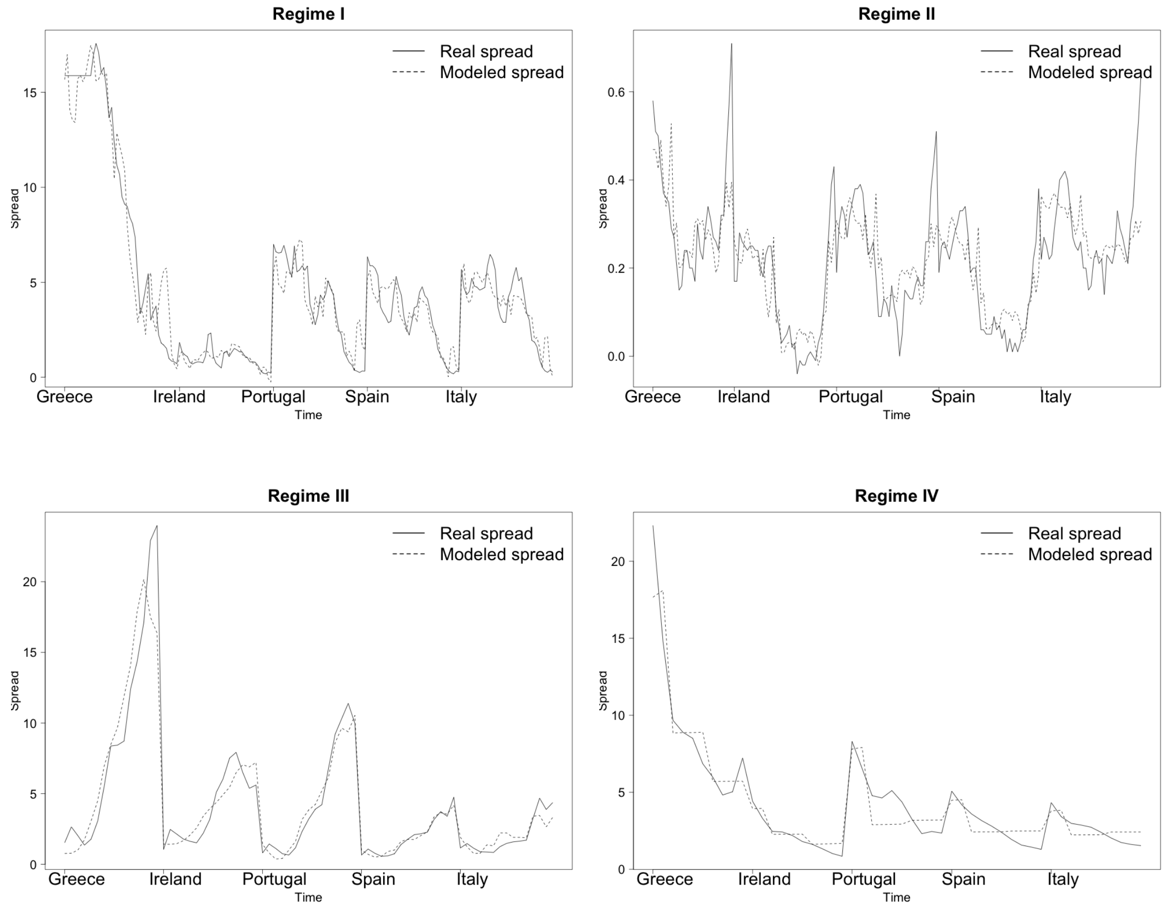


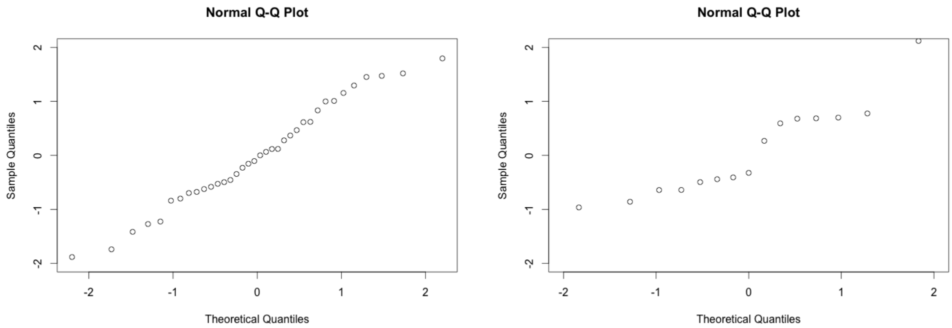
Figure 2.5: The modeled spreads obtain good fit with the real spreads

Visually we observe good model fit. However, if we look closer at Figure 2.5 we see that the models fall short in imitating the real spread at certain points in time. These points seem to recur at the same time for all countries, in connection to the regime switches. The regime switches are periods of change and instability, and it is therefore likely that the misfit is related to this. R^2 is not straightforward to apply as decision criteria for our model. This is related to the heteroscedastic total residual variance that follows from including random slopes in our model (ref. Section 3.1.3).

Overall, we observe a satisfactory model fit between the mixed effects models and the spreads for all countries and regimes.

3.2.3 Model Validity

To check each model's validity we run four standard tests on the residuals: Q-Q plots, ADF tests, Durban-Watson tests and ACF/PACF-plots. We create one Q-Q plot per country per regime, in total 20 plots. Figure 2.6 displays two of the Q-Q plots.

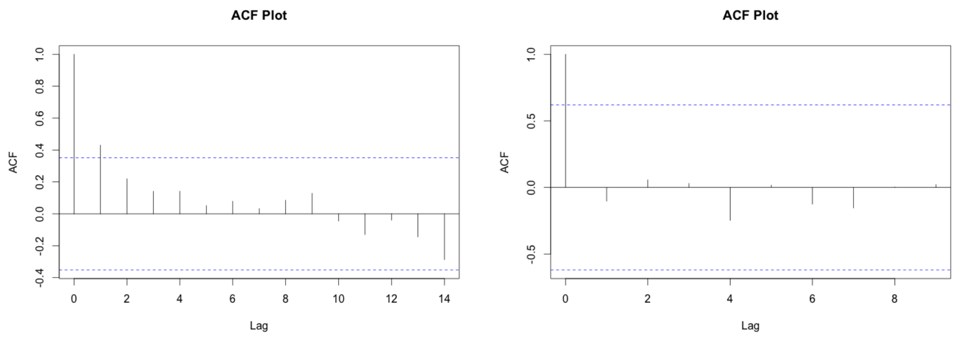


(a) Italy, Regime I (b) Portugal, Regime III

Figure 2.6: Q-Q plot (a) suggests normally distributed data, (b) suggests a dispersed and skewed distribution

For a perfect normal distribution the points would lie on the line $y = x$. In Figure 2.6a we see that the points are close to this line, and we thus have reason to believe that the data are normally distributed. This is the case for 16 of the 20 Q-Q plots. In Figure 2.6b the line is flatter, which indicates a more dispersed density distribution. The right hand side tail suggests that the distribution is skewed to the right. A likely reason is the small sample size, as the four non normal residuals where detected in Regime III and IV, which contains fewer data points than Regime I and II. The possible implication of non normal residuals is a less trustworthy regression result. We address this possible issue in in Section 3.4, where we perform robustness analyses on our regression results.

ADF- and KPSS-tests give ambiguous indications of whether or not the residuals are stationary. The Durbin-Watson tests and the ACF/PACF-plots indicate that the models have some autocorrelated residuals in Regime I, II and III, and no autocorrelation in Regime IV. Two of the ACF plots are shown in Figure 2.7.



(a) Greece, Regime II (b) Ireland, Regime IV

Figure 2.7: ACF-plot (a) indicates autocorrelation of lag one, (b) indicates no autocorrelation

The autocorrelated residuals most likely originate from omitted variables, meaning that there exists drivers of the yield spreads that our model does not capture. As discussed earlier, it is natural that our models have unexplained components.

To summarize, the results seem to be trustworthy. We will in Sections 3.4 perform two robustness tests to certify their validity.

3.3 Results

We estimate four regression models, one for each regime. As for the moving average model we remove insignificant values until only significant variables remain. The exception is the intercept. Tables 2.7 to 2.10 on page 35 report the regression results. In the following sections we present the results in light of our hypothesis.

From the mixed effects model we extract three general observations. First, the intercepts are large compared to the explanatory coefficients in all regimes except Regime III. This implies that a large part of the movement cannot be described by the regressors. As mentioned in Section 2.2, we believe the unexplained components are linked to among others political risk and spillover effects, which we will further explain in the proceeding chapters. Second, Greece stands out as the country with the greatest deviations from the common movements. This reveals Greece as a likely source of spillovers to the other countries. Third, we again observe that our parameters fundamentally change across regimes.

3.3.1 Regime I

Like for the MA model, an apparent characteristic is how the parameters' sign is opposite to what we expect. We observe that this is true also for the common movement. As mentioned, this irrational pricing of risk seems to be caused by psychology, linked to the monetary and budgetary requirements by the Maastricht Treaty.

3.3.2 Regime II

We observe an increase in the significance level for the the debt ratio compared to Regime I, indicating that the debt ratio has become a more important driver. This does not correspond to our results from the MA model, where we find that fiscal fundamentals are less significant than market sentiments in this regime. The mixed effects model does thereby not confirm our assumption that the market underpriced risk after the euro adoption.

There are few variations between the countries, suggesting a collective pricing of risk. It appears like the adoption of the euro made investors consider the default risk of the euro area countries unitedly. This is consistent with our previous findings.

3.3.3 Regime III

The debt ratio is clearly the most important driver of yield spreads in Regime III. We believe this is a result of a wake-up call based on the revelation of Greece's real debt levels in 2010. Change in GDP is not significant. We interpret this as fear spreading among the investors after the wake-up call, causing them to focus on the negative fundamental debt.

The country deviations have increased slightly from Regime II. As for the MA results, we understand this as a shift towards a more independent pricing.

3.3.4 Regime IV

In Regime IV, the only significant explanatory variable is the change in GDP. An explanation might be that in response to the announcement of the OMT program, investors regain confidence. Their attitude seems to be more positive, as they emphasize economic growth rather than debt. The decrease in spreads seem to be purely based on psychology, as the debt levels in reality continue to increase (ref. Figure 2.2).

Overall, the panel data results emphasize the importance of psychology. In the first regime we again observe an irrational relationship between drivers and spreads. As mentioned, we interpret this as evidence of yield manipulation and an optimism towards the introduction of the euro. Furthermore, we observe that the market seems to pay attention to different fundamentals over time, triggered by economic announcements. An example is how the debt focus in Regime III shifts towards a focus on economic growth after the OMT announcement. This way, psychology determines which fundamentals that are emphasized.

Our motivation for including a panel data model was to easier observe and differentiate between common factors and country-specifics. The common factors confirm many of our discoveries from the MA-model, as well as providing new information, particularly in Regime III and IV. The country-specific factors show that Greece stands out. In all regimes, Greece has especially high impact on the mean and easily attract attention as the oddity. We will get back to this in Chapter 3, where we analyze Greece's impact on the other countries.

Panel Data Results

Table 2.7: Panel data results, Regime I

	Intercept	ΔGDP	$\frac{D}{GDP}$	VIX
Common	7.9883[5]	0.7349***[6]	−8.2048*	−1.1818***
Country deviations				
Greece	27.9303	0.6723	−18.5723	−1.0182
Ireland	−7.0862	−0.4602	8.3417	0.7631
Portugal	−11.5188	0.3391	0.2486	−0.0167
Spain	−8.6984	−0.1443	5.0622	0.3943
Italy	−0.6269	−0.4070	4.9188	−0.1225

Table 2.8: Panel data results, Regime II

	Intercept	ΔGDP	$\frac{D}{GDP}$	VIX
Common	0.2269***	−0.0528***	0.0791***	0.0596***
Country deviations				
Greece	0.0182	−0.0147	0.0042	0.0128
Ireland	0.0142	−0.0115	0.0033	0.0100
Portugal	0.0053	−0.0043	0.0012	0.0037
Spain	−0.0052	0.0042	−0.0012	−0.0037
Italy	−0.0325	0.0262	−0.0075	−0.0229

Table 2.9: Panel data results, Regime III

	Intercept	ΔGDP	$\frac{D}{GDP}$	VIX
Common	1.6911[7]	–	8.0108***	0.9217***
Country deviations				
Greece	−8.8077	–	4.0356	0.3454
Ireland	3.9764	–	−4.7677	−0.5286
Portugal	3.7373	–	1.2722	0.2310
Spain	5.8260	–	−3.3223	−0.3111
Italy	−4.7321	–	2.7823	0.2633

Table 2.10: Panel data results, Regime IV

	Intercept	ΔGDP	$\frac{D}{GDP}$	VIX
Common	3.8988***	-1.7348***	–	–
Country deviations				
Greece	3.1358	−2.3264	–	–
Ireland	−1.0793	0.8007	–	–
Portugal	0.2211	−0.1640	–	–
Spain	−1.0102	0.7494	–	–
Italy	−1.2675	0.9403	–	–

[5] p-value > 0.20

[6] Significance levels: * = 0.1, ** = 0.05, *** = 0.01

[7] p-value > 0.52

3.4 Robustness Analyses

As we did for the MA model (ref. Section 2.3), we perform two robustness tests on our mixed effects model to examine its stability. Results are presented in Appendix A.3.

3.4.1 Robustness Test A: Replacing VIX with VSTOXX

For all three regimes the parameter values stay almost identical. With only one exception, all signs remain the same after the substitution both for the common factors and the country deviations. The most noticeable difference is in Regime IV where VSTOXX is significant while VIX is not. As the fourth regime is very short, it is not surprising that it is less robust than the other regimes. Overall, the test results attest to structural validity in our model.

3.4.2 Robustness Test B: Exclude Part of the Dataset

In all regimes, the parameter sign, significance level and values stay almost identical both for the common and the country-specific factors. We therefore have reason to trust that our models are robust and capture the most important characteristics of the spreads in each regime.

4 Overall Results and Discussion

In this chapter we have introduced a moving average model and a mixed effects panel data model to understand the yield spread drivers in the euro area. We have focused on the explanatory power of fiscal fundamentals versus psychology. In this section we discuss our overall findings and draw conclusions in the light of our regime framework and hypothesis.

4.1 Results in a Regime Perspective

Regime I: Manipulation of Spreads
In the first regime the parameter values tend to have opposite signs of what is expected. We interpret this irrational pricing as psychology associated with optimism towards the newfound monetary union, and as yield manipulation motivated by the countries' need to meet certain budgetary requirements.

Regime II: Collective Underpricing of Risk
In the second regime, the MA model shows greater significance for the VIX than for the fiscal fundamentals. This is in accordance to the general belief that the market underpriced risk, almost ignoring the fiscal fundamentals. In addition, the intercepts in both models are large compared to the explanatory variables, illustrating that there might be psychological effects that our models do not capture. We observe small country deviations in the mixed effects model, which indicates that the market in this regime considers the default risk of the euro area holistically, rather than evaluating each country individually.

Regime III: Wake-Up Call
The MA model shows increasing significances for the fiscal fundamentals compared to the previous regime. The mixed effects model reveals the debt ratio as the most important driver. We believe this is a result of a wake-up call from the revelation of the real Greek debt level. We interpret this debt focus as fear spreading among the investors.

In the MA model we observe that the parameters in Regime I and III often are similar, but reversed. The mixed effects model shows that the country deviations have increased from the previous regime. Together, these two observations underpin our assumption that the market in Regime III is beginning to price the countries more individually.

Regime IV: Readjusting the Risk Premiums
The MA model shows that some of the explanatory variables have reverse dependency

from what one could expect, as was the trend in Regime I. An explanation of this is that the market in Regime III overpriced risk, so that the spreads in Regime IV are subject to a readjustment as a result of the OMT announcement. In the mixed effects model we see more clearly how the market in Regime IV becomes less risk averse and more optimistic, as they emphasize economic growth rather than debt. This is purely based on psychology as the debt level in reality continues to increase and is likely provoked by the OMT announcement. In addition, the fact that VIX is not significant in the mixed effects model, and only significant in one country in the MA model, indicates that yield spreads in Regime IV are less driven by market sentiments, and more driven by each country's fundamentals. We note, however, that psychology seems to determine which fundamental the market focuses on.

4.2 Overall Findings

The distinct changes between the regimes attest to the regime framework as an advantageous perspective. Both fiscal fundamentals and investor's risk perception changes across the four regimes. The results show that Greece is an oddity, and has an especially high impact on the common movements. A considerable part of the explanatory power is captured in the model intercepts, implying unexplained components. This may be caused by imperfections as well as effects such as spillovers. Altogether we find evidence that fiscal fundamentals drive the yield spreads in the long run, while psychology outweighs these factors on a short term in response to economic events.

In the next chapter we supplement the regression analyses with an analysis of spillover effects.

Chapter 3

SPILLOVER EFFECTS

Financial crises tend to occur in clusters, and a large number of studies have therefore been devoted to analyze spillover effects between markets. Over the last years we have seen a particular increase in integration in the euro area. It is therefore likely that spillover effects are an increasingly important determinant of the countries' default risk. In the preceding chapter we analyzed each country's default risk individually. In this chapter we study their cross-country relationships, specifically how spillover effects from the Greek government bond market have affected the Irish, Portuguese, Spanish, and Italian markets since the most recent financial crisis.

The chapter proceeds as follows. First, we consider the literature on spillover effects, including definitions of terms and methodologies to measure interdependence and contagion. Next, we consider the important issue of how spillover effects occur and how they are likely to affect the GIPSI countries in the future. We find Greece to be the most important source of spillover effects among the GIPSI countries, and we apply the cross correlation method to analyze the magnitude of spillover effects from Greece to each country. Last, we draw conclusions and consider the spillover effects as an integrated part of our analysis of fundamentals and psychology as yield spread drivers.

1 Literature on Spillover Effects

A number of researchers consider spillover effects as the third driver of yield spreads, adding to fiscal fundamentals and market sentiments (Caceres et al., 2010; Beirne and Fratzscher, 2013). We split the term spillover effects into interdependence and contagion, to view spillover effects as an integrated part of our analysis of fundamentals versus psychology as drivers of yield spreads. We define interdependence as stable cross-market linkages. Interdependence entails spillovers originating from other markets based on observable factors, such as a direct economic relationship from trade. Contagion is non-observable. It explains a psychological factor, which in many cases can be interpreted as the market's exaggeration of the observed interdependence. That is, interdependence is a stable relationship over time, while contagion occurs as a change in comovements after a financial crisis.

In this section we consider the literature on spillover effects. We start by discussing the various definitions of spillover effects, before we comment on the subsequent different methodologies to measure spillovers. Last, we present an overview of the different approaches in Table 3.1.

1.1 Definitions of Terms

There is a widespread disagreement in the literature about the definitions of the terms spillover effects, interdependence, and contagion. Briefly summarized there are two main strands; those who see spillover effects as a whole (Doukas, 1989; Caceres et al., 2010; Arghyrou and Kontonikas, 2012) and those who distinguish between interdependence and contagion (Forbes and Rigobon, 2002; Pesaran and Pick, 2007; Metiu, 2012; Forbes, 2012; Elkhaldi et al., 2014; Tonzer and Buchholz, 2014). Both Forbes and Metiu explain that interdependence is a stable relationship, while contagion arises from periods of financial turmoil. They define contagion as a significant increase in cross-market linkages after a shock. Common for both strands is the idea that credit events are transmissive from one market to another, and that the unobserved, psychological effect plays an important role in this transmissions. Those who see spillover effects as a whole often name this effect contagion, which can be confusing since "contagion" then refers to what we in this paper call spillover effects.

1.2 Methodologies

Just like there exists various definitions of spillover effects, there is also a variety of methodologies. In this section we discuss a selection of these. An extended overview is presented in Table 3.1.

The majority of previous work uses cross-market correlation coefficients to measure spillover effects (Forbes and Rigobon, 2002; Pesaran and Pick, 2007; Metiu, 2012; Tonzer and Buchholz, 2014). Contagion emerges from periods of financial instability, when the market is more volatile than usual. As correlation is calculated from volatilities, the change in market volatility during turmoil will bias the correlation coefficient. The authors propose various solutions to account for this bias. Forbes and Rigobon derive an adjusted correlation coefficient. Their method is intuitive, and straightforward to apply if it is known which market is the original source of the spillover effects. A drawback is that the method relies on static correlations.

Elkhaldi et al. (2014) and Tonzer and Buchholz (2014), on the other hand, apply dynamic conditional correlations (DCC) developed by Engle (2002) to obtain volatility adjusted correlations. The DCC method can thus trace out the effects from the change in investors' behavior in response to market events. The method, however, depends on estimated probabilities and the results are therefore subject to a high level of uncertainty.

Metiu (2012) and Beirne and Fratzscher (2013) examine spillover effects through a regression model of yield spreads. Interdependence is measured through one of the independent variables and contagion is measured through analysis of the residuals. In the regression model they include a dummy variable to indicate whether or not the market is experiencing a crisis. Beirne and Fratzscher predefine the state of the market, while Metiu use probabilities and VaR. Their approaches are similar to regime switching models, which we considered for our own regression in Chapter 2 Section 1.5. However, our dataset of quarterly data would have to be replaced by daily or intra-daily data in order for a regime switching model to be applicable.

Arghyrou and Kontonikas (2012) create what they call a principal component which splits the euro area into two groups: The core, including Germany et cetera, and the periphery, including the GIPSI countries. The principal component is the risk involved in investing in periphery bonds relative to the risk of investing in core bonds. It is linked to contagion through two channels. First, an increase in core-periphery divergence may cause an increase in other periphery countries' spreads, i.e. intra-periphery contagion. Second, an increase in divergence may cause contagion from the periphery to the core due to an increased probability of future financial rescues funded by the core. Like Arghyrou and Kontonikas we consider intra-periphery spillovers. Their method, however, does not distinguish interdependence from contagion.

Doukas (1989) has a quite different, but interesting approach. He examines whether systematic risk elements enters into the default risk perception of lending institutions. A high degree of contagion would imply a high level of systematic risk in the sovereign bond market. A low level of contagion would imply that sovereign risks are basically independent and diversifiable, meaning it can be minimized by holding a geographically diversified portfolio of sovereign bonds. Doukas does not distinguish interdependence from contagion.

Overview of the Literature on Spillover Effects

Table 3.1: Literature on spillover effects

Paper	**Definition of Contagion**	**Methodology**
Doukas (1989)	Spillover effects	Test whether systematic, undiversifiable risk enters the default risk perception of lending institutions
Forbes and Rigobon (2002)	Significant increase in cross-market linkages after a shock	cross correlation: Compares correlation coefficients before and after a shock. Adjusts for increasing market volatility
Pesaran and Pick (2007)	Unpredictable, high correlation during financial turmoil	Canonical econometric model
Caceres et al. (2010)	Spillover effects	GARCH model including the probability of distress in a market, conditional on distress in other markets.
Arghyrou and Kontonikas (2012)	Spillover effects	Principal component analysis
Forbes (2012)	Interdependence: Stable, high correlations across markets over time Contagion: Spillovers from extreme negative events / financial turmoil	cross correlation and extreme value analysis
Metiu (2012)	No definition, but distinguish interdependence from contagion	Extension of Pesaran and Pick (2007)'s canonical econometric model. Uses VaR to examine correlation in the residuals
Beirne and Fratzscher (2013)	Spillover effects, but distinguish three types: Fundamentals contagion, regional contagion and pure contagion	Standard panel model with the different contagion types as explanatory variables. Use VaR to evaluate the distribution of the residuals to find "pure contagion"
Elkhaldi et al. (2014)	Phenomena triggered by extreme financial turmoil	Dynamic conditional correlation (DCC)
Tonzer and Buchholz (2014)	Phenomena triggered by extreme financial turmoil	DCC from a multivariate GARCH model. Adjust for increasing market volatility

2 Channels of Spillover Effects

Forbes (2012) shows that spillover effects have increased over the past decades, as a natural consequence of globalization. We are interested in the current and future effects of interdependence and contagion. For this purpose, we examine four sources of spillovers: International trade, banking institutions, international portfolio investors and wake-up calls. We focus on how these channels affect the countries' default risks, what influence they are likely to have in the future, and how policies can be made to mitigate the undesired spillover effects while preserving the beneficial.

2.1 International Trade

Forbes shows that the members of the European Union (EU) are more exposed to international trade than other advanced economies. This is not a surprising result, as reducing international trade barriers is an important purpose of the union. This crucial advantage, however, also represents a source of spillovers. The most recent financial crisis caused a majority of the euro area countries to experience decreasing incomes. Their import levels thus declined, affecting other countries' export (OECD, 2010). This is a simple, but effective example of a spillover effect, which is especially relevant in the euro area where the countries do not have the opportunity to strengthen their competitiveness through currency devaluation.

The profitable trade treaties in the EU create substantial benefits for the countries involved, and it is therefore likely that the international trade will continue to increase. Spillovers from trade are usually predictable, as import and export adjust relatively slowly to changes in incomes and prices. In addition, spillover effects from trade can be minimized by diversifying across countries and industries, as Doukas (1989) mentions (ref. Section 1.2).

2.2 Banking Institutions

Banking institutions are closely linked to the solvency and liquidity of a country, which again affects yield spreads. In the euro area the banks have a particularly close relationship as they share the same currency, and to some extent are under the control of the European Central Bank (ECB). This implies that a solvency crisis in one euro country can easily transmit to others, as the most recent financial crisis has shown. An example is how people started withdrawing their bank deposits as the financial crisis worsened in early 2012. This was especially the case in Greece, Portugal, and Spain (van Rixtel and Gasperini, 2013). Greece have also experienced large bank withdrawals over the last six months, as a result announcements of future currency restrictions and taxes on ATM withdrawals (Fosse and Fredriksen, 2015). Such bank runs reduce the banks' asset values and increase the non-performing loans. That is, it reduces the banks' solvency. As a result, the banks are forced to reduce international lending and supply, which again reduce the liquidity of other countries.

A criticism of the euro collaboration is how the currency was introduced without a banking union. Since 2008 we have seen the vicious circle of how the euro area banks' fragile credit conditions both have affected their home country and led to spillovers. In 2012 the situation forced the euro area leaders to take action and establish a banking union. The banking union links the national central banks and the ECB with a set of common rules dictated by the ECB. The banking union have implemented several measures to mitigate the undesired effects of spillovers. For instance, they have initiated policies to save banks in distress through the European Stability Mechanism. Furthermore, the ECB announced[1] the OMT program and guaranteed for banking deposits up to EUR 100,000 to prevent panic withdrawals. Additionally, the central bank this January announced the program of quantitative easing.

The trend of power shifting from the local central banks to the ECB is likely to continue, and it is thus likely that the banking union in the future will contribute to mitigate undesired spillovers. Furthermore, the banks are subject to higher liquidity coverages than before, which is also likely to limit the spillover effects. On the contrary, someone has to pay for the expensive policies, and the policies can therefore also worsen the fiscal situation in less distressed euro area countries. This way, the banking union may also increase the spillover effects.

2.3 Portfolio Investors

Forbes (2012) finds that the euro area countries are more exposed to spillovers from portfolio investments than its peers. A natural explanation for this is the high degree of financial integration. This financial integration is of course desirable, but it also contributes to contagion and interdependence. When the financial shock initiated by the

[1] The OMT is so far only an announcement, but it still proved to have a major impact on the financial markets in 2012 (ref. Figure 1.1)

Lehman collapse hit the euro area, investors had to rebalance their portfolios to remain a certain risk profile. The rebalancing is a source of spillover effects, and a risk aversion is created towards the countries hit the hardest. Forbes discovers that this risk aversion is often exaggerated and falsely transmitted across countries, causing contagion. In Figure 1.1 of the yield spreads we observe a herding pattern, which De Grauwe (2012) refers to as under- and overpricing of risk. This pattern follows from the fact that investors tend to follow each other, and as a consequence we can observe a self-fulfilling risk aversion. An example is in 2011, when the Italian and Spanish markets encountered a market freeze as investors lost confidence. We believe the fear lead investors to cause contagion effects in other euro area markets, in addition to the direct interdependence effects arising from investors' international holdings of equity and debt.

When it comes to mitigating spillover effects caused by portfolio investors, Forbes finds that it is not the net value of a country's international portfolio flows and investment positions that determines spillovers, but the gross value. In other words, if a country's large income is balanced out by large costs, the country is still exposed to income risk. Forbes also shows that a country's total international exposure through portfolio investments, does not affect its vulnerability towards spillovers. That is, what matters is the proportion of liabilities compared to assets in the portfolio; the larger the proportion of liabilities, the more vulnerable the country is to spillovers. To summarize, a country can limit its exposure to spillover risk through diversifying its income and increasing the solvency of its balance sheet.

2.4 Wake-Up Calls

The European Commission defines a wake-up call as a reaction to new information concerning a country, which also leads to a change in risk perception of other countries (The European Commission, 2014). Naturally, the risk of wake-up calls is greater in countries where it exists uncertainty about the economic fundamentals and the financial institutions. An illustrative example is Greece after April 2010, when their real debt level and budget deficit became known to the public.

A wake-up call affects the risk perception in a country, and increases the concerns for a country's fundamentals. In Greece's example the wake-up call lead to an ongoing crisis of confidence[2].

[2]The European statistics agency has since 2004 worried about the trustworthiness of the Greek fiscal numbers. At regular intervals they sent delegations to Athens to improve the reliability of the numbers, but without recognizing the falsifications until January 2010

Financial concerns can lead investors to change their attitude, and thus cause both interdependence and contagion through a self-fulfilling prophecy. An even more dramatic consequence can occur if a country-specific wake-up call limits the ability of local financial institutions to provide liquidity to the extent where financial markets freeze (ref. Section 2.3). In the euro area the common currency allows for the consequences of a wake-up call to easily spread. In addition the euro area share a number of macroeconomic and institutional similarities, like governance over a number of policies. As a result, any new information on a country can be perceived by investors as the future outlook of other euro area countries as well.

There are ways that the policymakers can act to limit the undesired spillovers from wake-up calls. As policy announcements can cause wake-up calls (ref. Section 2.2), policymakers need to make clear statements where rules for the process of the policies are explained, making it easier for investors to trust the differences between the countries. An example of how an announcement can change investors' risk perception is ECB's OMT program, which altered the market behavior in August 2012, even though it has yet to be implemented. Of course, the policymaker over time must show commitment to its promises to maintain investors' trust.

In conclusion, we have seen frequent examples of spillovers and their effect on yield spreads in the euro area over the last years. The four channels illustrate how spillovers both transmit between countries due to psychological factors and through actual fundamental relationships. Our analysis of the channels shows that spillovers are likely to be an increasingly important determinant of investors' perception of a country's default risk. In the proceeding sections we numerically analyze the magnitude of spillover effects from Greece to the IPSI countries.

3 Cross Correlation Method

In this section we analyze the magnitude of spillover effects from the Greek government bond market to the Irish, Portuguese, Spanish and Italian markets. We apply the adjusted cross correlation coefficient method developed by Forbes and Rigobon (2002) (ref. Section 1.2). This method is preferred due to its intuitiveness and because it distinguishes interdependence from contagion. In addition, examining the correlation coefficients is in itself interesting. We start by defining Greece as the source of spillovers before we attend to the technicalities of the method, including adjustments for the heteroscedasticity in financial markets, and a description of the procedure. Last, we present the results followed by a discussion of our findings.

3.1 Greece as the Source of Spillover Effects

In order to apply the cross-country correlation method and analyze the spillover effects, we must first define the origin of the spillovers. A review of newspapers, economic journals and articles suggests that Greece has been the most important source of spillovers since the last financial crisis. Arghyrou and Kontonikas (2012) specify that Greece was the epicentre of the European sovereign debt crisis, and that Greek yield spreads thus should form the basis for spillover analyses. Caceres et al. (2010) estimate cross-country spillover effects between ten of the euro area countries, including GIPSI. They find that Greece is undoubtedly the largest contributor to spillover effects. Arghyrou and Kontonikas and Caceres et al.'s assertion is consistent with our findings in Chapter 2 where Greece stands out from the other countries (ref. Chapter I Section 4).

3.2 Adjustment for Market Heteroscedasticity

Our objective for applying cross correlation is to investigate the level of interdependence and contagion in the GIPSI countries since the last financial crisis, and thereby be able to discuss spillovers as indirect drivers of yield spreads. cross correlation unveil comovements through studying the change in correlation coefficient after a financial crisis. The standard cross-market correlation coefficient is defined as

$$\rho_{x,y} = \frac{cov(x,y)}{\sigma_x \sigma_y}. \tag{3.1}$$

Traditionally, the method of cross correlation has analyzed if ρ significantly changes after a shock. Forbes and Rigobon, however, show that ρ will be subject to a larger change than the true level of contagion implies. This bias is due to the heteroscedasticity we observe in financial markets, where market volatility increases during turmoil. Studies of comovements based on cross correlation coefficients therefore tend to exaggerate the importance of contagion relative to actual interdependence.

3.3 The Procedure

In Section 1 we define spillover effects as a composition of contagion and interdependence. We interpret contagion as a significant change in cross-market linkages after a shock. Interdependence is the cross-market linkage that remains stable, unaltered by market turmoil. This definition forms the basis for our application of the cross correlation method. To implement the method we follow a procedure of seven steps. We start with our dataset of 10 year government bond yields for each GIPSI-country, extracted from the Thomson Reuters Eikon database. First, we transform the yields to daily change in yields with expectation zero. Next, we find Greece to be the source of the spillover effects (ref. Section 3.1). In order to measure contagion we must divide the dataset into two groups, so that the market volatility is lower in the first group (pre-crisis) and higher in the second (post-crisis). We set September 15th 2008, the day of the Lehman collapse, as the transition date between the two groups (ref. Chapter 1). We let each group span over six years, so that the pre-crisis is similar to Regime II and the post-crisis corresponds to Regime III and IV. For each of the two groups we calculate the variance-covariance matrix

$$cov(x, y) = \frac{1}{N-1} \sum (x - \bar{x})(y - \bar{y}),$$

to find country-specific volatilities

$$\sigma_x = \sqrt{\sigma_x^2},$$

and furthermore, the standard correlation coefficients defined by Equation 3.1 in Section 3.2. The difference between the pre-crisis and the post-crisis correlations are the spillover effects. To distinguish between interdependence and contagion we need to adjust the post-crisis correlation coefficient (ref. Section 3.2). Based on an assumption of a constant unobserved linear relationship between the returns in two markets

$$y_t = \alpha + \beta x_t + \epsilon_t, \qquad \epsilon_t \sim \ (0, \sigma^2), \tag{3.2}$$

Forbes (2012) defines the following adjustment coefficient for the relative increase in market variance:

$$\delta = \frac{\sigma_{x,post}^2}{\sigma_{x,pre}^2} - 1. \tag{3.3}$$

The adjustment coefficient captures the change in correlation that follows from the aforementioned volatility increase, even when β in Equation 3.2 is held constant. Based on Equations 3.2 and 3.3 she derives the adjusted post-crisis correlation coefficient

$$\rho^*_{post} = \rho_{post}\sqrt{\frac{1+\delta}{1+\delta\rho^2_{post}}}.$$

The correlation coefficients ρ_{pre}, ρ_{post}, and ρ^*_{post} forms the basis for our cross correlation analysis of interdependence and contagion. In the next section we present the results.

4 Results and Discussion

The cross correlation analysis gives two results. First, we observe high correlations between the markets, as well as a decrease in correlations after the crisis. Second, we observe the magnitude of the interdependence and contagion from Greece to the other markets in reaction to the crisis. We will discuss the implications of the results in Sections 4.1 and 4.2.

Tables 3.2 to 3.4 present the cross-market correlations. Figure 3.1 illustrates the correlations graphically. Together the three correlations give the magnitude of the spillover effects from Greece to the other countries. The difference between ρ_{post} and ρ^*_{post} is contagion, and the difference between ρ^*_{post} and ρ_{pre} is interdependence.

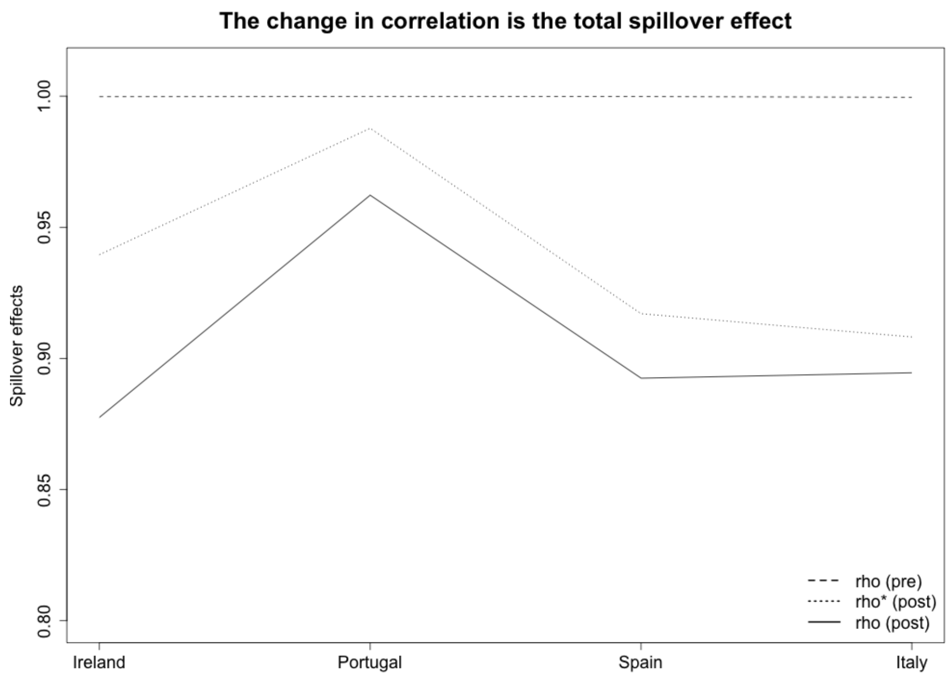


Figure 3.1: Cross-market correlations change in response to the crisis

Cross-Market Correlations

Table 3.2: Standard correlation coefficients (pre-crisis)

ρ_{pre}	Greece	Ireland	Portugal	Spain	Italy
Greece	1.000	0.999	0.999	0.999	0.999
Ireland		1.000	0.999	0.999	0.999
Portugal			1.000	0.999	0.999
Spain				1.000	0.999
Italy					1.000

Table 3.3: Standard correlation coefficients (post-crisis)

ρ_{post}	Greece	Ireland	Portugal	Spain	Italy
Greece	1.000	0.878	0.962	0.893	0.895
Ireland		1.000	0.955	0.960	0.958
Portugal			1.000	0.964	0.964
Spain				1.000	0.995
Italy					1.000

Table 3.4: Adjusted correlation coefficients (post-crisis)

ρ^*_{post}	Greece	Ireland	Portugal	Spain	Italy
Greece	1.000	0.940	0.988	0.917	0.908
Ireland		1.000	0.985	0.970	0.964
Portugal			1.000	0.973	0.969
Spain				1.000	0.996
Italy					1.000

4.1 Cross-Market Correlations

We observe remarkably high correlations between all the markets during the pre-crisis; each of the cross-market correlations is above 0.99. This result is consistent with our previous findings. In Regime II in Figure 1.1 we recognize a strong comovement between the countries, before the yield spreads diverge in Regime III and IV. In Chapter 2 we conclude that the market before the crisis considers the countries' default risks altogether, and overlook the country-specific differences.

Furthermore, we observe a decrease in cross-market correlations in response to the financial crisis. That is, when the volatilities increase, the correlations decrease. Usually, the opposite is true (Forbes and Rigobon, 2002; Forbes, 2012; Metiu, 2012). Forbes and Rigobon analyze stock market correlations in South America and Asia and allege that the correlation coefficient will always increase when the market volatility increases. Since our finding disagrees with previous work, we performed a correlation analysis on the GIPSI equity markets as well. We used historical data of the main stock market indices in each country, extracted from the Bloomberg database. The analysis of the equity returns confirmed the decreasing cross-market correlations. Our observation is also consistent with Figure 1.1 and the conclusion in Chapter 2. We can interpret the change in correlations as a wake-up call, where the investors become more concerned about each country's individual factors. That is, after the crisis the individual factors become more prominent in determining the yield spreads.

4.2 Interdependence and Contagion

Figure 3.2 shows the magnitude of the spillover effects from the Greek government bond market to the Irish, Portuguese, Spanish and Italian markets.

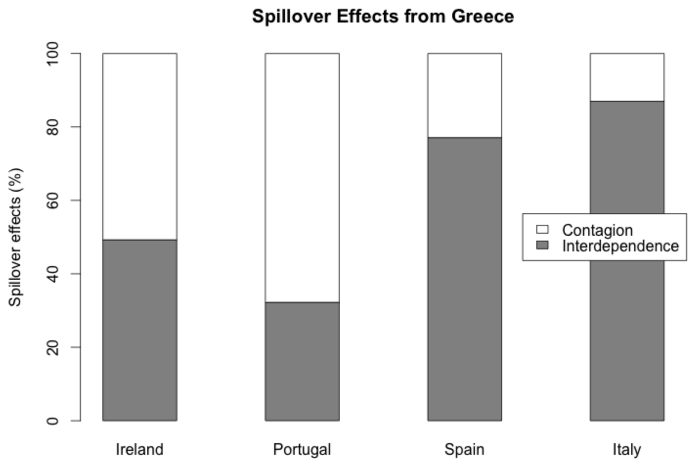


Figure 3.2: Relative proportions of interdependence and contagion in each market

We observe both interdependence and contagion for all four countries. Ireland, Spain and Italy experience the largest spillovers from Greece. Specifically, Italy and Spain are mainly affected through interdependence, while Ireland and Portugal are more affected through contagion. That is, it seems that Italy and Spain have relationships to Greece that affect their fiscal fundamentals, while the spillovers to Ireland and Portugal to a greater extent can be explained by psychology.

In Section 2.1 we mention international trade as an important source of interdependence. A review of international trade reveals that Italy and Spain are two of Greece's most important trade partners. Italy stands for nine percent of Greek export, and eight percent of Greek import. Spain is the tenth largest importer to Greece. Ireland and Portugal are not on the lists. The EU as a whole stands for over 45 percent of Greek exports and imports. We also observe that overall Greek imports have decreased while exports have remained at the same level over the last three years (Enterprice Greece, 2014). It is natural that a country in distress has to decrease its import. In this case, a direct consequence for Spain and Italy is the interdependence[3] we observe in Figure 3.2. That Ireland and Portugal are not particularly important trade partners for Greece is consistent with the proportion of interdependence that we observe in the two countries.

The contagion we observe in all four countries suggests that IPSI's dependency to Greece is exaggerated by the market. An interpretation of the contagion is that Greece negatively impact investors' perception of risk in Ireland, Portugal, Spain and Italy during the crisis,

[3]Trade contributes to the total interdependence. There are likely other sources as well.

more than it already does through interdependence. An implication can be the self-fulfilling prophecy of a bad equilibrium, where fear of high default risk leads to an actual increase in default risk:

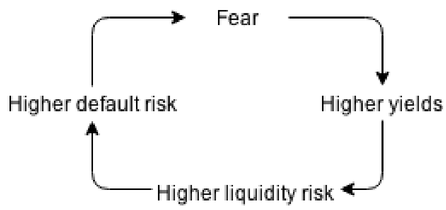


Figure 3.3: The self-fulfilling prophecy of bad equilibrium

In conclusion, our analysis of spillover effects suggests that the countries are closely linked both through actual interdependence and through contagion. Spain and Italy are dependent on Greece as a trade partner, while Ireland and Portugal are subjects to contagion from the Greek market. Overall, the analysis confirms that the countries are susceptible to a self-fulfilling liquidity crises initiated by financial distress in Greece.

Chapter 4

OVERALL IMPLICATIONS

A prominent finding in the preceding chapters is the role of psychology as a driver of yield spreads. Herding behavior and self-fulfilling prophecies seem to overshadow the actual default risks in time periods, before policy announcements lead to wake-up calls and shifts in risk perception. In this chapter we consider the overall implications of our findings, and comment on psychology's effect on yield spreads.

The chapter proceeds as follows. First, we consider the implications of psychology over the time perspective we analyze. This includes a discussion of the irrational underpricing in the two first regimes, and of the herding that leads to self-fulfilling prophecies. Last, we address ECB's policy announcements and how the banking union seems to impact the market.

1 The Role of Psychology

In this chapter we take a holistic approach to discuss implications of our overall results. That is, we combine our analyses of sovereign effects, market sentiments and spillovers:

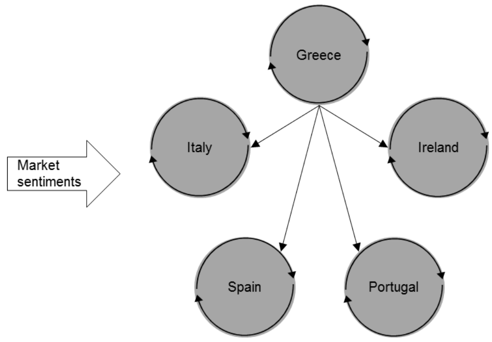


Figure 4.1: Sovereign effects, market sentiments and spillovers influence the spreads

Through the regime framework we discover the importance of psychology in determining spreads. The models reveal that the market's perception of risk changes across time in response to economic events. In shorter time periods the fiscal fundamentals are outweighed by market sentiments. In this section we discuss the irrational underpricing that takes place before the crisis, as well as the herding behavior and self-fulfilling prophecies that seem to occur in cycles over time.

1.1 Irrational Underpricing

Figure 1.1 implies that economic events change investors' perception of a country's default risk. Our analyses reveal distinct differences in the pricing of risk over the four regimes. In the first regime we observe patterns of irrational pricing. This reverse relationship is explained by a yield manipulation, which took place before the introduction of the euro. In other words, investors' optimistic expectations for the monetary union led them to ignore the increasing debts.

In the second regime investors seem to have confidence in the new-found monetary union. Optimism and psychological factors outweighs the fiscal fundamentals, as the countries' default risks seem to be judged holistically. It seems that investors believe the monetary union provides safety and hence leads to limited default risks. Their perception is shared by the rating agencies, who distributed top ratings to the euro area government bonds (De Grauwe and Moesen, 2009; De Grauwe, 2012).

In the time periods before the financial crisis it appears like investors are ignoring the challenges related to the common currency, such as the euro being introduced without a banking union and that the countries issue debt in a currency which they cannot control. The underpricing implies the short term effects of psychology, and show markets in a state of good equilibrium. As we discuss in the following section, herding is an important reason for the irrational underpricing.

1.2 Herding Behavior

We can view the abrupt changes in yield spreads as mispredictions of the default risk. We observe that the "forecast errors" that become evident in each regime shift seem to be significantly larger than the average difference between the country-specific forecasts. Taleb (2010) explain this behavior as herding. This seems to be the case during all four regimes. Despite the differences in fiscal fundamentals, the countries' default risks are priced in the same manner. Figure 1.1, the regression results, and the high cross-market correlations all attest to this finding. The herding behavior is especially apparent in Regime II, where the countries' spreads almost perfectly comove, and the yield spreads seem to be in a good equilibrium. For Regime III the panel data model designate Greece as an oddity. It seems that the herding behavior in this regime originated from a fear that the Greek default risk would spread to IPSI, causing spillovers and a bad equilibrium. An overall observation we draw is that either trust or fear spreads among investors and leads to a self-fulfilling equilibrium.

1.3 Self-Fulfilling Prophecies

In September 2008 the financial crisis breaks loose, and the real Greek debt level is exposed. Fear spreads among investors, and debt becomes the most important driver of the spreads. Our three analyses all find that the risks are priced more individually in Regime III. It appears that the market in this regime is driven by fear, initiating a downward spiral where the actual default risks increase (ref. Figure 3.3). That is, fear of the high debt levels leads the GIPSI-countries from a good equilibrium in Regime II to a bad equilibrium in Regime III.

Overall, the euro area seem to be more fragile and susceptible to self-fulfilling liquidity crisis than stand-alone countries, because they have no power to increase money supply or force inflation to deal with excessive debts. It is apparent that the GIPSI-countries have suffered due to negative psychological effects after the crisis. In the proceeding section we discuss how the ECB can impact the market psychology.

2 Policy Announcements

In this section we address ECB's policy announcements and how the banking union can influence the psychological effects.

2.1 The OMT Program

In Regime IV we observe yet another example of how announcements affect the market. After the OMT announcement, our results suggest that the market is readjusting its perception of risk by shifting its focus from debt to growth, resulting in lower risk premiums. An interesting matter is that the program up until this point is only an announcement; a promise of a safety net if the countries' default risks become too high. Krugman (2014) claims that the safety induced from the OMT program to an extent relies on a bluff, in the sense that nobody knows what would happen if the OMT were required.

We find it difficult to understand why the OMT program have received such an immense response from the market, while other help packages have not resulted in clear effects on the GIPSI spreads. Even though Figure 1.1 shows how the spreads decrease after the OMT announcement, it is reasonable to believe that the other rescue packages has participated in lowering the spreads in Regime IV as well. A reason for the market response can be that the OMT program is considered as a back-stop to counter market freeze and default. Even though Greece, Ireland, Portugal and Spain already had loans from the ECB and IMF, the OMT program was announced as a powerful tool provided by the ECB to overcome the financial crisis, providing hopes for a new-found fellowship among the union members.

2.2 Lender of Last Resort

As the debt crisis in Europe deteriorated and revealed the challenges related to the monetary union, the policymakers in 2012 realized that a banking union was needed to stop the vicious circle of credit conditions for the national central banks and the liquidity of their respective home countries. The banking union led to a power shift from the national central banks to the ECB. The current discussion is whether the ECB should take on the role as lender of last resort in the euro area, a role that the national central banks still holds.

Overall, our results imply that psychology overshadows actual default risk in shorter time periods, due to herding behavior and self-fulfilling prophecies. Psychology also seems to determine whether the market focuses on positive or negative fundamentals. In general, we recognize the effect of psychology on the yield spreads, and further, ECB's effect on the psychology. In the proceeding chapter we make conclusive remarks, including a discussion of model limitations and a final conclusion.

Chapter 5

CONCLUDING REMARKS

Our three analyses provide similar results: Fiscal fundamentals drive the spreads in the long run, while psychology outweighs these factors on a short term in response to economic events. Within the regimes we observe herding behavior, leading to a self-fulfilling good or bad equilibrium.

In this chapter we first discuss model weaknesses and assumptions. Next, we attend to the conclusion, including contributions, a review of our hypothesis and models, findings, future implications, and suggestions for further research.

1 Model Limitations

In this section we review and discuss the limitations of our three methodologies. We address challenges linked to model assumptions and data frequency, and examine the trustworthiness of our overall results.

1.1 Simplifications

The two regressions and the correlation analysis aim to model the real world through linear relationships. Clearly, this implies severe simplifications. The potentially unrealistic assumptions we make include no omitted variables and no endogeneity, in addition to stationary normally distributed residuals with expectation zero. In our attempt to model the spreads there are several explanatory variables that we could include in our general model. It is thus not unlikely that our regression models have omitted variable biases. Furthermore, endogeneity can arise from omitted variables, loops of causality or autoregression. Loops of causality is relevant both in our regression analyses in relation to self-fulfilling effects, and in our analysis of the spillover effects, as Greece is also influenced by the other countries. Our datasets include non-stationary variables. Non-stationarity can lead to invalid hypothesis tests, and thus a misguided understanding of the variable significances. A final important model assumption is normally distributed residuals with expectation zero. As we aim to model a world where normality seldom applies, this assumption will never perfectly hold.

The decision criteria we use to go from a general to a specific model relies on statistical significance. The concept of statistical significance is justified under a set of assumptions, such as normality, which are likely not perfectly fulfilled. This problem is, however, present in essentially all regression models. As Box and Draper point out "all models are wrong, but some are useful" (Box and Draper, 1987, p.424).

1.2 Data Frequency

Another model imperfection is the low frequency of our data. This is especially a challenge in Regime III and IV, which spans over short time periods and thus contains few data points. This can have implications for the robustness of the results.

1.3 Discussion

A regression model will never perfectly capture a relationship between the dependent variable and the explanatory variables. The risk of omitted variable bias is therefore natural. However, it is not worrisome as long as the residuals do not trend. Testing in Chapter 2, Sections 2.1.4 and 3.2.3, reveals that the residuals behave approximately as white noise. Omitted variable bias is thus not a major concern for our models. In Chapter 2 Section 2.4.1 we discuss the uncertain direction of the causal relationship between unemployment rate and spreads. We choose to exclude unemployment rate from the model to avoid this potential bias, and to cope with multicollinearity. Originally, we also considered credit ratings as a variable, but refrained because it potentially could lead to endogeneity. In Chapter 2 Section 1.3.3 we address the non-stationarity of our data. Our regime framework copes with the modelling issues related to non-stationarity. Overall, our results are consistent for all three models and agree with what we observe from Figure 1.1 of the yield spreads. We therefore have reasons to trust our findings.

The frequency of our data is a larger concern. To understand the implications, we perform robustness tests for both the moving average model and the panel data model in Chapter 2, Sections 2.3 and 3.4. The robustness tests show solid parameter values, however, slightly less so in Regime III and IV, as expected. In general, the tests confirm trustworthy results.

As our objective is to explain, and not to predict, we are most concerned with a good model fit. Overall, our models obtain good fit with the real spreads, the error terms behave nicely, and the three analyses report consistent results that are also coherent with the graphical findings.

2 Conclusion

We contribute to the literature in six ways. First, by employing an extensive time perspective and including data from before the euro. This enables us to observe how the introduction of the common currency affected the drivers of the spreads. Second, we use three economic events to divide the time perspective into regimes of contrasting risk perceptions. The flexibility allows for the parameters to be fundamentally different across the regimes. Third, we fit moving average models to each country in each regime. This gives flexibility both across regimes and countries. Furthermore, we fit mixed effects panel data models to each regime to easily understand the common movements, compared to the country-specific deviations. Last, we include a spillover analysis that considers both fundamental and psychological effects. Particular for the analysis is that we consider spillovers among the GIPSI-countries, and not from GIPSI to the other euro area countries, as previous work does. Overall, we hope to contribute to a broad understanding of fundamentals and psychology as yield spread drivers.

To study the drivers behind euro area yield spreads over time, we define the hypothesis that fiscal fundamentals drive the yield spreads in the long run, while psychology outweighs these factors on a short term. To address the hypothesis we introduce a regime framework, and perform two regression analyses and a cross-market correlation analysis.

The model structure fundamentally changes over time, justifying the use of flexible models through the regime framework. It also confirms our belief that economic events affect the market's perception of risk. In Regime I we find indications of manipulation of the yields as the countries are preparing for the euro. In the second regime, our models suggest that the market judges sovereign risk in the GIPSI-countries holistically, rather than taking individual considerations. We interpret this as an overconfidence in the newfound monetary union. In Regime III, during the financial crisis, the individual fundamentals become more important, in particular the debt ratio. After the OMT announcement, initiating Regime IV, investors shift their attention from debt to growth. It is thought provoking that the market first focuses on the unfavourable fundamental debt, leading the spreads to escalate, and then on the positive fundamental growth, making the spreads decline. A possible explanation is that investors consider a shorter time perspective when there is a serious risk of default, and thus worry about the countries' abilities to meet their debt obligations. During more optimistic periods, however, they focus on factors that apply in a longer time perspective, such as growth.

Furthermore, we observe that Spain and Italy's fundamentals are exposed to interdependence from Greece through trade, while Ireland and Portugal are more influenced by contagion. The contagion we observe in all four markets suggests that the situation in Greece creates fear among the investors, leading the GIPSI-countries into a self-fulfilling bad equilibrium. We observe clear differences in the intercept between regimes. This underpins an unobserved factor of changing market sentiments in response to economic events, confirming the impact of psychology in the short term. Overall, we find that fiscal fundamentals drive the spreads in the long run, while psychology outweighs these factors on a short term in response to economic events.

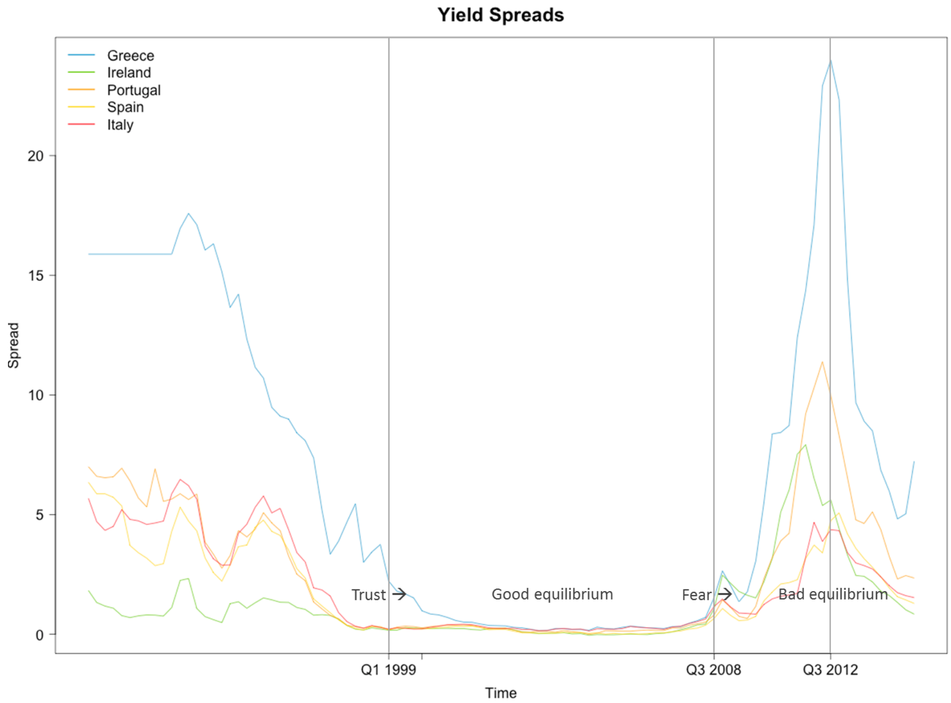


Figure 5.1: Psychology leads to short term self-fulfilling prophecies

Our analyses lead us to believe that irrational elements affect the pricing of sovereign default risk. Psychology plays an important role, and it seems that the ECB to some extent can influence the psychology of the market. A further power shift from the national central banks to the ECB would create a stronger banking union, which likely could limit the irrational part of the pricing. Providing ECB the role as lender of last resort is one initiative that could further strengthen the banking union. This is, however, a difficult and ongoing discussion, as it may not be reasonable to let countries with substantial fiscal discipline bear the burden of countries with poor discipline. Generally speaking, the irrational pricing element is an area that requires further research.

We propose four suggestions for further research on the drivers of euro area yield spreads. First, we note that a large part of the regime shifts is captured in the intercept, and thus unexplained components are present. One way to cope with this can be to reconsider the choice of explanatory variables through testing a general model with more variables. Second, we suggest performing the analysis with higher data frequency. This makes the results in Regime III and IV more trustworthy. In addition, it allows for an extension to a Markov regime switching model to predict the spreads. Higher data frequency also opens for spillover analysis as part of the regression model. Third, we propose game theory as an interesting approach to understand the market's risk perception, considering the ECB and investors as decision makers. Last, we suggest performing spillover analysis over shorter time intervals and smaller crisis, and thereby observe the change in contagion over time. This adds to the analysis of psychology versus fundamentals as yield spread drivers over time.

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Appendix A

1 Explanatory Variables

Greece

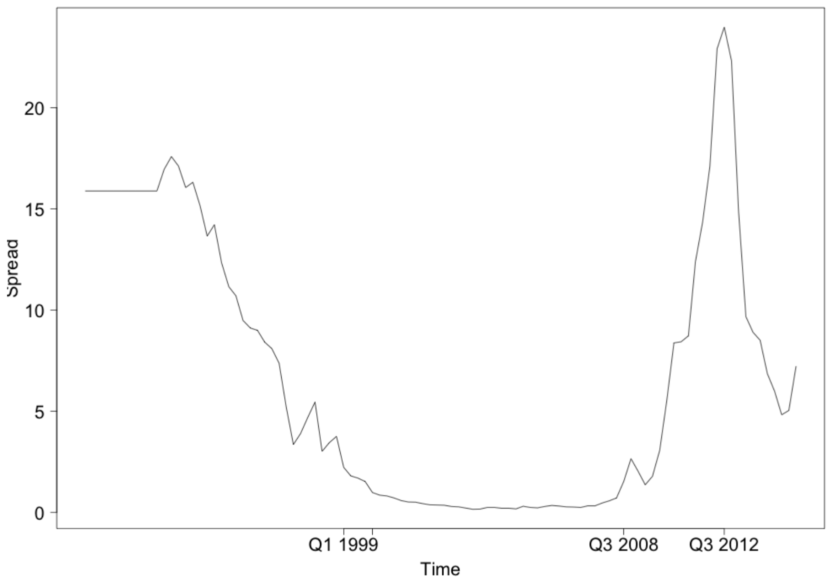

Figure A.1: Greece, spread

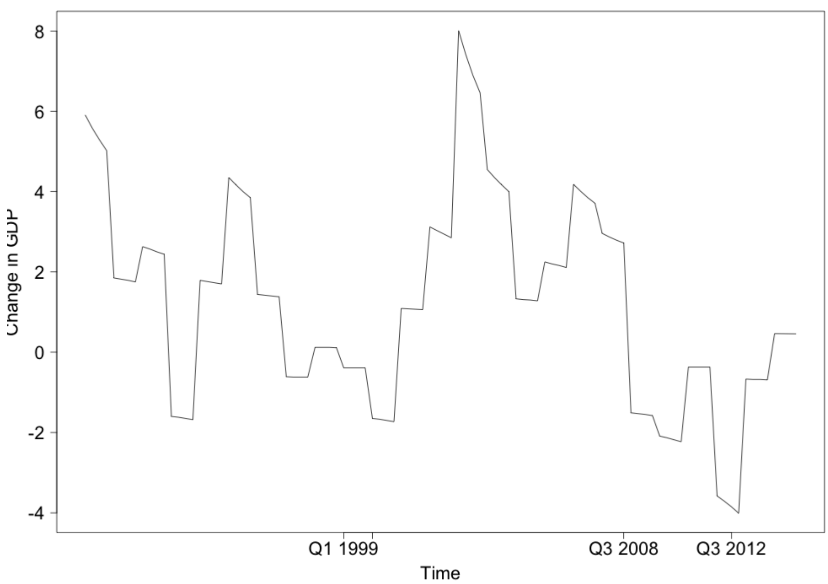

Figure A.2: Greece, change in GDP

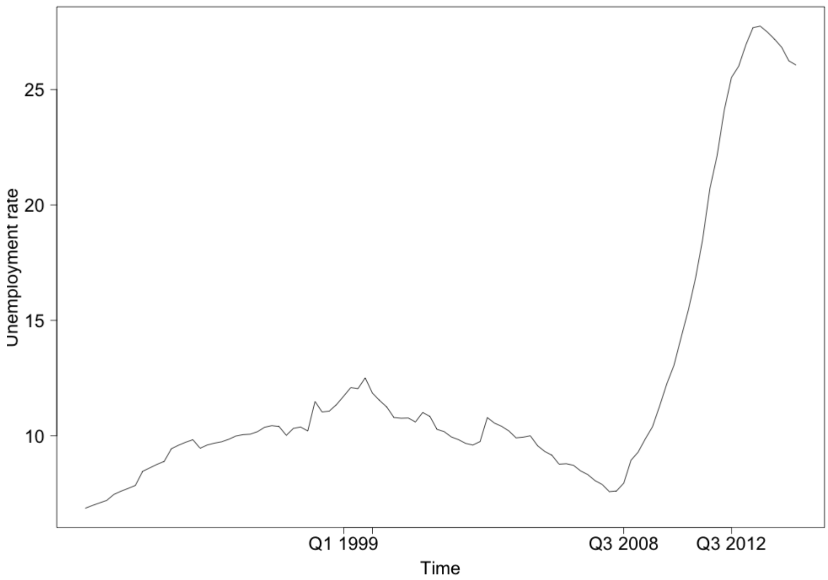

Figure A.3: Greece, unemployment rate

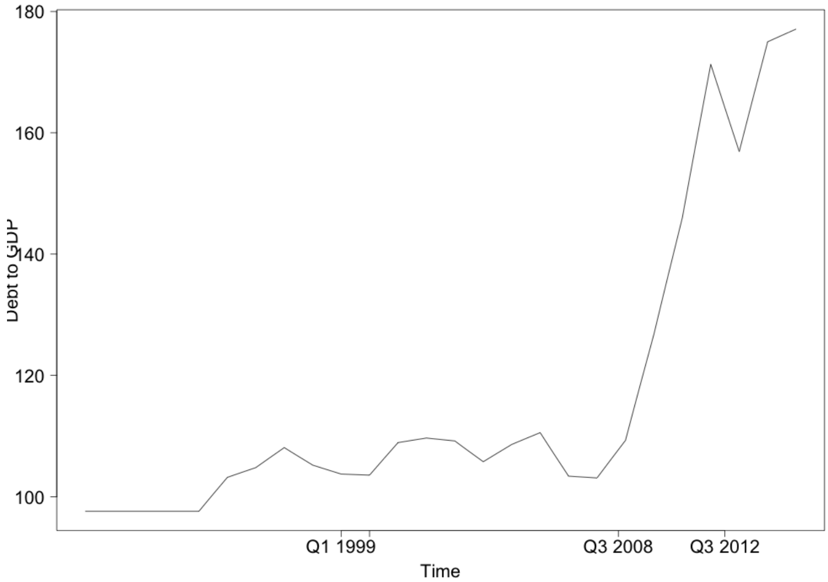

Figure A.4: Greece, debt to GDP

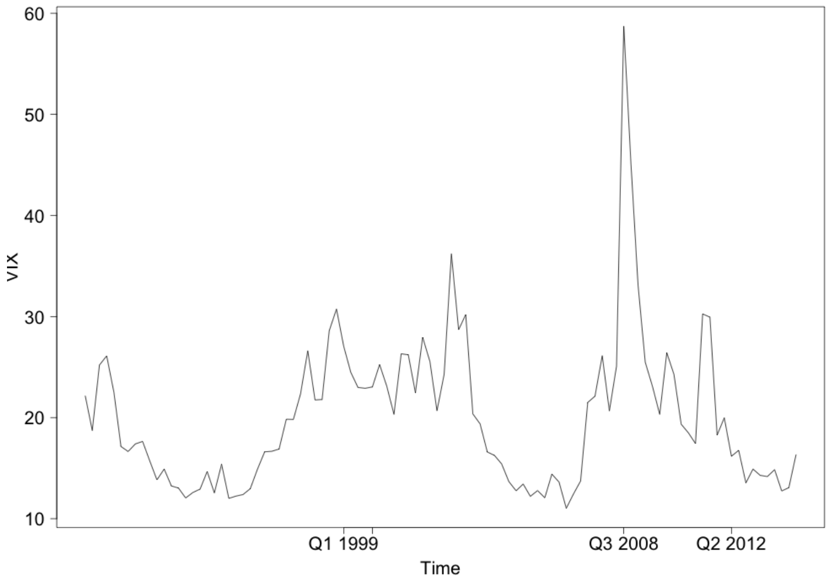

Figure A.5: Greece, VIX

Ireland

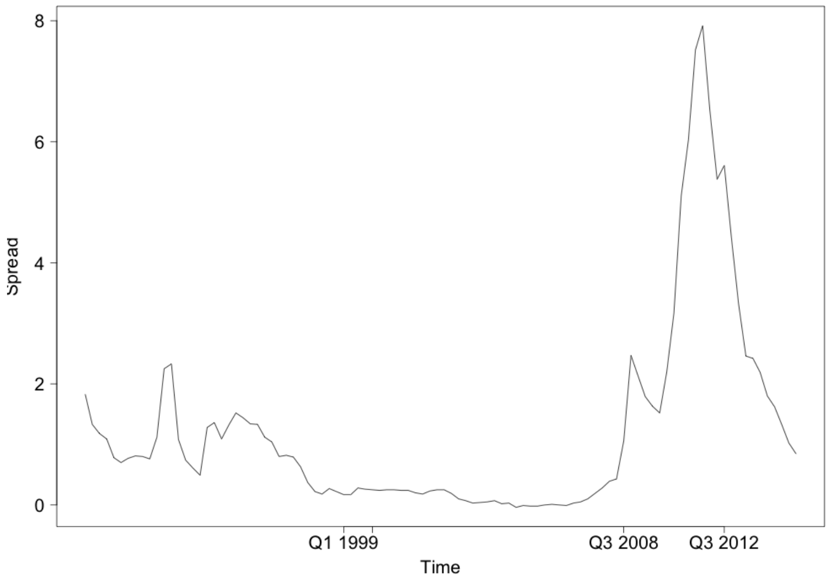

Figure A.6: Ireland, spread

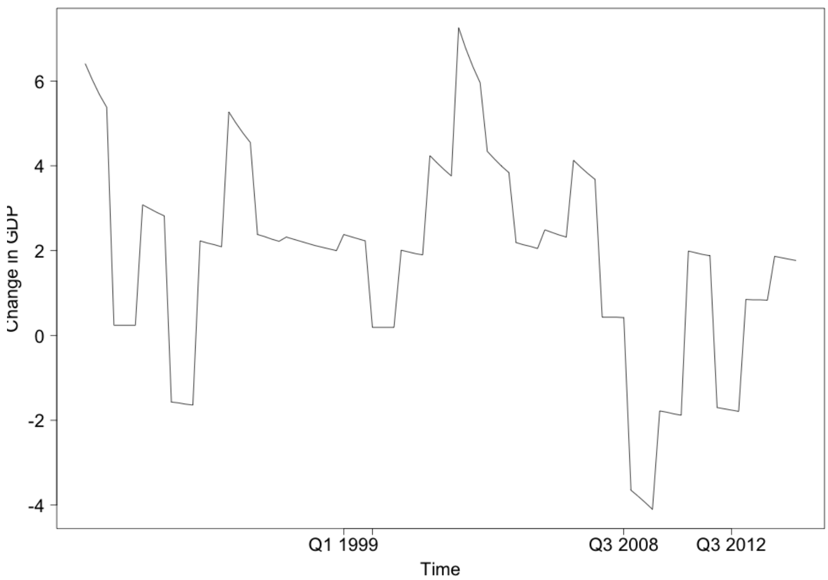

Figure A.7: Ireland, change in GDP

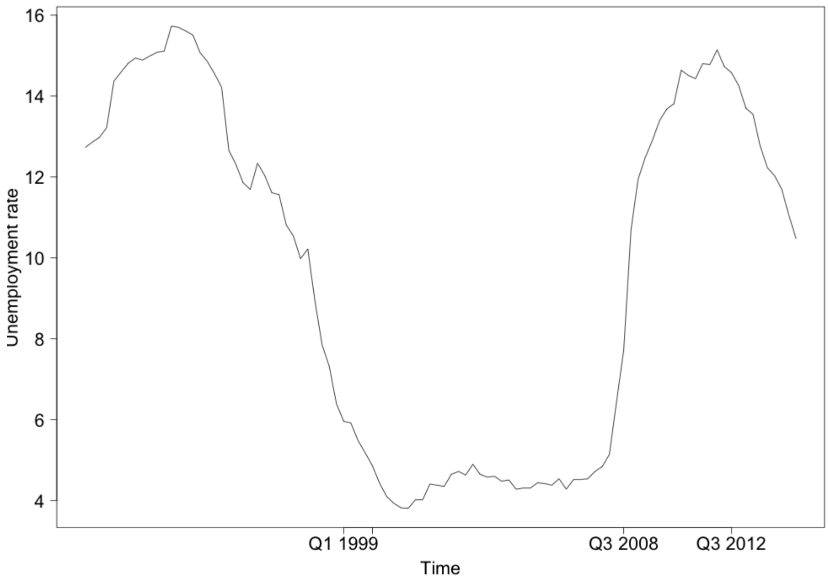

Figure A.8: Ireland, unemployment rate

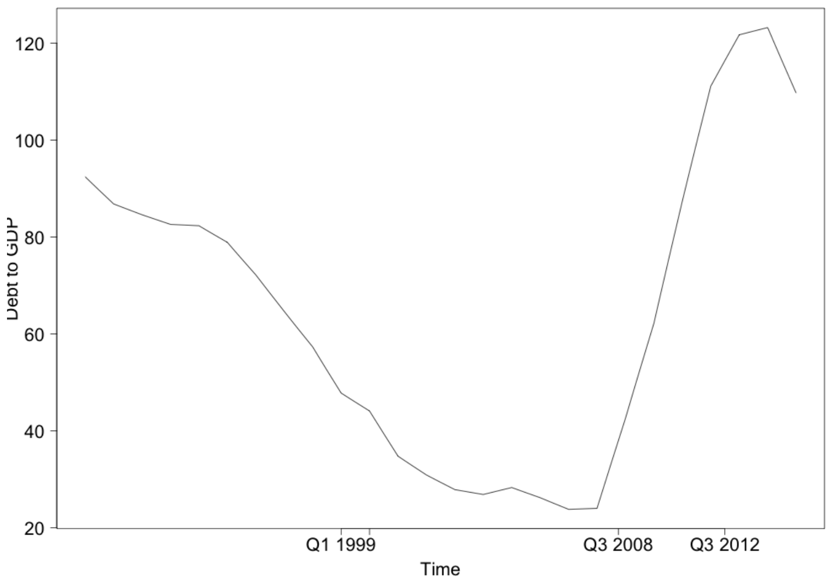

Figure A.9: Ireland, debt to GDP

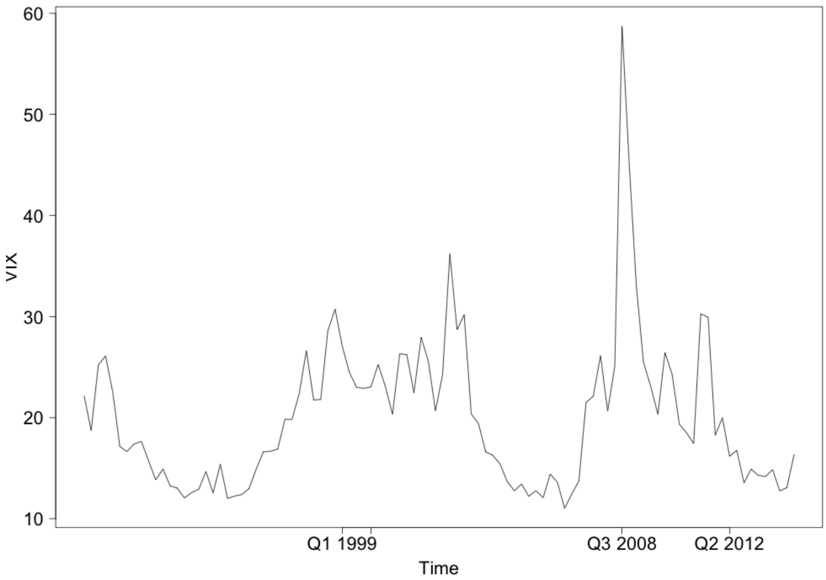

Figure A.10: Ireland, VIX

Portugal

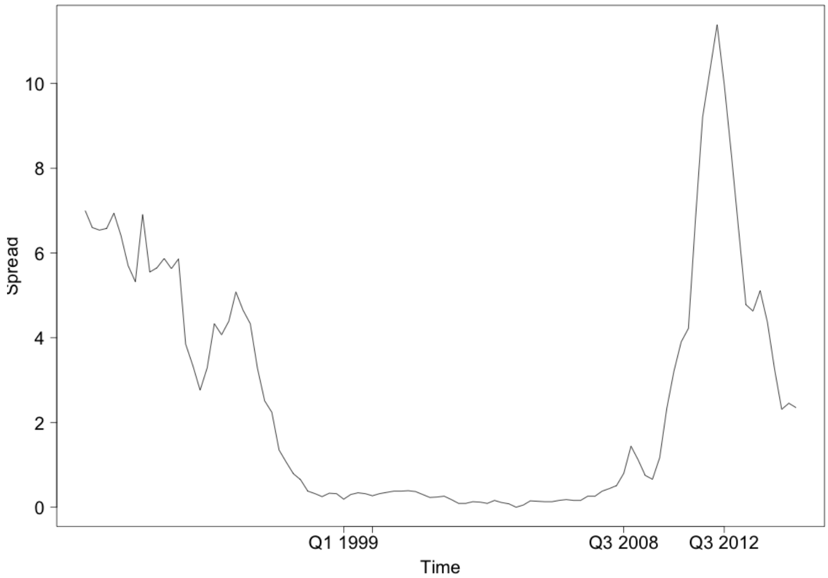

Figure A.11: Portugal, spread

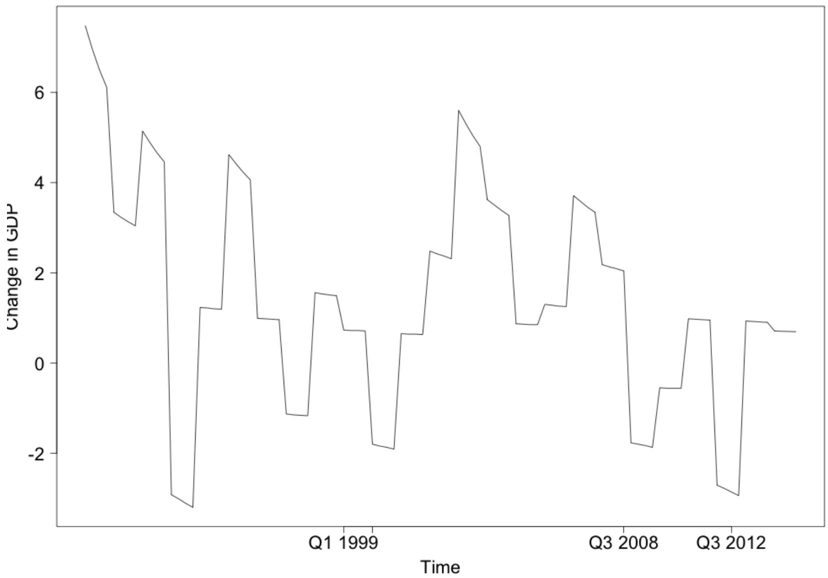

Figure A.12: Portugal, change in GDP

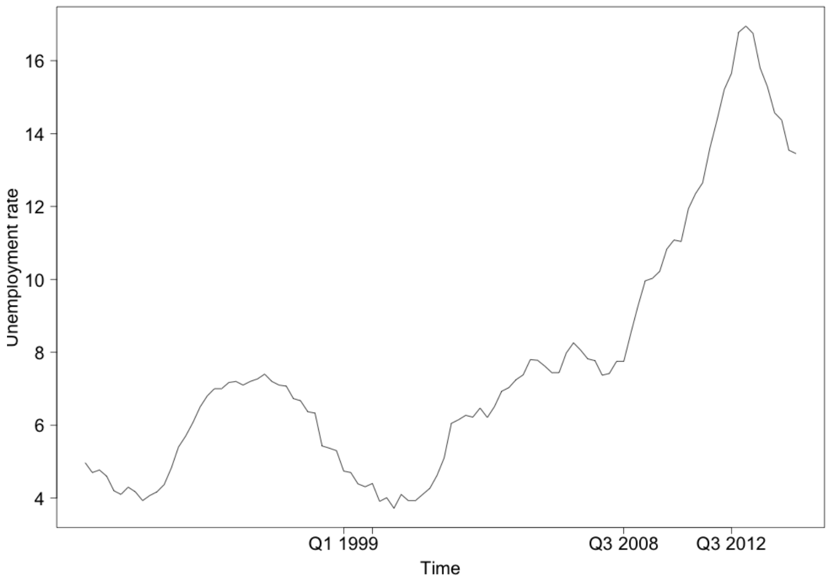

Figure A.13: Portugal, unemployment rate

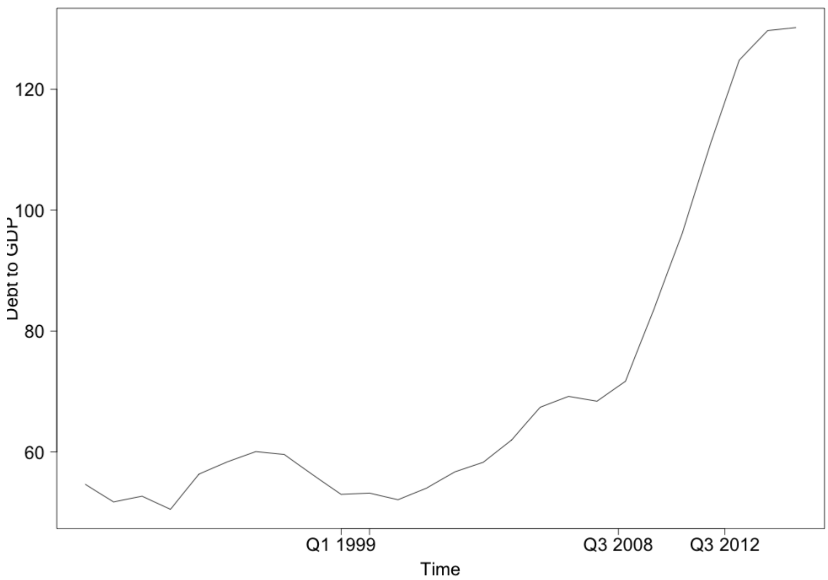

Figure A.14: Portugal, debt to GDP

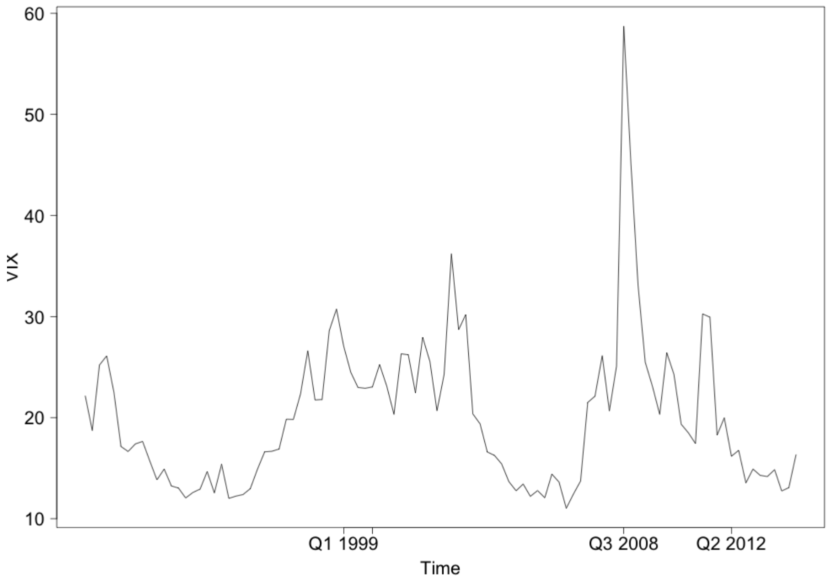

Figure A.15: Portugal, VIX

Spain

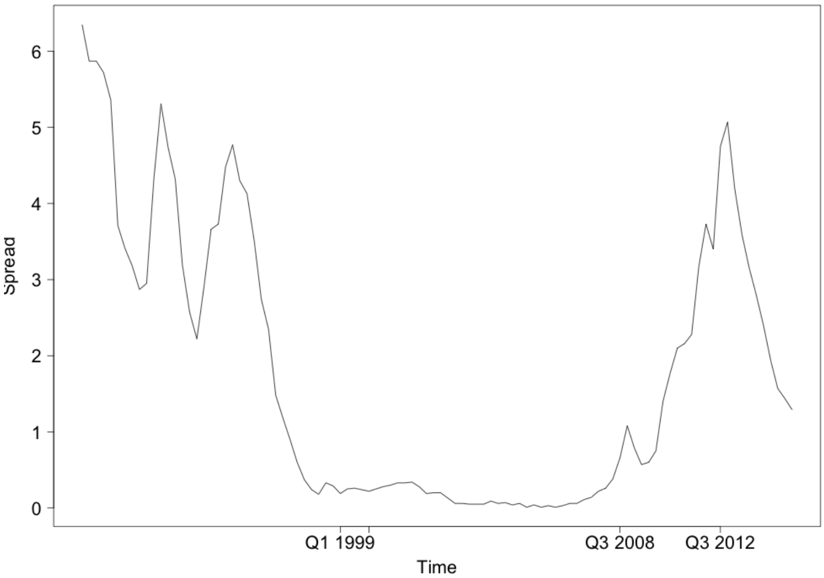

Figure A.16: Spain, spread

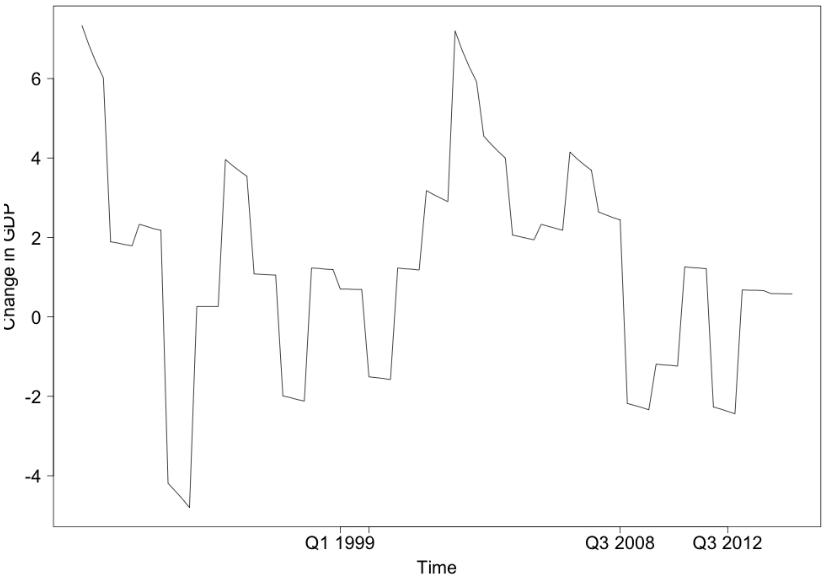

Figure A.17: Spain, change in GDP

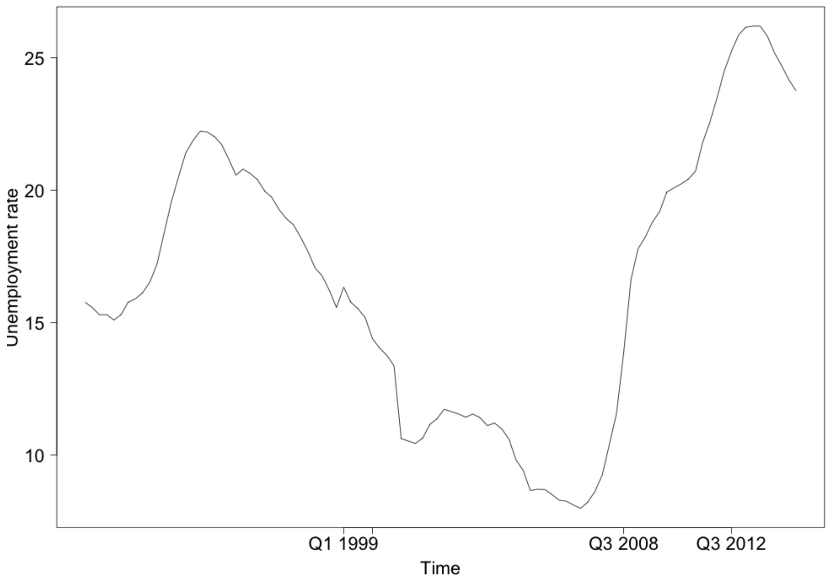

Figure A.18: Spain, unemployment rate

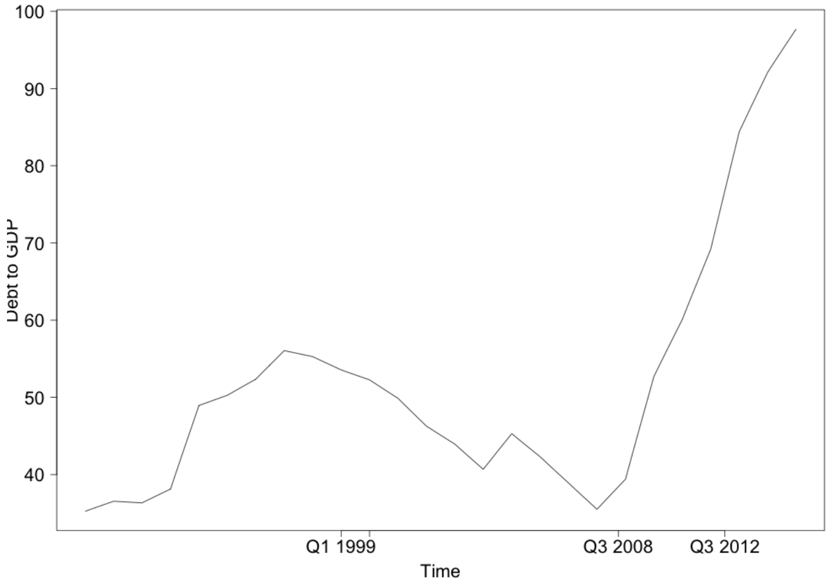

Figure A.19: Spain, debt to GDP

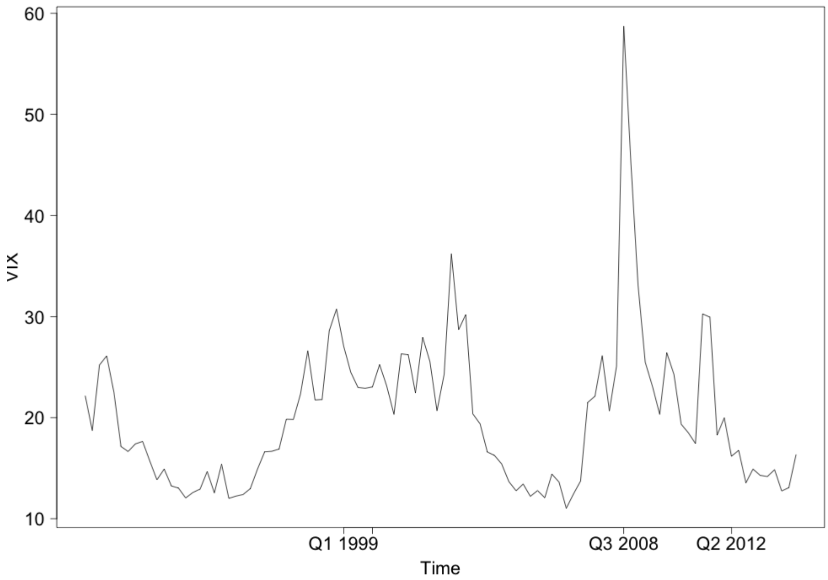

Figure A.20: Spain, VIX

Italy

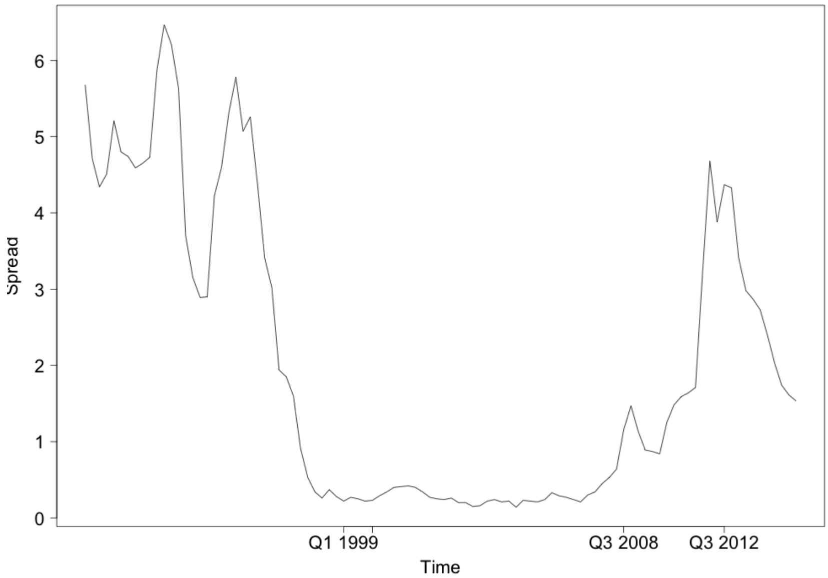

Figure A.21: Italy, spread

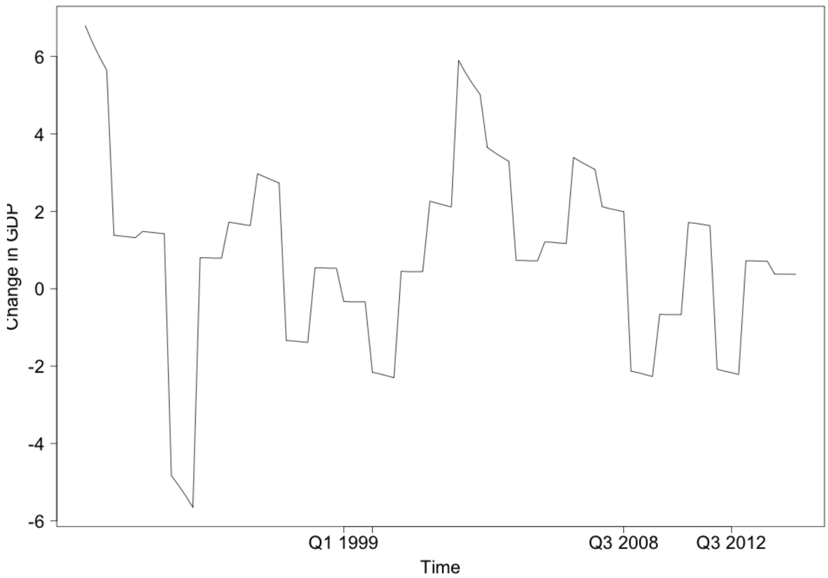

Figure A.22: Italy, change in GDP

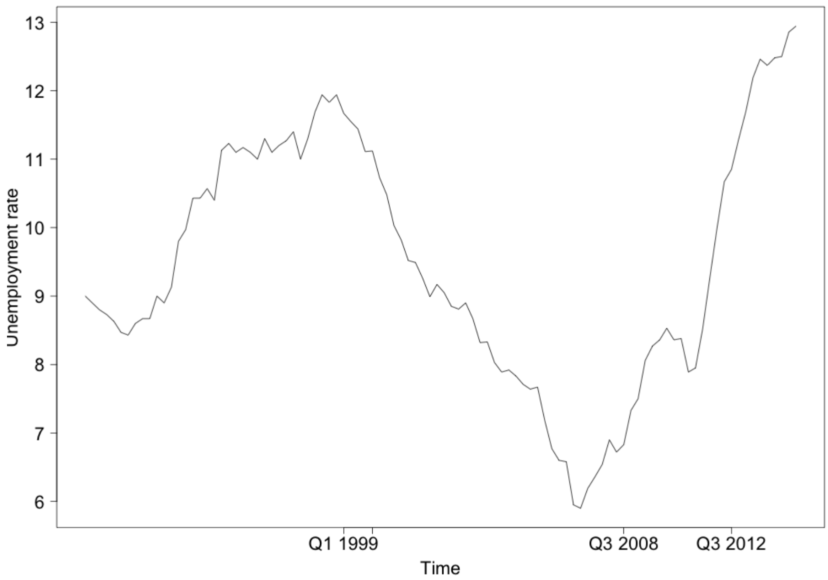

Figure A.23: Italy, unemployment rate

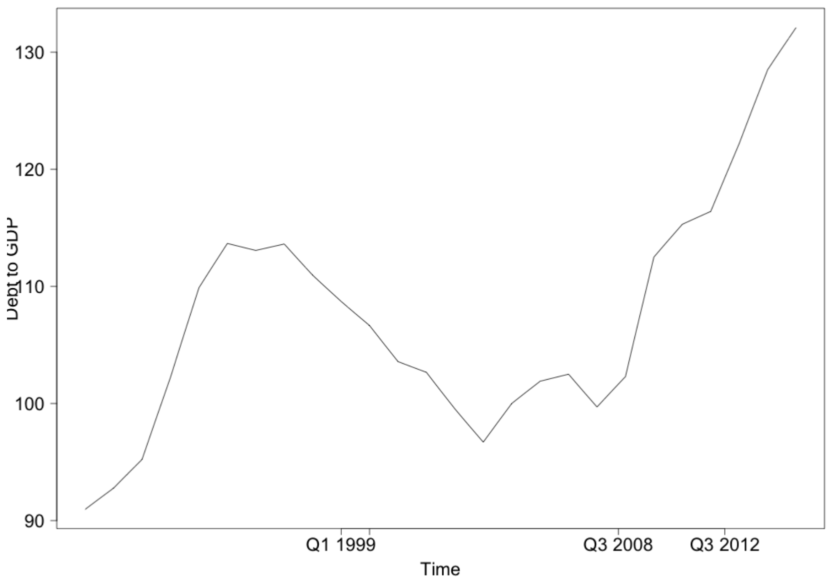

Figure A.24: Italy, debt to GDP

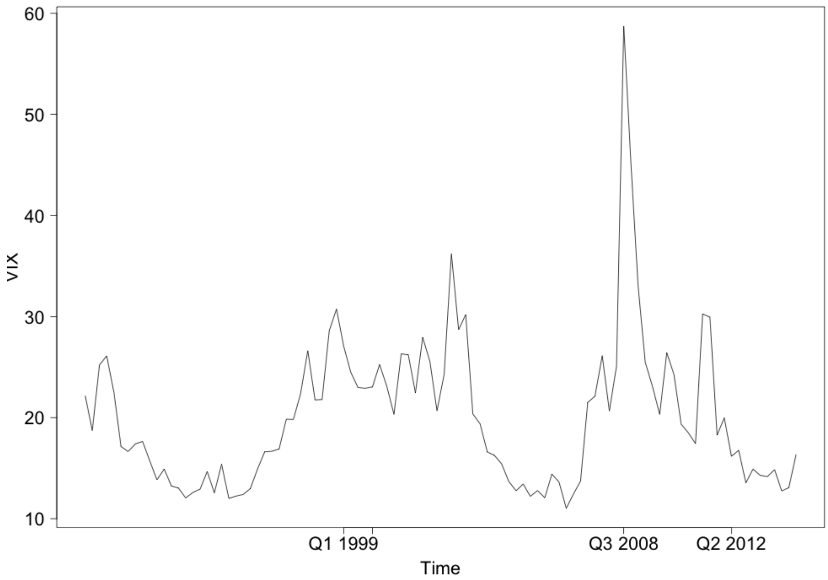

Figure A.25: Italy, VIX

2 Robustness Tests for the Moving Average Model

Robustness Test A

Table A.1: Robustness test A, moving average, Regime II

Country	Intercept	ΔGDP	UR	$\frac{D}{GDP}$	VSTOXX	ϕ
Greece	0.4497***[1]	−0.0535**	−0.1500**	-	0.0689***	1.0000***
Ireland	0.4427***	−0.0298*	-	0.2504***	0.0319**	0.7230***
Portugal	0.1553***	-	−0.4675***	1.0167***	-	0.5989***
Spain	0.1564***	−0.0520***	-	-	0.0402***	0.6841***
Italy	0.2879***	−0.0514***	−0.1004***	-	0.0316**	0.6700***

Table A.2: Robustness test A, moving average, Regime III

Country	Intercept	ΔGDP	UR	$\frac{D}{GDP}$	VSTOXX	ϕ
Greece	7.3424***	−0.6278**	7.3424***	-	1.1533***	−1.000***
Ireland	5.3343**	-	-	2.6915***	-	0.9452**
Portugal	2.4772*	−0.7026*	−8.6501**	17.2163***	0.7906*	0.6855**
Spain	3.8052*	-	1.1374*	2.8380***	0.5819***	0.6472***
Italy	8.2122***	0.3980***	5.9979***	-	0.2431**	0.9999***

Table A.3: Robustness test A, moving average, Regime IV

Country	Intercept	ΔGDP	UR	$\frac{D}{GDP}$	VSTOXX	ϕ
Greece	7.4570***	−3.2487***	-	-	1.8553***	−1.0000***
Ireland	4.5979***	−0.5848***	2.4313***	-	-	−0.9999***
Portugal	4.9269***	-	-	−15.0326***	-	1.000***
Spain	−5.1556***	-	-	−5.6695***	0.1131***	−1.000***
Italy	2.6430***	-	-	−5.6431***	0.1038**	0.9999***

[1]Significance levels: * = 0.1, ** = 0.05, *** = 0.01

Robustness Test B

Table A.4: Robustness test B, moving average, Regime I

Country	Intercept	ΔGDP	UR	$\frac{D}{GDP}$	VIX	ϕ
Greece	25.9332***[2]	-	−6.8528***	−19.0763***	−1.7653***	0.5968***
Ireland	1.0597***	-	-	0.4917***	-	1.0000***
Portugal	−2.2306*	0.5764***	−4.8068***	-	−0.8846***	0.5908***
Spain	−7.2580***	0.2903**	2.2903***	−5.5046***	0.2523*	1.0000***
Italy	2.6378***	-	−3.9722***	-	−0.7935***	0.6359***

Table A.5: Robustness test B, moving average, Regime II

Country	Intercept	ΔGDP	UR	$\frac{D}{GDP}$	VIX	ϕ
Greece	0.3879***	−0.0559*	−0.0812*	-	0.0443*	0.3740[3]
Ireland	0.4751***	-	-	0.2887***	0.0308**	0.7445***
Portugal	0.1703***	-	−0.3378***	0.7599***	0.0360***	1.0000***
Spain	0.2927***	−0.0301**	-	0.1948*	0.0365***	0.61082***
Italy	−0.3584*	-	−0.0918***	0.5825***	0.0403***	0.7003***

Table A.6: Robustness test B, moving average, Regime III

Country	Intercept	ΔGDP	UR	$\frac{D}{GDP}$	VIX	ϕ
Greece	6.7631***	−0.8916**	7.1831***	-	1.3795***	−1.0000***
Ireland	5.3057***	-	-	2.7790***	-	0.8615***
Portugal	5.5393***	−0.7792***	-	11.2802***	1.7573***	0.1650[4]
Spain	4.0883**	-	0.8948*	3.0282***	0.6018***	0.4852**
Italy	9.1186***	0.4106***	6.9117***	-	0.4445***	1.0000***

Table A.7: Robustness test B, moving average, Regime IV

Country	Intercept	ΔGDP	UR	$\frac{D}{GDP}$	VIX	ϕ
Greece	6.6294***	−4.6823***	-	-	-	−1.0000***
Ireland	4.5209***	−0.6395***	2.2266***	-	-	−1.0000***
Portugal	5.1698***	-	-	−13.8981***	0.2787**	1.0000***
Spain	−5.5666***	−0.0466*	-	−5.9633***	-	−1.0000***
Italy	2.6693***	-	-	−4.5985***	0.1802*	1.0000***

[2] Significance levels: * = 0.1, ** = 0.05, *** = 0.01
[3] p-value ≥ 0.25
[4] p-value ≥ 0.5

3 Robustness Tests for the Panel Data Model

Robustness Test A

Table A.8: Robustness test A, panel data, Regime II

	Intercept	ΔGDP	$\frac{D}{GDP}$	VSTOXX
Common	0.2272***[5]	−0.0589***	0.0799***	0.0428***
Country deviations				
Greece	0.0127	−0.0103	0.0030	0.0097
Ireland	0.0203	−0.0165	0.0049	0.0156
Portugal	0.0038	−0.0031	0.0009	0.0029
Spain	−0.0036	0.0029	−0.0009	−0.0028
Italy	−0.0331	0.0269	−0.0080	−0.0255

Table A.9: Robustness test A, panel data, Regime III

	Intercept	ΔGDP	$\frac{D}{GDP}$	VSTOXX
Common	1.6280[6]	-	7.7270***	0.9092***
Country deviations				
Greece	−8.8312	–	4.3799	0.6288
Ireland	3.9764	–	−4.7677	−0.5286
Portugal	3.7373	–	1.2722	0.2310
Spain	5.8260	–	−3.3223	−0.3111
Italy	−4.7321	–	2.7823	0.2633

Table A.10: Robustness test A, panel data, Regime IV

	Intercept	ΔGDP	$\frac{D}{GDP}$	VSTOXX
Common	3.9949***	−1.3671***	–	0.6145*
Country deviations				
Greece	3.6591	−1.6895	–	1.3277
Ireland	−1.3021	0.5866	–	−0.4674
Portugal	0.1612	−0.0494	–	0.0499
Spain	−1.1393	−0.0494	–	−0.4109
Italy	−1.3790	0.6336	–	−0.4993

[5] Significance levels: * = 0.1, ** = 0.05, *** = 0.01

[6] p-value > 0.5

Robustness Test B

Table A.11: Robustness test B, panel data, Regime I

	Intercept	ΔGDP	$\frac{D}{GDP}$	VIX
Common	7.9768[7]	0.6721***[8]	−8.1708*	−1.1284***
Country deviations				
Greece	27.8390	0.6851	−18.5385	−0.9516
Ireland	−7.0946	−0.4274	8.2410	0.6563
Portugal	−11.4987	0.2768	0.2650	0.0607
Spain	−8.6336	−0.1586	5.1090	0.3676
Italy	−0.6121	−0.3759	4.9235	−0.1329

Table A.12: Robustness test B, panel data, Regime II

	Intercept	ΔGDP	$\frac{D}{GDP}$	VIX
Common	0.2148***	−0.0524***	0.0782***	0.0557***
Country deviations				
Greece	0.0082	−0.0054	0.0011	0.0066
Ireland	0.0176	−0.0115	0.0023	0.0141
Portugal	0.0084	−0.0055	0.0011	0.0067
Spain	−0.0023	0.0015	−0.0003	−0.0018
Italy	−0.0320	0.0209	−0.0041	−0.0256

Table A.13: Robustness test B, panel data, Regime III

	Intercept	ΔGDP	$\frac{D}{GDP}$	VIX
Common	1.5867[9]	–	7.8371***	0.9735***
Country deviations				
Greece	−8.4047	–	3.1283	0.3078
Ireland	4.1541	–	−4.4153	−0.5210
Portugal	3.5959	–	1.9706	0.2936
Spain	5.6351	–	−3.2399	−0.3533
Italy	−4.9805	–	2.5563	0.2727

Table A.14: Robustness test B, panel data, Regime IV

	Intercept	ΔGDP	$\frac{D}{GDP}$	VIX
Common	4.0324***	−1.7652***	–	–
Country deviations				
Greece	3.0427	−2.5267	–	–
Ireland	−1.0688	0.8754	–	–
Portugal	0.2227	−0.1627	–	–
Spain	−0.9603	0.7916	–	–
Italy	−1.2363	1.0223	–	–

[7] p-value >0.2

[8] Significance levels: * = 0.1, ** = 0.05, *** = 0.01

[9] p-value >0.5