# Contagion in EMU government bond markets

## An analysis of the periphery

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August 13, 2015

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**Abstract**

This thesis provides an analysis on the impact of contagion on the government bond markets of the countries belonging to the EMU periphery. The main finding of the thesis is that the literature so far did not take into account two things sufficiently. First, the presence of unit roots in variables which means that in regression specifications in levels the case of spurious regression cannot be ruled out. Second, the poolability assumption does not seem to hold for the periphery. Separating the periphery sample into a Spain & Italy sample and a Ireland & Portugal sample shows that the government bond yield spreads of the different samples respond in a different way on the different independent variables which means that the homogeneity assumption does not hold. Taking these factors into account shows that there is very limited evidence for a wake-up-call contagion effect and strong evidence for a shift contagion effect in the Spain & Italy sample during the European sovereign debt crisis.

# 1 Introduction

In 2007 the housing bubble in the United States burst. Decreasing house prices in combination with the difficult mortgage backed securities system caused a decrease in mutual trust for commercial banks in the United States and some commercial banks came into trouble, the best known case is probably the bankruptcy of Lehman Brothers in 2008. Because of the globally interlinked banking system this American financial crisis soon became a global financial crisis and also European commercial banks got into trouble. To bail-out some commercial banks and to counteract a possible recession some European countries increased government expenditures, causing increasing budget deficits and public debt. First, financial markets did not seem to bother about the increasing public debt in some European countries but from 2010 government bond yield spreads started to increase for some countries in the Eurozone. The increase of government bond yield spreads for predominantly countries belonging to the EMU periphery (Ireland, Greece, Spain, Italy and Portugal) is one of the factors which occurred in and contributed to the European sovereign debt crisis. An explanation for the increasing government bond yield spreads might be that the risk investors faced on this bonds increased during this period. This thesis will study the relationship between several risk factors and the government bond yield of the EMU periphery countries compared to a risk free country [1].

The aim of this thesis is to answer whether financial markets started to price government bonds of the EMU periphery differently during the crisis than before the crisis. This is in the literature called a contagion effect. In the literature there is a consensus that there are three main factors determining government bond yields spreads in the Eurozone:

1. Fundamental, sovereign or default risk.
2. Liquidity risk.
3. (Global) risk aversion of financial markets.

As there are different determinants of government bond yields there are also different kinds of contagion. An example of one kind of contagion is wake-up-call contagion which means that financial markets price fundamental risk differently during the crisis than before the crisis. The theory behind wake-up-call contagion is that before the crisis financial markets believed that EMU countries were not likely to default and did not look at fundamentals like the debt to GDP ratio. Since financial markets did not look at fundamentals the role of fundamentals as a government bond yield determinant was small before the crisis. During the crisis however a default becomes more likely for some countries and financial markets start to look at the fundamentals of these countries again which means that fundamentals play a larger role in how government bonds are priced during the crisis than before the crisis. The extent to which the impact of the fundamentals on government bond yield spreads changes is called the wake-up-call contagion effect. The other contagion kinds which have been researched in this thesis are regional-, shift- and pure contagion. The main focus will be on the impact of wake-up-call- and shift contagion on government bond yield spreads of the periphery.

The extent to which financial markets price risk is highly relevant since an increase in the interest rate of a specific bond in combination with a possible public debt of the issuing country might bring a country in severe trouble. To pay off the existing debt countries issue

[1] The government bond yield spread is the difference between the government bond yield of a specific country and the government bond yield of a risk free country.

bonds. It is harder to reduce the existing government debt if a country has to pay a higher interest rate on its' issued bonds and if a country cannot succeed to diminish the government debt it can end up in a vicious circle with a higher government debt causing a higher interest rate which causes on its' turn a higher government debt and so on. For policy makers it is essential not to end up in this vicious circle which is easier if the determinants of government bond yields are known.

# 2 Literature review

## 2.1 Theoretical relationship government bond yield and risk

If a country borrows money from investors, these investors face risk. The most familiar example of risk investors face is sovereign risk which is the probability that a country does not honor its obligations from the agreement. Take as an example the case that a country issues treasury bills. Investors lend out money to a country because the country promises in the future to pay back the borrowed money plus some additional interest. In this case the sovereign risk is the probability that the respective country does not pay back the borrowed sum plus the interest in the future. If investors (through financial markets) argue that a bond gets more risky the bonds will become less popular. The investors will demand a higher yield to compensate for the additional risk so the market price of the bond will fall (since the nominal value of a bond and the fixed interest payment do not change after a bond has been issued). A high demanded yield signals that it is hard for a country to attract capital. If a country by issuing a new bond wants to attract the same amount of money it has to pay a higher fixed interest rate.[2] The government bond yield spread between a specific bond and a risk free bond gives an indication of the riskiness of the specific bond.

## 2.2 Theoretical determinants government bond yield spreads

According to Codogno et al. (2003) there are four determinants of government bond spreads: exchange rate risk, capital controls, liquidity (risk) and default risk (or in the terminology of this thesis: sovereign or fundamental risk). The introduction of the Euro in 1999 eliminated exchange rate risk as a determinant of yield spreads and being a EU member state also prohibits capital controls. So for government bonds of Euro-countries only default- and liquidity risk matter. Another in the literature often described determinant of government bond yield spreads is global risk aversion of financial markets (Klepsch, 2011).
The early literature on explaining government bond yield spreads for EMU-countries after

[2]To see the positive theoretical link between risk, the interest rate and the demanded yield on a bond it is useful to use the formula of the market price of a issued bond.

$$Market\ Price\ Bond_{t=0} = \frac{nominal\ value\ bond\ at\ maturity}{(1+Yield)^T} + \sum_{i=1}^{T} \frac{interest\ payment}{(1+Yield)^i}$$

where T: total number of interest payments

The market price can be seen as the amount the market currently is willing to lend out to the issuing country. The market wants to be compensated for the additional risk and will demand a higher yield. So if a country want to receive a high market price for its' issued bond it will have to increase the yearly interest rate it pays. This is the theoretical reasoning behind the positive relationship between sovereign risk and both the interest rate as the yield of a bond.

introduction of the Euro focused on separating domestic- (or idiosyncratic) and international (or systematic/ common) risk factors. Default risk and liquidity risk are treated as domestic factors while the risk aversion of financial markets is treated as an international risk factor (Gómez-Puig et al., 2014).

### 2.2.1 Default risk

Default risk means the probability that the bond issuing country does not meet its' obligations and does not pay back the promised amounts to the buyers of the bonds.
Pagano and Thadden (2005) subdivide default risk into the country specific default risk and the sensitivity of a country to a common shock in the Eurozone. As an example for the latter they use the scenario that the Euro stops to exist. The response on this common shock is different for the different Eurozone countries. Financial markets might keep such an scenario into mind while assessing default risk. Codogno et al. (2003) and Gómez-Puig (2006) argue that default risk might have increased after the introduction of the Euro since individual member states do not have the possibility to print additional money to meet future obligations. Gómez-Puig (2006) adds the fact that both the ECB as individual governments are not allowed to bail-out governments in trouble as a reason for an increase in default risk. Financial markets measure default risk by examining the underlying fundamentals of the country. Often used proxies in the literature for default risk are government debt to GDP ratio, the ratio of government debt to tax revenue, current account position, real effective exchange rate, economic growth (de Grauwe and Ji, 2013) and credit ratings from rating companies (Gómez-Puig, 2006).

### 2.2.2 Liquidity risk

A bond is said to be liquid if it is easy to sell the bond, in other words the easiness to convert the bond into cash. Logically the more liquid the bond is, the lower the liquidity risk, the lower the demanded yield on a government bond.
Favero et al. (2005) subdivide the liquidity component into three subcomponents. First, illiquidity creates trading costs (Amihud and Mendelson, 1986). Second, it can create additional risk (Pástor and Stambaugh, 2003). According to this view trading costs are not constant over time. Investors face the risk that trading costs might increase in the future. Third, illiquidity can interact with risk. Favero et al. (2005) show that financial markets react less on additional risk for current less liquid bonds but more for future less liquid bonds. Financial markets punish additional risk for current less liquid bonds less heavily because for example high transaction costs effectively reduce the financial gain of selling. Selling of an illiquid bond by definition will yield less than selling a liquid bond. So if risk suddenly increases it is less profitable to sell an illiquid bond than selling a liquid bond. In other words the variance of the bond prices decreases if a bond is more illiquid (Pagano and Thadden, 2005). The reason that financial markets punish additional risk for future less liquid bonds more heavily is that if something goes wrong in the future it will be hard to sell the bond because it is illiquid.
In the litereature the Bid-Ask spread, Amount of outstanding sovereign debt (Gómez-Puig, 2006) and the turnover ratio (total trading volume divided by the total value of stock outstanding) (Codogno et al., 2003) are often used proxies for liquidity risk. Inoue (1999) shows that for G10 countries the larger the value of total outstanding sovereign debt, the larger the market for the bond which increases the liquidity of a specific bond. Note that if larger markets will increase liquidity, investors will prefer larger markets because it reduces liquidity

risk. This process will make it hard for new bond markets to emerge because new markets start small (with low liquidity and high liquidity risk). So liquidity is self-reinforcing: liquidity will increase because new markets will not emerge. Investors will have to invest in already existing bond markets which increases liquidity of this market which makes it even harder for new bond markets to emerge (Economides and Siow, 1988). This is likely to be one of the reasons for European countries to create a more integrated bond market.

### 2.2.3 (Global) Risk aversion

Klepsch (2011) identifies risk aversion as a third determinant of government bond spreads of Eurozone countries. The literature in general finds a positive relationship between government bond spreads and risk aversion of financial markets. In other words the more risk averse financial markets become the higher the government bond yield spread. In earlier contributions many academics found a strong effect of a common international risk factor on government bond yield spreads (Codogno et al., 2003; Bernoth et al., 2004; Favero et al., 2005) which in later articles has been interpreted as risk aversion of financial markets. The most used proxies for global risk aversion (in the case of EMU government bonds) are the Volatility Index of Chicago Board Exchange (VIX) (Gerlach et al., 2010; Gómez-Puig et al., 2014) or the spread between the yield of US AAA corporate bonds and the yield of 10-year US government bonds (Codogno et al., 2003).

### 2.2.4 Other common risk factors

Giordano et al. (2013) use two additional proxies for common risk: 1) the monetary policy rate set by the ECB 2) an index of economic policy uncertainty. The latter is derived from a relatively new index created by Baker et al. (2015). The initial idea of including the short run interest rate as a common risk factor came from Manganelli and Wolswijk (2009). Note, that the short run policy interest rate of the ECB is a common risk factor since it is the same for all EMU countries though it is not a proxy for risk aversion of financial markets because the short run interest rate is an instrument of the ECB to keep yield spreads within the Eurozone low while risk aversion is a common factor which has an impact on European government bond markets from outside the Eurozone According to (Manganelli and Wolswijk, 2009) it is important to add the short term interest rate as a variable which explains government bond yield spreads because failing to add it might entail an omitted variable bias. They argue that the short term interest rate is correlated to both the risk aversion variable as the government bond yield spread for the following reason. The short term interest rate influences the state of the economy and the state of the economy on its' turn has an impact on risk taking behaviour of financial markets. A higher short term interest , which is a monetary tightening, has a negative impact on the state of economy. In recessions financial markets get more nervous which means that risk aversion increases during recessions. If these two channels are combined it is straightforward to observe that a higher short term interest causes global risk aversion to increase. In the same time a higher short term interest rate might also involve that financial markets get less positive about the future financial situation of a country which increases the government bond yield spread. So there is also a positive correlation between the short term interest rate and the government bond yield spread. This omitted variable bias might cause an overestimation of the impact of the risk aversion variable (see figure 1 on page 5). Another benefit of including the short term interest as a determinant of government bond yield spreads is that it shows the impact of conventional monetary policy on government

bond yield spreads.

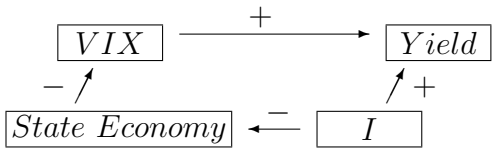


Figure 1: Potential omitted variable short term interest rate

## 2.3 Development of government bond yield spreads in the Eurozone

### 2.3.1 Introduction of the Euro

One of the important aims to create the monetary union is to create a more integrated bond market which implies that government bond yields within the Eurozone would converge which theoretically makes sense because exchange rate risk and capital risk were eliminated after the introduction of the Euro. To avoid large fiscal deficits from members within the Eurozone the founders of the Euro created the Stability and Growth Pact, including a no-bail out clause. The no-bail out clause implies that countries within the Eurozone will not bailout others if they come into severe financial trouble.

### 2.3.2 Development of government bond spreads 1999-2014

When observing the government bond yield spreads before and after the introduction of the Euro it is evident that just before 1999 the government bond yield spreads already approximately converged showing the forward looking behavior of financial markets. Before the Euro actually had been introduced financial markets already realized that exchange rate risk would be eliminated after the introduction of the Euro. Financial markets anticipated which caused government bond yield spreads already converged before the introduction of the Euro. Until the global financial crisis the government bond yield spreads were nihil. After the global financial crisis of 2008 it initially appeared that financial market did not care about European sovereign debt although government bond yield spreads slightly to started increase (Lane, 2012). However in late 2008 cross border capital flows started to decrease within the Eurozone because investors started to reassess their international exposure levels (Milesi-Ferretti and Tille, 2011). However, government bond yield spreads remained more or less stable until late 2009 when the sovereign debt crisis hit the Eurozone. In the last part of 2009 mainly the countries belonging to the periphery reported worse government debt to GDP ratio's than expected and the government bond yield spreads diverged after 2010 (Lane, 2012) (See figure 2 on page 6 for the behaviour of government bond yield spreads during . Many academics argue that the government bond yield spreads of the periphery were, according to the underlying fundamentals, underpriced before the crisis and overpriced during the crisis (Beirne and Fratzscher, 2013; Aizenman et al., 2013). For the northern European countries they find the opposite: before the crisis government bond yield spreads were overpriced and during the crisis underpriced. It is hard to argue whether bonds are under- or overpriced because financial markets are forward looking. Financial markets might base their estimations

of sovereign risk on their expectations of the future values of the fundamentals. The authors who argue that periphery bonds are currently overpriced often base their conclusion on the values of current fundamentals. The current values of the fundamentals are however not necessary equal to the expectation of the future values of the fundamentals. So it is probably not correct to draw overpricing conclusions based on the current values of the fundamentals. This thesis will try to catch the pricing of risk and will not try to draw an conclusion whether some government bonds are over- or underpriced.

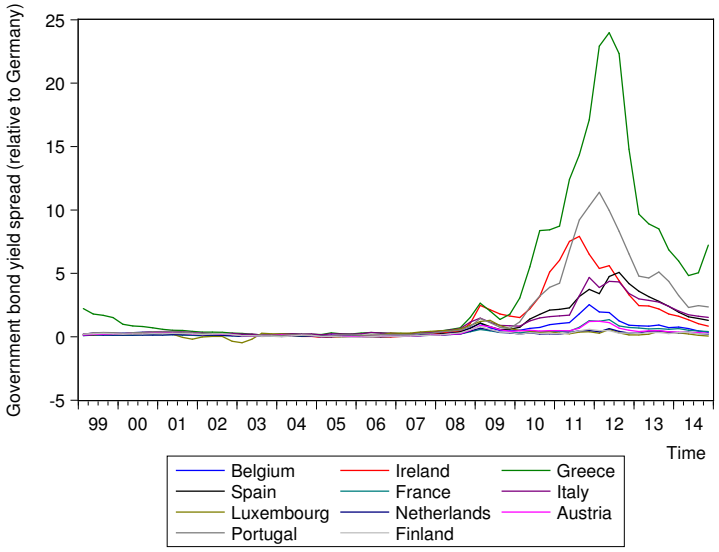


Figure 2: Government bond yield spreads, period 1999-2014

## 2.4 Empirics: determinants of government bond yield spreads before crisis

During the period between the introduction of the Euro and the financial crisis government bond yield spreads converged, though not completely which means that there are still factors which make government bonds from Eurozone countries imperfect substitutes. The literature in general finds a minor role for default risk in explaining government bond yield spreads for the period before 2008 compared to the period after 2008.

The early literature on explaining government bond yield spreads for EMU countries after the introduction of the Euro focused on separating domestic- (or idiosyncratic) and international (or systematic/ common risk factors). Default risk and liquidity risk are treated as domestic factors while the international factors proxy for risk aversion of financial markets (Gómez-Puig et al., 2014). A next thing which can be concluded from separating domestic and international factors is whether government bond yield spreads are driven by systematic/ common risk or idiosyncratic/ individual risk.

The work of Codogno et al. (2003) is one the best known early works in this field. To assess the impact of default risk on government bond yield spreads they use international factors, country-specific fundamentals and an interaction between international factors and country-specific fundamentals. International factors are used to control for time-invariant liquidity factors, which is reasonable if liquidity factors and international factors interact. The country-

specific fundamentals measure the direct impact of sovereign risk on government bond yield spreads and the interaction term captures the additional effect of the country-specific fundamentals in combination with international factors. Remarkable is that they find that default risk does not play a role in explaining government bond yield spreads except for Austria, Spain and Italy. For Spain and Italy the country-specific fundamentals play a significant role and for Austria the interaction term of the country-specific fundamentals and international risk factors. For the other Eurozone countries only the international risk factors play a significant role in explaining government bond yield spreads.

This declining role of fiscal performance in pricing of sovereign risk has consistently been found in the literature for the period before the financial crisis (Codogno et al., 2003; Bernoth et al., 2004; Klepsch, 2011). An explanation might be that financial markets did not believe that the no-bailout clause of the Maastricht treaty was credible (Klepsch, 2011). Bernoth et al. (2004) however find that although the linear effect of the debt to GDP ratio's decreased the non-linear effect increased which means that countries will be punished less for their debt to GDP ratio's but that this effect declines if the debt to GDP ratio increases. Another finding is that the debt service ratio also has a significant effect on government bond yield spreads and explains more of the total variation than debt to GDP ratio's or deficit to GDP ratio's (Bernoth et al., 2004).

The evidence of the impact of liquidity risk on government bond yield spreads before the crisis is mixed. Some argue that the impact of liquidity risk decreased after the introduction of the Euro (Codogno et al., 2003; Klepsch, 2011). Klepsch (2011) mentions increasing financial market integration as a reason for this finding. Gómez-Puig (2006) however finds that the marginal impact of liquidity on government bond yield spreads increased after the introduction of the Euro (the more liquid the bond market the lower the spread). This means that after the introduction of the Euro financial markets valued liquidity more than in the period before the Euro. To determine whether liquidity risk in total decreased or increased total government bond yield spreads after the introduction of the Euro information on both the change in liquidity as how much financial markets value liquidity is needed. The finding of Gómez-Puig (2006) only shows the impact of one additional unit of liquidity risk after the introduction of the Euro, in other words how much financial markets value liquidity which is in line with the finding of Bernoth et al. (2004) that the yield of German bonds is lower than of EMU countries with better fiscal positions because the German bond market is much larger than of the countries' with better fiscal positions; the larger the market the more liquid the bond which causes a lower yield.

Although Codogno et al. (2003) also find a significant impact of liquidity factors on government bond yield spreads, they argue that the fact international factors remain significant after controlling for liquidity factors show that these international factors primarily measure the creditworthiness of the issuers of the bond and that liquidity factors matter to a less extent. Before the crisis academics primarily found that government bond yield spreads of Eurozone countries were driven by systematic or common risk (Geyer et al., 2004; Pagano and Thadden, 2005). This finding is consistent with the for example the work of Codogno et al. (2003), seen the fact that the international risk factors significantly explained government bond yield spreads for approximately all Eurozone countries, while country-specific fundamentals were only significant for some countries.

Pagano and Thadden (2005) argue that the aim of a fully integrated Eurozone bond market (which means that government bond yields are the same for all Eurozone countries) did not succeed yet (although government bond yield spreads converged before the financial crisis) because of two main factors: 1) default risk differences between member states 2) financial

markets fear a possible break-up of the Eurozone. Although the role of default risk declined in explaining the spreads it still explains why the spreads did not fully converge. Liquidity factors play in their view a minor role in explaining government bond yields spreads of EMU countries.

## 2.5 Empirics: determinants of government bond yield spreads during the crisis

Barrios et al. (2009) find that international factors, which they define as a proxy for general risk aversion, offer the main explanation of increasing government bond yield spreads within the Eurozone, which is in line with the finding of Codogno et al. (2003) for the period before the crisis. However Barrios et al. (2009) find that default risk factors play a larger role after the crisis than in the study of Codogno et al. (2003) since both pure country-specific fundamentals as the interaction effect of international factors with country-specific fundamentals play a non-negligible role in explaining government bond yield spreads in their sample.
Mody (2009) argues that after the rescue of the commercial bank Bear Stearns financial markets take into account the stability of the banking sector of a country in pricing a government bond. If the banking sector is not stable financial markets will fear a bail-out which increases public debt and an increasing public debt on its' turn increases the probability of a default. The importance of fundamentals increases if risk aversion increases which means that if investors get more risk averse fundamentals get more important (Barrios et al., 2009; Gerlach et al., 2010; Attinasi et al., 2009; Haugh et al., 2009). Both Gerlach et al. (2010) as Attinasi et al. (2009) find like Mody (2009) a positive significant effect of the fragility of the financial sector on government bond yield spreads. The former use the value of total assets in the banking sector (relative to GDP) and the ratio of equity relative to the value of total assets in the banking sector as proxies for the fragility of the financial sector, while the latter use different dummies for rescue announcement as a proxy. Recently, academics argued that that financial markets also take the exposure of commercial banks to risk of foreign commercial banks into account. The last centuries commercial banks throughout Europe became increasingly active in cross-border activities (Allen et al., 2011). If a German bank for example has a lot of stocks in an Italian bank, the investors of German state bonds indirectly face additional default risk in the case of bankruptcy of the Italian Bank. A suitable proxy for this additional cross-border risk is according Gómez-Puig et al. (2014) the value of foreign claims to GDP ratio provided by the Bank of International Settlements. Finally Gómez-Puig et al. (2014) argue that it is important to include indebtness of the private sector as an important default risk fundamental.
For the period after the financial crisis studies find in general a more important role for local (default risk or liquidity risk) factors. So after the crisis idiosyncratic or country-specific factors played a larger than before the crisis. The outcome of a larger role for idiosyncratic risk factors also makes sense since government bond yield spreads diverged after the financial crisis. Diverging spreads are more likely to happen if country-specific factors play a larger role (unless some countries are more heavily punished by international risk than others).

### 2.5.1 Impact monetary policy on EMU government bond spreads

After the financial crisis the effectiveness of monetary policy in reducing yields started slowly to gain importance. (Manganelli and Wolswijk, 2009) find a positive impact of the short term interest rate on the government bond yields. The impact is larger for EMU countries with a worse debt to GDP ratio. Mid-2012 the short term interest rate within the Eurozone approached zero. From that moment the short term interest rate approached zero and the ECB could not lower the interest rates more. After 2012 the ECB undertook more unconventional policies like OMT and Quantitative Easing. The impact of those unconventional policies is hard to measure with quarterly data. The literature which researches the impact of these policies uses often daily data. Altavilla et al. (2014) use daily data to find the impact of OMT announcements on government bond spreads of Germany, France, Italy and Spain. They find that after an stimulating announcement bond yields in Spain and Italy lowered while the yields for Germany and Franc remained unchanged. So OMT annoucements cause government bonds yields of Spain in Italy to converge towards the yields of Germany and France.

## 2.6 Contagion

This thesis will use the definition of contagion from Beirne and Fratzscher (2013). In their view contagion is ‘ the change in the the way countries’ fundamentals or other factors are priced during the crisis’ and contagion can be subdivided into three groups: wake-up call contagion or fundamentals contagion, regional contagion and herding contagion. First, wake-up call contagion means that financial markets price the fundamentals of an individual country differently in a crisis. Second, they define regional contagion as a rise in the impact of a negative shock in a neighbouring country on the government bond yield spread of a country. Last, herding contagion occurs in the case that financial markets panic which means that without an actual reason government bond spreads suddenly start to increase. Giordano et al. (2013) add shift contagion as a fourth kind of contagion. Shift contagion means that government bond yield spreads react more heavily on global risk aversion during the crisis than before the crisis.

### 2.6.1 Contagion in a monetary union from a theoretical perspective

In de Grauwe (2011) a theoretical multiple equilibrium model has been developed for countries within a monetary union. The multiple equilibrium model illustrates that a country might end up in a good- or a bad equilibrium. A good equilibrium implies a low government bond yield. A country will end up in a good equilibrium if either financial markets belief that it will not default or financial markets expect that another country within the monetary union will bail-out the country in case of a default. On the other hand a country will get into a bad equilibrium if it gets more likely a country will default which means that investors will not get back their money. Countries within a monetary union issue bonds in a currency which they do not control. So a country within a monetary union cannot print additional money to pay its’ debts which involves additional risk for investors. De Grauwe argues that a country within a monetary union can end up in both a good as a bad equilibrium because if the economy performs well investors are optimistic and believe that countries will bail each other out within the monetary union as necessary which reduces default risk. On the other hand if the economy performs worse investors do not longer believe that countries will help each other out if necessary which in combination with the fact that individual countries cannot

print additional money to fulfill its' debt causes that a country ends up in a bad equilibrium. So from a theoretical perspective contagion is more likely to occur for countries who are part of a monetary union than for stand-alone countries (de Grauwe and Ji, 2013).

### 2.6.2 Empirics: contagion during current crisis

A standard approach to detect wake-up-call- and regional contagion is to first find the date of a structural break and create a dummy for the period before and after the crisis. A significant interaction term of the explaining fundamental with the dummy shows that financial markets price a certain fundamental in a different way during the crisis. This does however not necessarily mean that contagion is the only explanation of diverging government bond yield spreads. To measure total impact of the different factors on government bond yield spreads Beirne and Fratzscher (2013) use a growth accounting approach. Gómez-Puig and Sosvilla-Rivero (2014) show that by using both Quandt-Andrews tests as Bai-Perron tests that approximately two third of all structural breaks occurred after November 2009. They argue that the probability of contagion to occur is largest after November 2009. Papandreou announced in November 2009 that Greece had far worse public finance statistics than expected.
Beirne and Fratscher (2013) detect herding contagion by examining tail-clustering of the residuals from the growth accounting approach. If many countries have large residuals around the same time this is an indication for panic in the market or herding contagion. Gómez-Puig et al. (2014) argue that herding behavior occurred in the Eurozone during the European sovereign debt crisis because the marginal effect of international factors (which measures the degree of risk aversion of investors) is greater during the sovereign debt crisis than before the crisis (in the framework of this thesis it is called shift contagion however). The effect has mainly been found for the periphery. If financial markets get more risk averse demand for bonds of the periphery decreases more than for the bonds of Northern-European countries. This can be interpreted by the flight-to-safe-havens hypothesis: if financial markets are nervous investors withdraw money from the countries with a bad reputation. In this sense shift contagion means that the impact of the flight-to-safe-havens hypothesis has increased during the crisis. de Grauwe and Ji (2013) observe the effect of herding behavior by adding time dummies to their fixed effect analysis to observe the impact of fundamentals on government bond yield spreads. A significant time dummy shows the effect of a certain period on government bond yield spreads independent from changes in the fundamentals. After measuring the impact of time dummies de Grauwe and Ji (2013) use a growth accounting approach as in Beirne and Fratzscher (2013) to measure the relative impact of herding- and wake-up-call contagion.
Although different methods were use both Beirne and Fratzscher (2013) as Gómez-Puig et al. (2014) find that the increase is government bond yield spreads within the Eurozone is due to both wake-up contagion as herding contagion. Herding contagion was more important during the global crisis of 2008 while wake up-call-contagion explained more of the increase in government bond yields during the European sovereign debt crisis (Beirne and Fratzscher, 2013).de Grauwe and Ji (2013) find that the government bond yield spreads are mainly driven by market sentiments or herding contagion. For the Northern-European countries these markets sentiments were positive causing lower government bond yield spreads compared to their underlying fundamentals while for the periphery these markets sentiments were negative causing higher government bond yield spreads.
Aizenman et al. (2013) use a different approach to detect contagion. First, they determine the in-sample determinants of sovereign yield spreads. By using the in-sample coefficients out-of-

sample forecasts are created. After observing large prediction errors for Eurozone countries after 2010 their finding is that financial markets started to price sovereign risk differently after 2010. Large prediction errors indicate that the coefficients from the in-sample period do not result into correct out-of-sample predictions which means that either the coefficients of the determinants changed or other factors started to play a role. For other comparable OECD countries large prediction errors already had been found in 2008 during the global financial crisis. The finding for Eurozone countries is in line with the structural break (November 2009) found by Gómez-Puig and Sosvilla-Rivero (2014).

# 3 Methodology

This thesis focuses on whether during the European sovereign debt crisis contagion had an impact on government bond markets of the periphery. The focus is on the following kinds of contagion:

- Wake-up-call contagion or fundamental contagion. Goldstein (1998) defines wake-up-call contagion as the fact that during a crisis financial markets start to focus more heavily on the country-specific fundamentals in assessing the risk of government bonds. (Beirne and Fratzscher, 2013; Giordano et al., 2013).

- Regional Contagion. Beirne and Fratzscher (2013) define regional contagion as a rise in the impact of a negative shock in a neighbouring country on the government bond yield spread of a country. If a country government bond yield spread responds more heavily during the crisis then regional contagion took place since in that case a country is more affected by a shock in neighbouring countries during the crisis than before the crisis.

- Shift Contagion. Forbes and Rigobon (2002) define shift contagion as the phenomenon that the cross-markets linkages in the bond pricing process significantly increase during a crisis. In this thesis following the approach of Giordano et al. (2013) the cross-markets linkages are measured by a common factor. So in this framework shift contagion means that during a crisis the bond yield spreads responds more heavily on the common factor global risk aversion of financial markets.

- Pure Contagion. Giordano et al. (2013) use a residual category (crisis dummy) since there might be another contagion effect besides wake-up call-, regional- and shift contagion. The impact of herding contagion from Beirne and Fratzscher (2013) belongs to this category.

## 3.1 Regression specification and selection of variables

The more general equation to research the impact of contagion is the following[3]:

$$\begin{aligned} s_{i,t} = \alpha_i + \alpha_1 s_{i,t-1} + \alpha_2 s_{i,t-2} + \alpha_3 s_{i,t-3} + \beta_1 f_{i,t} + \beta_2 reg_{i,t} + \beta_3 liq_{i,t} + \beta_4 ra_t \\ +\beta_5 \pi_{i,t} + \beta_6 i_t + \gamma_0 c_t + \gamma_1 f_{i,t} * c_t + \gamma_2 reg_{i,t} * c_t + \gamma_3 ra_t * c_t + \gamma_4 i_t * c_t + \epsilon_{i,t} \end{aligned} \tag{1}$$

$$|\alpha_1 + \alpha_2 + \alpha_3| < 1, \text{stability condition}$$

See table 1 on page 12 for an overview of the variables. The table also shows whether the variable is a country-specific- or a common risk factor. The dummy takes the value of 1 during the financial crisis and 0 before the financial crisis. The country-specific fundamental risk factors have been included to make detection of wake-up-call contagion possible and risk aversion has been included for the detection of shift contagion. Following Beirne and Fratzscher (2013) $R_{i,t}$ measures regional risk which is measured as the average yield spread[4] of the group [5] and including it in the equation makes detection of regional contagion possible. The liquidity factor has been added as a control variable. If there has not been controlled for liquidity risk it might bias the coefficients of the other variables if there is an omitted variable bias which means that the omitted variable is correlated with both the dependent variable as one or more independent variable(s) (Verbeek, 2012). The short term interest rate has been included for two reasons. First, it serves as a control variable. The second reason is to see the effectiveness of conventional monetary policy of the ECB on lowering government bond yield spread of the periphery in recessions. The inflation has been included only as a control variable.

| Variables main regression | | | | |
|---|---|---|---|---|
| **Fundamentals** | **Liquidity** | **Risk Aversion** | **Regional** | **Rest** |
| Debt to GDP ratio forecast ($Z_{i,t}$)<br>GDP growth ($Z_{i,t}$) | Amount outstanding debt ($Z_{i,t}$) | VIX ($F_t$) | Average spread group ($Z_{i,t}$) | Short run int. rate ($F_t$)<br>Inflation ($Z_{i,t}$) |
| Variables robustness checks | | | | |
| **Fundamentals** | **Liquidity** | **Risk Aversion** | **Regional** | **Rest** |
| Debt to GDP ratio ($Z_{i,t}$)<br>MFI debt to GDP ratio ($Z_{i,t}$)<br>Claims to GDP ratio ($Z_{i,t}$) | Bid-Ask spread ($Z_{i,t}$) | US corporate bond AAA spread ($F_t$) | | |

Table 1: Selection of variables

A higher debt to GDP forecast increases the government bond yield spread since a country with a higher debt to GDP ratio involves more credit risk. The forecast has been used instead of the current debt of GDP ratio because of the forward looking behaviour of financial markets (Attinasi et al., 2009). A higher GDP growth rate involves less credit risk (so the expected sign is negative). A country with more economic growth has a larger tax base which makes it

[3]Where $s_{i,t}$ is the government bond yield spread relative to Germany, $f_{i,t}$ country-specific fundamental risk factors, $reg_{i,t}$ regional risk factor, $liq_{i,t}$ liquidity risk factor, $ra_t$ risk aversion risk factor, $\pi_{i,t}$ inflation and $i_{i,t}$ the short term interest rate set by the ECB.

[4]The yield spread is the difference between the government bond yield of the respective country and the government bond yield of Germany

[5]Group: Ireland, Greece, Spain, Italy and Portugal. The yield spread of the country itself has been excluded, so it is not a common factor which is the same for all countries. The regional yield spread variable can be regarded as a quasi-common factor.

more easy for the country to pay-off the existing government debt (de Grauwe and Ji, 2013). More risk averse global financial markets [6] will probably increase the government bond yield spreads in the periphery. An explanation is the flight-to-safe-havens hypothesis (or flight-to-quality hypothesis)[7]. Countries which have more liquid government bonds are likely to have a lower government bond yield spread [8]. Because the image of the periphery might be that the periphery countries are similar the expectation is that a shock in one country in the periphery (which drives up its' yield spread) also has an impact on the government bond yield spreads of the other periphery countries because financial markets believe that this shock also will hit the other periphery countries (which means the correlation between the government bond yield spreads of the countries and the regional yield spread is positive) (Beirne and Fratzscher, 2013). The higher the inflation the higher government bond yield spread. If inflation increases government bonds get less popular because the value of money decreases. Financial markets will for this reason demand a higher return on government bonds which increases the government bond yield. If the short term interest is positively correlated with government bond yield spreads of the periphery, this is an indication that the ECB successfully manages to drive down the government bond yields of the periphery by using conventional monetary policy. A look on the $\gamma$ variables in equation (1) shows the impact of the different kinds of contagion on government bond yield spreads. A significant $\gamma$ with the correct sign shows whether contagion occurred in the government bond markets during the crisis (for an overview see table 2)[9].

| Variables main regression | | | |
|---|---|---|---|
| Contagion variable | Coefficient | Expected sign | Contagion kind |
| Crisis constant | $\gamma_0$ | +/- | Pure |
| Debt to GDP forecast | $\gamma_1$ | + | Wake-up call |
| GDP growth | $\gamma_1$ | - | Wake-up call |
| Regional | $\gamma_2$ | + | Regional |
| VIX | $\gamma_3$ | + | Shift |
| Variables robustness checks | | | |
| MFI debt to GDP ratio | $\gamma 1$ | + | Wake-up-call |
| Claims to GDP | $\gamma 1$ | + | Wake-up-call |
| US corporate bond AAA spread | $\gamma_3$ | + | Shift |

Table 2: Contagion overview

According to the literature one of the starting points of European sovereign debt crisis is 2009Q4 (Gómez-Puig and Sosvilla-Rivero, 2014) which makes theoretically sense because during the last quarter of 2009 countries started to report worse debt to GDP ratio's than expected (Lane, 2012) and it was the quarter that Papandreou announced that Greece had reported wrong information on debt levels and other fundamentals. However the breakdate can also be in another quarter (and it might even be different for the different countries/cross-

[6] If government bond markets get more risk averse both the VIX increase as the US corporate bond AAA spread increase.

[7] Financial markets are less willing to take risk which means that the demand for bonds of the periphery decreases and the demand for the bonds of a safe country like Germany increases. This will increase the government bond yield in the periphery and decrease the government bond yield in Germany which means that the government bond yield spreads of the periphery countries increases.

[8] The higher the amount of outstanding debt the more liquid the bond. The lower the Bid-Ask spread the higher the liquidity of the bond.

[9] The robustness check chapter explains the theory behind the signs of the fundamentals used in the robustness checks because the main goal of including them is to verify that their was no omitted variable bias rather than find a contagion effect.

section units). To verify the break-date Quandt-Andrews tests will be used. The Quandt-Andrews test shows the date which is most likely to be the breakdate [10].

## 3.2 Panel data

To estimate equation (1) the literature often makes use of panel data. Panel data pools the time series of different cross-section units to obtain more observations which makes statistical tests more powerful. Panel data models make a strong assumption however since panel data models assume that coefficients of the different variables are homogeneous.

### 3.2.1 Homogeneity assumption

The strong assumption panel data approaches make is that the estimated coefficients are homogeneous for all cross-section units [11]. However, serious problems arise if the homogeneity assumption does not hold in combination with a dynamic panel data approach. For the static panel approach the mean group estimator sti ll yields consistent estimates but this is not the case for the dynamic panel data approach. A falsely applied homogeneity assumption in combination with a dynamic setting causes autocorrelation and as in a dynamic timeseries approach autocorrelation causes inconsistent estimates (Pesaran and Smith, 1995)[12]. The fact that the regressions of this thesis make use of dynamic panel regressions makes the homogeneity assumption additionally important .

### 3.2.2 Fixed- or Random efects

To control for time-invariant heterogeneity between cross-section units it is possible to use fixed- or random effects. Fixed- and random effects models avoid omitted variable bias as long as omitted variables are not time-varying (or time-invariant). Estimating fixed- or random effects models involves Least Squares Dummy Variables (LSDV) instead of Ordinary Least Squares (OLS). The interesting part of fixed- and random effects models is that it measures the within variation since there has been controlled for differences between the cross-section units (between variation). According to Judson and Owen (1996) fixed effects models are preferred over random effects models in macroeconomic applications for two reasons. First, since in the random effects model the country specific intercept belongs to the error term, the random effects model does not allow for correlation between the country-specific intercept and other regressors. In this thesis the intercept might for example be correlated with an independent variable because of government reputation. One of the independent variables in this thesis is the government debt to GDP ratio forecast. It is likely that these two variables are correlated. A country with a low debt to GDP forecast is more likely to have a better government reputation. If a random effects model would have been used this would yield inconsistent estimates because of endogeneity. The fixed effects model does not have this problem. Second, the random effects model assumes a random sample of cross-section units. Often in macroeconomics cross-section units like countries are chosen because they are interesting to study which means that it is certainly not a random selection.

[10] See appendix for a more extensive explanation of the Quandt-Andrews test.

[11] The slopes of the variables are homogeneous. The constant can be heterogeneous.

[12] See the appendix why the mean group estimator does not yield consistent estimates in the case of a dynamic panel setting

### 3.2.3 Nickell bias in dynamic panel data models

In an innovative paper Nickell (1981) showed that dynamic panel data models in combination with fixed- or random effects suffer from a bias.

$$y_{i,t} = \alpha_i + \gamma y_{i,t-1} + \beta x_{i,t} + \epsilon_{i,t} \tag{2}$$

$\alpha_i$ is by construction correlated with $y_{i,t}$ and $y_{i,t-1}$. Since there is an error term ($\epsilon_{i,t-1}$) in $y_{i,t-1}$ there is correlation between $\alpha_i$ and $\epsilon_{i,t-1}$ which is an endogeneity problem. This causes that OLS (or LSDV) is not a consistent estimator in a dynamic panel data setting. The within transformation does not solve the problem. It successfully eliminates $\alpha_i$ but a new endogeneity problem arises.

$$(y_{i,t} - y_{i,t-1}) = \gamma(y_{i,t-1} - y_{i,t-2}) + \beta(x_{i,t} - x_{i,t-1}) + (\epsilon_{i,t} - \epsilon_{i,t-1}) \tag{3}$$

After applying a within transformation there is still the term $y_{i,t-1} - y_{i,t-2}$ in a dynamic panel data model which has correlation with $\epsilon_{i,t} - \epsilon_{i,t-1}$. This is again an endogeneity problem[13]. Nickell (1981) shows that the bias converges to zero if the time dimension approaches infinity [14]. How large the cross section dimension is does not matter for the size of the Nickell bias.

### 3.2.4 Potential solution to Nickell bias

Several methods have been used to avoid the Nickell bias. A common solution in the case of endogeneity biases is the use of instrumental variables or GMM methods. Andersen and Hsiao (1981) offer an easy applicable solution. They applied an within transformation as in (3) and as an instrument for the differenced lagged dependent variable they used either $(y_{i,t-2} - y_{i,t-3})$ or just the level of $y_{i,t-2}$. Arellano and Bover (1995) show however that the level version of the Andersen-Hsiao estimator yields large biases and large standard errors in case of a (potential) unit root of the dependent variable . Arellano and Bond (1991) build on the Andersen-Hsiao approach by adding additional instruments if t increases. Note however that as in every GMM method weak instrument biases might cause inconsistent estimates(Verbeek, 2012)[15].

### 3.2.5 Best method for solving Nickell bias

Nickell (1981) showed that the bias decreases if the time dimension increases. Most panel datasets (mainly in the field of microeconomics) have a large cross-section dimension and a short time dimension. Panel data sets used by macroeconomists often have a larger time dimension in which case LSDV offers credible estimates. Judson and Owen (1996) acknowledge this but argue that even for a $t > 20$ there are other estimators which yield more precise estimates. They compare different estimation techniques by estimating both $\beta$ and $\gamma$ with different time and cross-section dimensions. With a large time dimension they argue that the Andersen-Hsiao approach is advisable because of its' simplicity and more or less accurate estimate . Problems of the GMM estimator are as said before weak instrument bias and potential unit roots in the dependent variable.

[13] See appendix for details

[14] In other words the Least Squares Estimator yields more or less consistent estimates if the panel data set has a long time dimension

[15] See appendix for a more technical and extensive explanation

### 3.2.6 Method used to control for Nickell bias

The panel data set has quite a large time dimension of 60 which makes it reasonable to use the LSDV estimator since the Nickell bias will be negligible with a time dimension of 60 (Judson and Owen, 1996). Applying the Arellano-Bond estimator or other GMM methods yields in general large variances which makes it very likely to reject the contagion hypotheses. Another reason to avoid GMM approaches is that we do not have potential weak instrument biases. Given that the LSDV estimator provides reliable output in case of a panel dataset with a long time dimension the LSDV estimator is better in this case than a GMM estimator.

### 3.2.7 Unit roots

Many macroeconomic timeseries are known to contain a unit root which involves the risk of spurious regression. Spurious regression is the case that ordinary least squares (or LSDV) wrongly finds a significant relationship between two variables because two variables which both contain a unit root are regressed on each other [16]. The importance of unit root of variables in panel data sets depends on the structure of the data set. For a small time dimension and a large cross-section dimension potential unit roots in variables do not matter much. On the other hand if the time dimension is large and the cross-section dimension small potential unit roots need more attention (Baltagi, 2008) [17].
For panel data there are three tests common in the literature to test for unit roots: the Levin, Lin & Chu test, the Im, Pesaran & Shin test and the Fisher type test (Verbeek, 2012). The Levin, Lin & Chu test is the most simple test because it assumes the same unit root process for all cross section units while the others allow the different cross section units to have different unit root processes. These first generation panel data unit root test assume cross-sectional independence. If both the dependent as a dependent variable have a unit root it is possible that the error term does not contain a unit root in which case the non-stationary dependent and the non-stationary independent variable move together or in other words are cointegrated which means that there is a long run relationship between these two non-stationary variables.
The most common approach to deal with unit roots in a pure time series approach is taking the first differences of all variables with the goal to eliminate the stochastic trend from all nonstationary variables[18]. After taking the first differences it is allowed to interpret the coefficients as if the variables are measured in levels. In the case of unit roots in panel data

[16]Variables which contain a unit root are also called nonstationary variables. A nonstationary variable means that the variable in not mean reverting: the variable does not converge back to its' mean over time. In other words a shock in the error term persists forever (This persistence means that a variable has a stochastic trend). The consequence is that the mean of a variable is dependent on the sample and that a stable mean will not be found even if t goes to $\infty$. The variance explodes if t increases which means that it is not possible to interpret critical values from a ordinary least squares estimation with two non-stationary variables because the error term of such a regression is also I(1) except for the case of cointegration (Hill et al., 2012). Because of the unstable mean of non-stationary variables the estimated coefficients of a regression consisting of non-stationary variables (in the absence of cointegration) will depend on the sample which means that the estimated coefficients will not be structural.

[17]For cross-section data unit roots do not exist while for timeseries unit roots are dangerous. In the first case the cross-section characteristic dominates while in the latter the timeseries characteristic dominates. So it is rather intuitive that unit roots deserve more attention in the latter case.

[18]From now on: estimation in first differences means estimating the regression after taking the first differences of the variables in levels.

on the contrary the LSDV estimator provides consistent estimates of the long run average relationship if n and t converge to infinity (Phillips and Moon, 1999; Kao, 1999; Baltagi, 2008; Verbeek, 2012). According to Phillips and Moon (1999) the fact that the timeseries of different independent cross-section units are pooled together into a panel data set provides more information than individual timeseries. However, LSDV provides inconsistent estimates in the case of cointegration in a panel data set. This is in sharp contrast with a pure time series model (Kao and Chiang, 2000; Baltagi, 2008).
This thesis deals with unit roots by also estimating the equation in first differences. If unit roots are not a problem in this panel data set it will have similar results as the estimation in levels. Another benefit of the estimation in first differences is that cointegration is not likely to be a problem. For cointegration it is necessary that series in the regression are non-stationary. The goal of taking the first differences however is making the series stationary. So in the estimation in first differences cointegration is not likely to occur which means that the bias from Kao and Chiang (2000) is not a problem in the estimation in first differences.

## 3.3 Summary methodology

The regression specification to research whether contagion occurred in the government bond markets of the periphery is equation (1). In all specifications the White cross-section standard errors have been used [19]. The specification has been estimated in levels with lagged dependent variables, first differences with lagged dependent variables and levels without lagged dependent variables. The specification in without lagged dependent variables has been interpreted as the long run average relationship [20]. Giordano et al. (2013) use the long run average relationship to control for potential spurious regression [21].There are however some limitations of the average long run relationship specification. First, since this thesis only uses five cross-section units (which is not even close to infinity) unit roots may still play a role in this panel data set which means that it is still important to deal with potential unit roots and potential spurious regression in a cautious way and that output of specifications in levels should not be interpreted at first sight. Second, the long run average relationship specification does not have any lagged terms of the dependent variables. Government bond yields are known to show a high degree of persistence which makes it reasonable to add some lagged terms of the dependent variable. These lagged terms of the dependent variable control for some omitted variables and solve autocorrelation problems[22] To deal with the unit root problem a specification in first differences (with lagged dependent variables) has been

[19]The White cross-section standard errors are robust for cross-section heteroskedasticity and it allows for correlation between cross-section units. The White cross-section standard errors are advisable if the time dimension of the panel dataset is greater than the cross-section dimension. Since the cross-section in the sample are unlikely to be independent it is wise to allow for this correlation.

[20]since in the long run

$$y_{t-1} = y_t$$

[21]as mentioned in the methodology Phillips and Moon (1999) found that despite the presence of unit roots the Ordinary Least Squares estimator provides consistent estimates if the cross section dimension goes to infinity

[22]A disadvantage of adding lagged dependent variables is that if there is still some autocorrelation the OLS estimator yields inconsistent estimates of the coefficients (Verbeek, 2012). So it is important to get rid of all autocorrelation if lagged dependent variables are added. Failing to add lagged dependent variables if the dependent variable is highly persistent entails the risk of an omitted variable bias.

added. If unit roots do not play a role then the estimates of the long run average relationship specification and the specification in first differences would be similar.
In the case that the three estimated models yield similar estimates then the unit roots did not cause spurious regression which makes it possible to interpret the levels output. In the case that the levels output and the first differences output offer contradictory outcomes most weight needs to be put into the specification in first differences if there are a lot of unit roots in the variables since even in the presence of cointegration estimation in levels cause inconsistent estimates in a panel data set. If the estimation in levels without lagged dependent variables does not have similar estimates as the estimation in first differences then the long average relationship specification will be dropped in further estimations since the cross-section dimension apparently is too small to yield consistent estimates. It will not be necessary to use the Arrelano-Bond estimator to control for the Nickell bias since the panel data set has a suffciently large time dimension. The specifications in levels will have a country-specific fixed effects constant[23].

# 4 Data

The first part of table 9 on page 41 shows the source, the frequency and the modification from the author to get all data in the same frequency. The second part of the table shows the measurement unit and whether the variable has been measured relatively to Germany. A problem is that liquidity variables are generally available in higher frequencies than the fundamentals (Codogno et al., 2003; Pagano and Thadden, 2005). This thesis makes use of quarterly data which means that the higher frequency variables need to be modified. The method used is taking for the higher frequency variable the average for that period [24]. The debt to GDP ratio forecast on the contrary has been measured on a lower frequency. To make the data quarterly cubic interpolation has been used.

Quandt-Andrews tests have been used to verify the often used break used in the literature 2009Q4 as the most likely break (see table 3 on18). The Quandt-Andrews tests show that 3 countries indeed have there most likely break in 2009 (Spain, Italy and Ireland) and that two countries have their most likely break in 2010Q4.

| Country | Recommended Break | Max Wald F-statistic | P-value | Significance |
|---|---|---|---|---|
| Ireland | 2009Q4 | 163.937 | 0.000 | *** |
| Greece | 2010Q4 | 57.605 | 0.000 | *** |
| Spain | 2009Q1 | 22.673 | 0.006 | *** |
| Italy | 2009Q3 | 28.173 | 0.001 | *** |
| Portugal | 2010Q4 | 42.341 | 0.000 | *** |

H0: no breakpoint within 25 percent of trimmed data.
* significant at 10% level; ** significant at 5% level *** significant at 1% level
Variables tested for: d(Debt to GDP ratio forecast) d(growth) d(regional) d(outstanding debt) d(vix) d(interest)

Table 3: Quandt Andrews breaktest with unknown break

[23]Note that the constant drops out in the estimation in first differences.

[24]For example, to get data for the Bid-Ask spread 1999Q1 the average Bid-Ask spread during 1999Q1 has been calculated

To check for non-stationarity of variables both Levin, Lin, Chu tests as Im, Pesaran, Shin tests have been performed for the variabeles which have different values for the different cross-section units. The common factors have the same values for the different cross-section units which means that for the common factors it is possible to test for stationarity with the Augmented Dickey-Füller test. For most variables the tests give similar conclusions. The tests show that 8 out of 11 variables show an indication to contain a unit root, 1 is dubious and 2 do not give an indication to contain a unit root[25]. So it is important to be cautious with interpreting regressions in levels. The results can be seen in the table 4.

| Variables in main regression - panel unit root tests | | | | | | |
|---|---|---|---|---|---|---|
| Series | Specification | LLC statistic | P-value | IPS statistic | P-value | Order of integration |
| Government bond yield spread | Intercept | -0.213 | 0.416 | -0.288 | 0.387 | I(1) |
| GDP growth | Intercept | 0.513 | 0.696 | -1.059 | 0.145 | I(1) |
| Regional spread | Intercept | 0.063 | 0.525 | -0.013 | 0.495 | I(1) |
| Amount outstanding debt | Trend & intercept | 2.347 | 0.991 | 2.335 | 0.99 | I(1) |
| Inflation | Intercept | -0.456 | 0.324 | -2.463 | 0.007 | I(0)/I(1) |
| Variables in robustness checks - panel unit root tests | | | | | | |
| Series | Specification | LLC statistic | P-value | IPS statistic | P-value | Order of integration |
| Bid-Ask spread | Intercept | -2.31 | 0.01 | -3.339 | 0.000 | I(0) |
| MFI debt to GDP ratio | Intercept | -0.592 | 0.267 | 1.401 | 0.919 | I(1) |
| Claims to GDP ratio | Intercept | 0.782 | 0.782 | -0.032 | 0.487 | I(1) |
| Common variables - timeseries unit root test | | | | | | |
| Series | Specification | ADF statistic | P-value | | | Order of integration |
| VIX | Intercept | -3.291 | 0.019 | | | I(0) |
| Short term interest rate | Trend & intercept | -3.301 | 0.076 | | | I(1) |
| US corporate bond AAA spread | Intercept | -2.035 | 0.272 | | | I(1) |

**Levin Lin Chu test** H0 hypothesis: all series contain a unit root, HA hypothesis: none of the series contains a unit root. **Im Pesaran Chin test** H0 hypotehsis: all series contain a unit root, HA hypothesis: at least one of the series does not contain a unit root. **Augmented Dickey Füller test** H0 hypotheis: the series contains a unit root, HA hypothesis: the series does not contain a unit root

Table 4: Unit root tests

# 5 Results

To research the impact of contagion on the government bond markets of the EMU periphery several regression specifications have been used. The main regression specification is similar to the specification used by Giordano et al. (2013) [26]. The regression specification is the same as equation (1):

$$s_{i,t} = \alpha_i + \alpha_1 s_{i,t-1} + \alpha_2 s_{i,t-2} + \alpha_3 s_{i,t-3} + \beta_1 f_{i,t} + \beta_2 reg_{i,t} + \beta_3 liq_{i,t} + \beta_4 ra_t$$
$$+\beta_5 \pi_{i,t} + \beta_6 i_t + \gamma_0 c_t + \gamma_1 f_{i,t} * c_t + \gamma_2 reg_{i,t} * c_t + \gamma_3 ra_t * c_t + \gamma_4 i_t * c_t + \epsilon_{i,t}$$

$$|\alpha_1 + \alpha_2 + \alpha_3| < 1, \text{stability condition}$$

Where fundamentals ($f_{i,t}$) are measured by the debt to GDP forecast and GDP growth rate,

[25]Note that the short term interest rejects the 0-hypothesis of non-stationarity at the 8% significance level. So one could also put the short term interest rate in the dubious group given the fact that it is theoritcally not appealing that the short term interest rate contains a unit root.

[26]Note that the average regional spread also has been added since it is also interesting to research whether there is an regional contagion effect as tested by Beirne and Fratzscher (2013)

regional ($reg_{i,t}$) by the average spread of the group (the country itself excluded), liquidity ($liq_{i,t}$) by the volume of outstanding debt and risk aversion ($ra_t$) by the Volatility Index (VIX) of the Chicago Board Exchange. The other explanatory variables are inflation($\pi_{i,t}$) and the short term interest rate set by the ECB ($I_t$). In the first specifications following the largest share of the literature the short term interest has not been added in the regression. Initially, the crisis dummy takes value 1 after 2009Q4 (which is in line with the literature (Gómez-Puig and Sosvilla-Rivero, 2014) and the Quandt-Andrews test indeed showed that 3 out of 5 cross-section units had their most likely break in 2009). As a robustness check later on the same regressions will be ran with a crisis dummy which takes value 1 after 2010Q4 since 2 out of 5 cross-section units have there most likely break in 2010 according to the Quandt-Andrews tests.

The specifications have been estimated in levels with lagged dependent variables, in first differences with lagged dependent variables and in levels without lagged dependent variables (which is called the long run average relationship specification). To show that similar output has been obtained as in Giordano et al. (2013) first the regression will be ran for the all EMU-countries sample [27].

## 5.1 All EMU- countries sample

The estimation output of equation (1) of the all EMU-country sample can be found in table 10 on page 42. In general the estimates are similar as in the paper written by Giordano et al. (2013). For the specification in levels the signs are all the same except for the debt to GDP ratio for the entire sample period (it has the expected sign in this thesis).The liquidity variable for the entire sample is also significant and has the correct sign[28]. In terms of significance there are some differences. For the debt to GDP forecast contagion coefficient a highly significant coefficient has been found but for the VIX the entire period coefficient is only significant at the 10% significance level. The VIX contagion variable is significant though which is not the case in the paper by Giordano et al. (2013). Another remarkable finding is that the specification in levels for the all countries sample used in this thesis finds both a strong fundamental contagion effect for GDP growth as for the debt to GDP forecast. In the framework of Giordano et al. (2013) only the debt to GDP ratio shows a fundamental contagion effect on the 10% significance level. Approximately the same conclusions can be drawn from the average relationship. The signs are the same except for the VIX which does not have the expected sign (it is insignificant however). The significance levels are far more clearcut than in the specification in levels with lagged dependent variable terms which is easily understandable because adding lagged dependent variables controls partly for omitted variable bias. Summarizing, the estimated signs of the variables are in many cases as expected.

If the first differences have been used as a cure for potential spurious regression the output changes. The regional yield is highly significant now and all potential variables for wake-up call- or fundamental contagion turn out to be non-significant. The sign of the debt to GDP forecast even turns (although it does not significantly differ from zero). It seems to be that

[27] Similar output is a signal that similar data has been used.

[28] Note that liquidity improves if the volume of outstanding debt increases. Giordano et al. (2013) use the Bid-Ask spread however. If liquidity improves the bid-ask spread narrows. So the expected sign in the specification of this thesis is exactly the opposite of the expected sign in the specification from Giordano et al. (2013)

the wake-up call contagion finding found in the literature Giordano et al. (2013); Beirne and Fratzscher (2013); Gómez-Puig et al. (2014) might be driven by spurious regression which would in fact mean that there is no impact of wake-up call contagion on EMU government bond yield spread. Another difference is that the VIX contagion coefficient is not significant anymore but that the VIX entire period coefficient is significant now at the 10% significance level.

## 5.2 Periphery sample

Since the case of Greece is rather extreme the specification has been estimated for the periphery with Greece and without Greece to check for the poolability condition (or homogeneity assumption).

### 5.2.1 Periphery sample with Greece

The output for the periphery country sample can be found in table 11 on page 42. The signs look again fine for the specification in levels and long run average relationship specification. Only GDP growth does not have the expected sign in the long run average relationship specification and the average regional yield in the specification in levels (both do not differ significantly from zero). The significance levels are more or less similar as in the all EMU-countries sample. A striking difference between the specification in levels and the long run average relationship specification is the VIX. The levels specification shows a significant effect for the VIX in the entire sample period but no clear effect for shift contagion. For the long run average relationship specification the opposite is true. After taking the first differences again many of the effects disappear and surprisingly the wake-up-call contagion effects gets an unexpected sign (although it does not differ significantly from zero). As in the in in the all EMU-countries sample the average yield in the region also seems to have a role in explaining yields. Although the regional contagion coefficient differs significantly from zero there is no indication of regional contagion since it has the wrong sign.

So surprisingly no evidence for effect of fundamentals have been found in the periphery sample which is not consistent with the literature. There seems only to be a significant common driver [29]. This is not a satisfying result since after the crisis government bond yield spreads diverged (see figure 3 on page 22). There are only two explanation for this divergence to occur. There is a country-specific factor which has an impact on the government bond yield spreads of the periphery or the common risk factor has a a different impact on the government bond yield spread of the different countries which casts doubt on the poolability assumption.

[29] Regional yield can be regarded as a quasi-common factor and VIX is significant at the 12% significance level

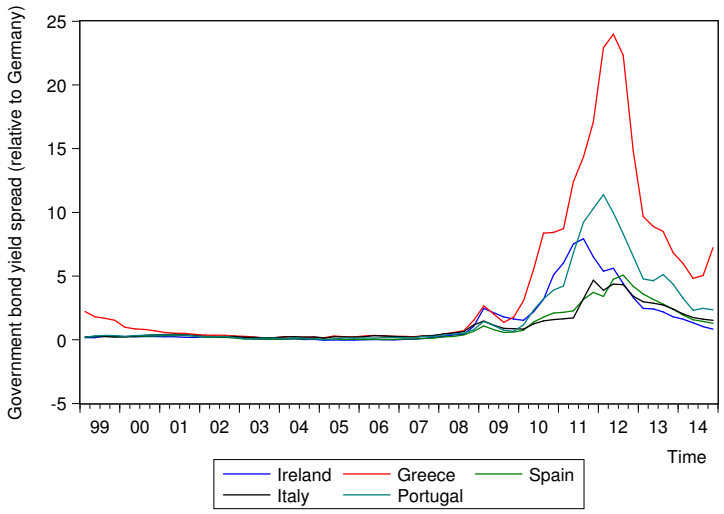


Figure 3: Government bond yield spreads periphery, period 1999-2014

### 5.2.2 Periphery sample without Greece

So the unsatisfactory outcome from the periphery sample asks for more attention given the recent behaviour of spreads during the European sovereign debt crisis. To start following Giordano et al. (2013) Greece has been removed from the periphery sample. If the output of the specification in levels is compared between the sample of the periphery excluding Greece (see table 11 on page 42) with the sample of the periphery without Greece (see table 12 on page 43) the main difference is that the fundamental contagion variable from the debt to GDP forecast becomes insignificant if Greece has been excluded (while it was significant at the 1% significance level if Greece has been included). This does not necessarily have to be a strange outcome since from all countries in the periphery Greece has the most worrysome debt to GDP ratio. So after excluding Greece the evidence for fundamental contagion becomes much weaker. The main difference between including and excluding Greece is in the specification in first differences though. If Greece has been excluded the shift contagion variable becomes strongly significant[30], the dampening effect of the average yield spread in of the other countries in the periphery during the crisis becomes stronger, the liquidity factor plays a strongly significant role and the inflation variable turn out to be significant at the 10% significance level. Disappointing as it is fundamentals still do not play a significant role in explaining government bond yield spreads in the specification in first differences.

[30]If the government bond yield spread truly is non-stationary then a note should be made about interpretation of the coefficients of the variable VIX (and later on the variables bid-ask spread, inflation and maybe the short term interest rate) in the estimation in levels since this variable is stationary in levels. In the case that the government bond yield spread is non-stationary then it meanders since shocks do persist forever. Stationary variables though return to their mean which means that it is impossible to find a relationship in the long run between a non-stationary variable and a stationary variable. This would mean that a significant effect of a stationary variable would never be structural. The estimation in first differences does not have this problem though since the government bond yield spread is I(1). By taking the first differences the stochastic trend has been removed which means that it is possible to interpret the coefficients of these variables in the estimation in first differences.

## 5.3 Preliminary conclusion

The analysis so far shows that the literature did not take into account unit roots and spurious regression sufficiently. The often found fundamentals contagion (Aizenman et al., 2013; Beirne and Fratzscher, 2013; Giordano et al., 2013; Gómez-Puig et al., 2014) does not seem to hold in the specification in first differences. Since table 4 shows that both the government bond yield spreade, the debt to GDP forecast as GDP growth are I(1) this finding in the literature might be driven by spurious regression which means that there in fact does not exist a causal relationship between these fundamentals and the government bond yield spreads in the periphery. That after taking the first differences no evidence has been found for an important role of fundamentals on government bond yield spreads during the crisis is dissatisfying since it would mean that yield spreads would be similar and as shown by figure 3 that is not the case during this European sovereign debt crisis (or the government bond yield spreads of the countries respond in a different way on a common factor like VIX, i.e. in some countries the impact of shift contagion or VIX in the entire sample is stronger than in the other country).

Another finding is that government bond yield spread seem to respond in a different way in Greece than in the other periphery countries which means that the poolability assumption does not seem to hold if Greece is included in the panel data regression. So the decision of Giordano et al. (2013) to drop Greece from their sample is probably a good one[31]. In the remaining part of this thesis Greece will be dropped from the periphery country sample.

## 5.4 Impact conventional monetary policy ECB on government bonds yield spreads

As argued by Manganelli and Wolswijk (2009) it is important to include the short term interest rate set by the ECB as an determinant of government bond yield spreads. First, it is interesting to see whether conventional monetary policy is effective to push government bond yield spreads in the desired direction. Second, failure of including the short term interest rate might entail omitted variable bias since Manganelli and Wolswijk (2009) find that the short term interest rate is both positively related to government bond yields as with general risk aversion of financial markets which means that the impact of the risk aversion of financial markets will be overestimated if the short term interest has not been included in the regression (see figure 1 on page 5).

The estimation output can be found in table 13 on page 44. Comparing the output of the periphery excluding Greece with the output of table 12 on page 43 shows the size of the omitted variable bias if the short term interest rate has not been included. Both in the levels case as in the first difference case there are no sign switches. The impact of the short term interest is the same in levels as in first differences. In the entire sample period it has a negative sign but it is not significant. During the crisis the impact is positive and significantly different from zero: a decrease in the short term interest, decreases the average yield spread of the periphery. This is a promising outcome for the ECB since one of the goals of setting

[31] Giordano et al. (2013) argue that they drop Greece because it is the 'ground zero country' although the output does not change if Greece has been included. In that perspective questions raise why they do not include Greece in that case because if that is true the poolabililty assumption holds and including Greece would yield additional observations which increases the power of statistical tests.

a lower interest rate is decreasing the government bond yield spread of the periphery in the Eurozone. Both in the estimation in levels as the estimation in first differences evidence has been found for the omitted variable bias as argued by Manganelli and Wolswijk (2009). In the estimation in levels including the short term interest causes the shift contagion parameter to be insignificant and the impact of the VIX during the entire sample period decreases (i.e. the coefficient becomes smaller). In the estimation in first differences the same conclusion can be drawn comparing the coefficients of the shift contagion parameters. Another interesting change is that the wake up-call contagion effect from the debt to GDP forecast becomes stronger after the short term interest rate has been included (in the levels case it becomes even significant at the 5% significance level). Since the impact of both the short term interest rate as the debt to GDP forecast on government bond yield spreads is positive this can only explained by a negative impact of either the short term interest rate on the government debt to GDP ratio forecast[32]. An explanation might be that both the short term interest rate as the short term interest rate set by the ECB are influenced by the state of the economy. As figure 9 on page 40 shows during the crisis the debt to GDP ratio (relative to Germany) increases[33]. This might explain the negative correlation between the debt to GDP ratio and the short term interest rate (because the ECB tried to boost the economy during the crisis by lowering the short term interest rate) which means that failing to include the short term interest rate as an determinant causes that the impact of the debt to GDP forecast on government bond yield spreads has been underestimated [34](see figure 4).

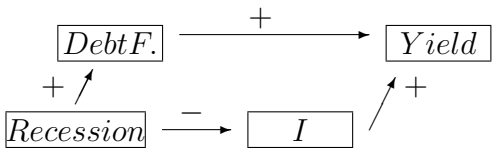


Figure 4: Potential omitted variable short term interest rate

The rest of the outcomes remain similar as in the case that the short term interest had not been included. On average the government bond yield spread still increases if the average yield of the other periphery countries increases. The effect dampens during the crisis. The liquidity parameter is now significant in both the estimation in levels as the estimation in first differences which means that creating a more integrated government bond markets for the EMU countries (by exchange risk elimination) successfully decreased the government bond spread for the average country belonging to the periphery (excluding Greece). This is consistent with Pagano and Thadden (2005) who also found that increased integration of

[32]Correlation analysis indeed shows a negative correlation between the government debt to GDP ratio forecast and the short term interest rate during the crisis. If 2009Q4 has been used as crisisdummy the correlation is -0.41 and in the case of 2010Q4 even -0.46.

[33]For the debt to Ratio forecast the same pattern applies). At the same the ECB tries to boost the economy of the Eurozone by lowering the short term interest rate (see figure 8 on 40

[34]In bad economic times debt to GDP ratio's increase which on its' turn (at least theoretically) increase government bond yield spreads. In the same time the lower short term interest rate lowers government bond yield spreads. Failing to include the short term interest means that the regression does not catch the negative impact of short term interest rates on government bond yield spreads. OLS will attribute this negative impact to government debt to GDP ratio (via the negative correlation between the short term interest rate and the debt to GDP forecast) which means that the impact of the debt to GDP on government bond yield spreads had been underestimated.

the EMU government bond markets successfully decreased government bond spreads in the Eurozone.

## 5.5 Poolability of EMU periphery

Heterogeneity bias in a dynamic panel data approach causes even the mean group estimator to be inconsistent (Pesaran and Smith, 1995) which means that it is important to verify whether the estimated coefficients in table 13 on page 44 are similar for all cross-section units. Estimating equation (1) for 1) Spain & Italy and 2) Ireland & Portugal shows some interesting insights. Lane (2012) argues that the yields of Spain and Italy show some degree of co-movement. A look at figure 5 on page 25 indeed shows that the government bond yield spreads of Spain and Italy move together. The same can be argued for Portugal and Ireland but it seems to apply to a less extent [35].

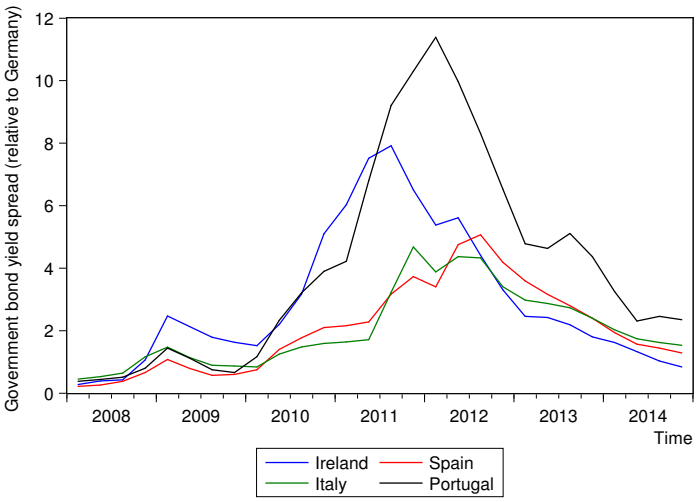


Figure 5: Government bond yield spreads periphery excl. Greece, period 2008-2014

The estimation output can be found in table 13 on page 44. An overview with signs and significance levels can be found in table 5 on page 27 for the estimation in levels and in table 6 on page 27 for the estimation in first differences. A first look on tables 5 and 6 shows immediately that the government bond yield spreads of both countries do not respond in a similar way to the all explanatory variables which casts clear doubt on the poolability of the data for the periphery. Theory[36] seems to predict the government bond yield spreads of Italy and Spain better than the spreads of Ireland and Portugal.
The estimates of equation (1) in levels show that the fundamentals explain Spanish and Italian government bond yield spreads in a significant way (with the expected sign) during the entire sample period which is not the case for Irish and Portuguese spreads. Wake-up-call contagion from GDP growth explains yield spreads in Portugal and Ireland partly during the

[35] Running the same specifications in a timeseries setting also shows that the signs of the coefficients of the different variables are similar for Spain & Italy and similar for Ireland & Portugal. So it seems justifiable to pool the data for Spain & Italy and for Ireland & Portugal.

[36] In the sense that the estimated sign is similar to the expected sign predicted by theory. Another indication is that the adjusted $R^2$ is higher for the Spain & Italy sample.

crisis which has not been found for the Spanish and Italian spreads. Shift contagion however has a significant impact on the Spanish and Italian government bonds yields spreads but not on the Irish and Portuguese bonds. Conventional monetary policy of the ECB (changing the short term interest rate), which seemed promising from the pooled periphery (excluding Greece) estimation, seems only to work for Ireland and Portugal. The conclusions drawn from this estimation in levels show an interesting insight: during the crisis wake-up-call contagion seems to play a role in Ireland and Portugal which is not the case in Spain and Italy. For Spain and Italy on the other hand shift contagions seems more important which on its' turn does not play a significant role in explaining government bond yield spreads in Ireland and Portugal. Summarizing, from the estimation in levels it seems unwise to pool Spain & Italy and Ireland & and Portugal together.

Again potential spurious regression has to be taken into account given the large amount of nonstationary variables in the dataset which means that it is unwise to rely completely on the estimation in levels. First thing to notice for the factors explaining Irish and Portugese government bond spreads is that relatively many signs switch if equation (1) has been estimated in first differences instead of levels[37]. The output seems promising though for explaining Spanish and Italian government bond yields spreads. Only 1 sign switches [38] and a lot of explanatory variables are significant with the expected sign.

Focusing on the estimation in first differences shows for Spain and Italy a strong significant effect for the liquidity factor (outstanding debt) with the expected sign. The global risk aversion variable (VIX) is significant during the entire sample period and there is also a significant additional shift contagion effect during the crisis. The short term interest rate set by the ECB shows a significant effect on the 10% significance level with the desired sign. The average government bond yield spread of the other periperal countries shows a significant effect during the entire sample period but it dampens during the crisis. So again there is no evidence for regional contagion.

The estimation in first differences for Ireland and Portugal shows less clear output. As is the case for Italy and Spain the average government bond yield spread is significant during the entire sample period and dampens during the crisis. The other (strongly) significant explaining factor of Irish and Portugese government bond yield spreads is the conventional monetary policy instrument of the ECB during the crisis. The significant wake-up-call contagion variable from GDP growth in the estimation levels seems again to be driven by spurious regression since it is not longer significant in the estimation in first differences.

[37]The signs of outstanding debt and short term interest rate (for the entire sample period) switches to the correct sign. The signs of the VIX and inflation (for the entire sample period) switch to the wrong sign though.

[38]GDP growth during the entire sample period switches to the wrong sign but is insignificant though.

| Dependent variable: Government bond yield spread (relative to Germany) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sample: | | Periphery excl. Gr. | | Sp & It. | | Ir. & Po. | |
| Independent Variable | Exp. Sign | Levels | Sig. Lv. | Levels | Sig. Lv. | Levels | Sig. Lv. |
| Debt to GDP ratio forecast | + | + | ** | + | ** | - | |
| Growth | - | - | | - | * | - | |
| Regional Yield | + | + | | + | *** | + | |
| Outstanding Debt | - | - | ** | - | * | + | |
| VIX | + | + | * | + | | + | ** |
| Inflation | + | + | | + | | + | |
| Interest Rate | + | - | | + | | - | |
| Debt to GDP ratio forecast*crisis | + | + | ** | + | | + | |
| Growth*crisis | - | - | ** | - | | - | ** |
| Regional Yield*crisis | + | - | | - | | - | |
| VIX*crisis | + | + | | + | *** | - | |
| Interest Rate*crisis | + | + | ** | - | * | + | *** |

The second column shows the expected sign for each explanatory variable based on the literature. A green cell denotes that the variable has the expected sign and a red cell denotes that a variable does not have the expected sign
Periphery excl. Gr. = Periphery excluding Greece, Sp. & It.= Spain and Italy, Ir. & Po. = Ireland and Portugal
All variables are relative to Germany except for VIX and the short term interest rate.
White cross-section standard errors. * significant at 10% level; ** significant at 5% level *** significant at 1% level

Table 5: Overview signs estimation in levels equation (1), crisisdummy: 2009Q4

| Dependent variable: Government bond yield spread (relative to Germany) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sample: | | Periphery excl. Gr. | | Sp & It. | | Ir. & Po. | |
| Independent Variable | Exp. Sign | 1st. dif. | Sig. Lv. | 1st. dif. | Sig. Lv. | 1st. dif. | Sig. Lv. |
| Debt to GDP ratio forecast | + | + | | + | | + | |
| Growth | - | + | * | + | | - | |
| Regional Yield | + | + | *** | + | *** | + | *** |
| Outstanding Debt | - | - | *** | - | *** | - | |
| VIX | + | + | | + | *** | - | |
| Inflation | + | + | | + | ** | - | |
| Interest Rate | + | - | | + | * | + | |
| Debt to GDP forecast*crisis | + | + | | + | | + | |
| Growth*crisis | - | - | | - | | - | |
| Regional Yield*crisis | + | - | *** | - | *** | - | ** |
| VIX*crisis | + | + | ** | + | *** | - | |
| Interest Rate*crisis | + | + | ** | - | | + | *** |

The second column shows the expected sign for each explanatory variable based on the literature. A green cell denotes that the variable has the expected sign and a red cell denotes that a variable does not have the expected sign
Periphery excl. Gr. = Periphery excluding Greece, Sp. & It.= Spain and Italy, Ir. & Po. = Ireland and Portugal
All variables are relative to Germany except for VIX and the short term interest rate.
White cross-section standard errors. * significant at 10% level; ** significant at 5% level *** significant at 1% level

Table 6: Overview signs first differences estimation equation (1), crisisdummy: 2009Q4

### 5.5.1 Preliminary conclusion from estimation in levels and estimation in first differences

Pooling the data of the periphery together to research determinants of EMU government bond yield spreads is unjustified. Failing to acknowledge this enhances heterogeneity bias which in combination with a dynamic panel data approach even causes that the mean group estimator yields inconsistent estimates (Pesaran and Smith, 1995). By separating into two groups (1. Spain & Italy 2. Ireland & Portugal) the following conclusions can be drawn.

### 5.5.2 Spain & Italy sample

An overview of the output for the Spain & Italy sample can be found in table 7 on page 31. First focusing on 2009Q4 shows that for the Spain & Italy sample the shift contagion parameter is strongly significant both in the estimation in levels as the estimation in first differences. So increasing risk aversion of financial markets clearly played a significant role in the increasing government bond yield spreads of Spain and Italy. An explanation might be the reputation of the Spanish and Italian government. If financial markets get risk averse they withdraw money from Italy and Spain (which lowers demand for these bonds which on its' turn increases the government bond yield) because the reputation of the government of these countries is bad. The average government yield spread of the other periphery countries is also strongly significant during the entire sample both in levels as in first differences. The liquidity factor is also significant both in the estimation in levels as im the estimation in first differences (although in levels it is only significant on the 10% significance level). In that sense one of the goals of creating the Euro, namely decreasing liquidity risk by eliminating exchange risk (Pagano and Thadden, 2005), succeeded and increased liquidity successfully decreased government bond yield spreads for Spain and Italy. The effect of conventional monetary policy during the crisis is not clear. The estimation in first differences shows a significant positive effect on the 10% significance level during the entire sample period while the estimation in levels shows a negative impact on the 10% significance level during the crisis. So for Spain and Italy not much evidence has been found for the positive relation of the short term interest rate on government bond yield spreads. Inflation and the global risk aversion variable (VIX) also have a significant positive impact in the estimation in first differences but this does not hold in the estimation in levels. So the estimation in first differences shows evidence for a common factor (namely VIX) driving government bond yields spreads in the pre-crisis period as found in the literature (Codogno et al., 2003; Bernoth et al., 2004; Favero et al., 2005). The finding in the estimation in levels (crisis dummy: 2009Q4) that both the debt to GDP ratio forecast as GDP growth have a significant impact on government bond yield spreads during the entire sample period is not structural since the coefficients get insignificant if the crisis dummy is changed to 2010Q4[39].
If the crisis dummy has been changed from 2009Q4 into 2010Q4 the output seems robust. Only 2 signs switch (the sign for the debt to GDP forecast in the entire sample changes from a + into a - in the estimation in first differences and the sign for the debt to GDP forecast in the crisis period changes in the estimation in levels from a + in a -). Both do not significantly differ from zero so it does not seem to matter much. The shift contagion parameter is still highly significant both in the estimation in levels as in the estimation in first differences. The impact of risk aversion of financial markets during the entire sample period also becomes highly significant. The most remarkable change is that the short term interest is not longer

[39]Remember however that both the government bond yield spread as GDP growth are I(1) which means that the case of spurious regression cannot be ruled out.

significant on the 10% significance level. However, the short term interest rate is significant during the crisis on the 10% significance level but does not have expected sign. The impact of inflation becomes significant on a higher significance level and the dampening effect of the average yield spread of the other periphery countries becomes less strong. Summarizing, taking 2009Q4 or 2010Q4 as crisis dummy does not matter for Italy and Spain. In both cases a very strong impact of global risk aversion (and especially during the crisis due to shift contagion) the government bond yield spreads has been found. For both crisis dummies evidence for wake-up-call contagion is low. If 2009Q4 is used both the levels as first differences do not show a significant indication for wake-up-call contagion from either the debt to GDP forecast or GDP growth. If 2010Q4 is used the wake-up-call contagion parameter of the debt to GDP forecast is significant on 10% significance level in the estimation in first differences but this effect has not been found in the estimation in levels [40].

### 5.5.3 Ireland & Portugal sample

An overview of the output for Ireland and Portugal can be found in table 8 on page 32. As said, the output is less promising than the output for Spain and Italy. Given the large variation in the government bond yield spread for these two countries during the crisis there is much variation to be explained. Again, after focusing on 2009Q4 as crisis dummy, the most convincing finding is the impact of conventional monetary policy. Both in levels as in first differences it is highly significant with the expected sign which has not been found for Spain and Italy. So for Portugal and Ireland the same impact of the short term interest rate on government bond yield spreads has been found as found by Manganelli and Wolswijk (2009). It seems that the ECB successfully managed to bring down the government bond yield spreads in Ireland and Portugal by lowering the short term interest rate. The other variables which potentially play a significant role in explaining Irish and Portuguese government bond yield spreads are either significant in levels or in first differences but not in both. So it is less convincing than the impact of the short term interest rate. As found for Spain and Italy the first differences estimation shows that the average yield spread of the other periphery countries influences the government bond yield spreads positively but this effect dampens during the crisis. The estimation in levels provides a significant impact of the VIX on the 5% significance level. So also for Ireland and Portugal some evidence has been found for a common factor driving government bond yields spreads in the pre-crisis period. The estimation in levels also shows a significant wake-up-call contagion effect on the 5% significance level from from the GDP growth variable.
If the crisis dummy has been changed from 2009Q4 into 2010Q4 the output seems again robust. The strong significant effect of the short term interest rate remains strongly significant with the expected sign. The positive effect of the average yield spread of the other periphery countries during the entire sample period gets stronger both in the estimation in levels as in the estimation in first differences while the dampening effect during the crisis weakens (it is not longer significant in the estimation in first differences but it is significant on the 10% significance levels in the estimation in levels now). As was the case for Spain and Italy there is slightly more evidence for wake-up-call contagion but the evidence is still weak because many variables contain a unit root in levels. The estimation in levels shows a significant effect on the 5% significance level for wake-up-call contagion from the debt to GDP forecast and a significant effect on the 10% significance level for wake-up-call contagion from GDP growth.

[40] Also note that all three variables are I(1) which means that this significant finding with 2009Q4 as crisis dummy might be due to spurious regression

There is more evidence for shift contagion since the shift contagion parameter is significant on the 10% significance level in the estimation in first differences.

### 5.5.4 Contagion evidence

The main question which this thesis tries to answer is whether contagion occured in the government bond markets of the periphery. Since Greece is an extraordinary case and it clearly biased the output of the pooled data, this thesis focused on the bond markets of the other countries belonging to the periphery.

In none of the specifications regional contagion has been found because all the significant regional contagion coefficiets have the wrong sign. This is consitent with Beirne and Fratzscher (2013). On the contrary, in all specifications the impact of the average yield spreads of the other periphery countries dampened during the crisis.
The wake-up-call contagion evidence is very limited. In the Ireland & Portugal sample wake-up-call contagion from the debt to GDP forecast had been found on the 5% significance level in the estimation in levels with 2010Q4 as breakdate and wake-up-call contagion from GDP growth in the estimation in levels (on the 5% significance level if 2009Q4 has been used as break-date and on the 10% significance level if 2010Q4 has been used as breakdate). For Italy and Spain wake-up-call contagion has only been found for the debt to GDP forecast on the 10% significance level in the estimation in first differences if 2010Q4 has been used as breakdate. The evidence for wake-up-call contagion is strongest in the Spain & Italy sample since the significant contagion effect from GDP growth for the Ireland & Portugal sample has been found in the estimation in levels which might be driven by spurious regression. That there does not seem to be a strong wake-up-call contagion effect is not consistent with the literature. Most academics find a significant wake-up-call contagion effect (Aizenman et al., 2013; Beirne and Fratzscher, 2013; Giordano et al., 2013; Gómez-Puig et al., 2014). They do not take into account unit roots however. In the estimation in levels the analysis of this thesis also often finds a wake-up-call contagion but this relation does not hold in the estimation in first differences which means that spurious regression is a non-negligible risk. Like de Grauwe and Ji (2013) this thesis finds that wake-up-call contagion does not play a significant role in explaining the government bond yield spreads for Spain and Italy. de Grauwe and Ji (2013) however find that half of the government bond yield spread for Ireland and Portugal is due to fundamentals which is not in line with this thesis. de Grauwe and Ji (2013) argue that there is cointegration and that is the reason why they are allowed to interpret the estimation in levels. In the case of a panel data set cointegration does not make it possible to interpret the estimation in levels (Kao and Chiang, 2000; Baltagi, 2008; Giordano et al., 2013) since the LSDV estimator still provides inconsistent estimates of the coefficients in that case.
The shift contagion evidence is very strong for Spain and Italy (in all cases it is strongly significant on the 1% significance level.). For Ireland and Portugal there is only some evidence. If the breakdate is 2010Q4 the estimation in first differences shows a significant shift contagion effect. The finding on shift contagion for Spain and Italy is consistent with the finding of de Grauwe and Ji (2013). They find that markets sentiments explain most of the government bond yield spread for Spain and Italy. Markets sentiments are similar to the concept risk aversion of financial markets. Gómez-Puig et al. (2014) also find shift contagion in the periphery [41]. From the analysis in this thesis it seems that shift contagion plays an important role in Spain and Italy but does not play a role in Ireland and Portugal.

[41] Although they do not call it shift contagion.

| Dependent variable: Government bond yield spread (relative to Germany) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Crisis dummy: 2009Q4 | | | | Crisis dummy:2010Q4 | | | | |
| Independent Variable | Levels | Sig. Lv. | 1st. dif | Sig. Lv. | Levels | Sig. Lv. | 1st. dif | Sig. Lv. | Exp. Sign |
| Debt to GDP forecast | + | ** | + | | + | | - | | + |
| Growth | - | * | + | | - | | + | | - |
| Regional Yield | + | *** | + | *** | + | *** | + | *** | + |
| Outstanding Debt | - | * | - | *** | - | | - | *** | - |
| VIX | + | | + | *** | + | *** | + | *** | + |
| Inflation | + | | + | ** | + | | + | *** | + |
| Interest Rate | + | | + | * | + | | + | | + |
| Debt to GDP forecast*crisis | + | | + | | - | | + | * | + |
| Growth*crisis | - | | - | | - | | - | | - |
| Regional Yield*crisis | - | | - | *** | - | | - | * | + |
| VIX*crisis | + | *** | + | *** | + | *** | + | *** | + |
| Interest Rate*crisis | - | * | - | | - | * | - | | + |
| Adjusted $R^2$ | 0.98 | | 0.73 | | 0.98 | | 0.72 | | |
| Observations | 122 | | 120 | | 122 | | 120 | | |

White cross-section standard errors. * significant at 10% level; ** significant at 5% level *** significant at 1% level
The second column shows the expected sign for each explanatory variable based on the literature. A green cell denotes that the variable has the expected sign and a red cell denotes that a variable does not have the expected sign
All variables are relative to Germany except for VIX and the short term interest rate.
A + denotes a positive sign, a - denotes a negative sign.
The regression output can be found in the appendix in table 13 and table 14

Table 7: Overview Output Spain & Italy sample

| Dependent variable: Government bond yield spread (relative to Germany) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Crisis dummy: 2009Q4 | | | | Crisis dummy:2010Q4 | | | | |
| Independent Variable | Levels | Sig. Lv. | 1st. dif | Sig. Lv. | Levels | Sig. Lv. | 1st. dif | Sig. Lv. | Exp. Sign |
| Debt to GDP forecast | - | | + | | - | | + | | + |
| Growth | - | | - | | - | * | - | | - |
| Regional Yield | + | | + | *** | + | ** | + | *** | + |
| Outstanding Debt | + | | - | | + | | + | | - |
| VIX | + | ** | - | | + | * | + | | + |
| Inflation | + | | - | | - | | - | | + |
| Interest Rate | - | | + | | + | | - | | + |
| Debt to GDP forecast*crisis | + | | + | | + | ** | + | | + |
| Growth*crisis | - | ** | - | | - | * | - | | - |
| Regional Yield*crisis | - | | - | ** | - | * | - | | + |
| VIX*crisis | - | | - | | - | | - | * | + |
| Interest Rate*crisis | + | *** | + | *** | + | *** | + | *** | + |
| Adjusted $R^2$ | 0.98 | | 0.61 | | 0.98 | | 0.62 | | |
| Observations | 122 | | 120 | | 122 | | 120 | | |

White cross-section standard errors. * significant at 10% level; ** significant at 5% level *** significant at 1% level
The second column shows the expected sign for each explanatory variable based on the literature. A green cell denotes that the variable has the expected sign and a red cell denotes that a variable does not have the expected sign
All variables are relative to Germany except for VIX and the short term interest rate.
A + denotes a positive sign, a - denotes a negative sign.
The regression output can be found in the appendix in table 13 and table 14

Table 8: Overview Output Ireland & Portugal sample

# 6 Robustness checks

In empiral settings several things can bias the results. According to Verbeek (2012) several factors might cause an endogeneity problem which means that Ordinary Least Squares (or LSDV) does not find the true consistent coefficient of a certain variable because there is correlation between an independent variable and the error term.

## 6.1 Sources of endogeneity and selection of robustness checks

The first factor which might cause endogeneity problems is measurement error which means that a proxy does not proxy as it should. For example, in this thesis the volume of outstanding debt proxies for the liquidity component. However if the amount of outstanding debt is not a good proxy for liquidity then the analysis does not show the true (or consistent) coefficient for liquidity (in other words there is a measurement error bias). An often used approach in the literature to tackle this problem is by replacing the proxy for another proxy and to check whether the estimates of the coefficients remain similar[42]. Following this approach, the proxy for liquidity amount of outstanding debt has been replaced by the Bid-Ask spread and the proxy for risk aversion of financial markets VIX has been replaced by the US Corporate AAA spread (a spread between US corporate bonds and US treasury bills) [43]. A third check for measurement error is replacing the debt to GDP ratio forecast with the debt to GDP ratio. A second source of endogeneity is an omitted variable bias. An omitted variable is a variable which has correlation with both the dependent as (one or more) independent variable(s). Failing to include this omitted variable causes that Ordinary Least Squares attributes the impact of the omitted variable to the independent variable (since it is correlated with the omitted variable). This causes that the independent variable has been under-/ or overestimated. It is impossible to control for all potential omitted variables. Still, to verify whether there is an omitted variable bias some variables have been included which might theoretically could bias the coefficients (see table 15 on page 45). First, the debt level of the banking sector relative to GDP has been included. Theoretically, a country faces more risk (which increases the government bond yield spread of a country) if the level of debt in the banking sector in a country is higher. So there is likely to be a positive correlation between the debt level of the banking sector relative to GDP and the government bond yield spread. There also might be a negative correlation between a heavily indebted banking sector and GDP growth [44]. If a country has a heavily indebted banking sector it might be hard for a countries' banking sector to fuel the economy by providing loans. An increase in loans increases investment which increases GDP growth (see figure 6 on page 34).

[42]For example, an indication that the used proxy is bad is when the sign switches if the proxy has been replaced by another proxy.

[43]Note again that liquidity is a idiosyncratic factor which means that has been measured relative to Germany and that risk aversion of financial markets is a common factor so that it is the same for all countries.

[44]Covariance analysis indeed shows a positive relationship between MFI debt and yield and a negative correlation between MFI debt and GDP growth for all samples, see table 15

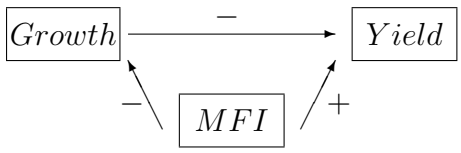


Figure 6: Potential omitted variable MFI to GDP ratio

Another variable which has been added is the level of international claims to GDP ratio. This variable measures international connectivity of banks. According to Gómez-Puig and Sosvilla-Rivero (2011) this variable can have two signs depending on the state of the economy. In a prosperous economic period banks will be better able to differentiate which makes the bank more efficient. This makes the bank (and the country) less dependent on domestic shocks which reduces the government bond yield spread. So there is a negative correlation between the size of inter-connectivity of banks and the government bond yield spread. In hard economic times however, this correlation might become positive. If banks of country have a lot of foreign claims, the banks are more vulnerable to systemic risk. In harsh economic times financial markets (and the European Commission who makes the forecasts) believe that systemic risk increases. Countries with a high claims to GDP ratio have banks which are more vulnerable to systemic risk and in the case of a systemic shock the banks are more likely to go bankrupt in which case the government might have to interfere. So the financial markets will lose some confidence in the country and because of the loss of confidence they will update their beliefs on the debt to GDP forecast. So in the case of a crisis there is an (indirect) channel from the claims to GDP ratio to the debt to GDP forecast which means that the claims to GDP ratio both explains some part of the yield as the debt to GDP forecast which means that failing to control for the size of inter-connectivity of banks might cause biased result of the debt to GDP forecast during the crisis because of an omitted variable bias. Since the a higher inter-connectivity on banks both causes a higher debt to GDP ratio and a lower yield spread failing to add the claims to GDP ratio might cause that no evidence of wake-up-call contagion from debt to GDP forecast has been found while in fact there is an effect[45]. See figure 7 on page 35 for an overview[46].

[45]Also note that during the crisis the impact of the claims to GDP ratio on government bond yields spreads might become positive through the new channel. See figure 7

[46]table 15 on 45 indeed shows a negative correlation in the the entire sample period. During the crisis however the correlation is positive. A look on table 15 shows indeed that the sign of the correlation between the debt to GDP forecast and the size of international claims to GDP changes during the crisis. Before the crisis there is approximately zero correlation between the size of international claims to GDP ratio and the debt to GDP forecast. After the breakdate of 2010 this changes to a positive correlation. A second interesting finding from table 15 might be the correlation between the international claims to GDP ratio and the government bond yield spreads. It is negative during the entire sample but it is offset by a positive effect during the crisis. his might be due to the positive channel from the international claims to GDP ratio on the government bond yield spread through the debt to GDP forecast.

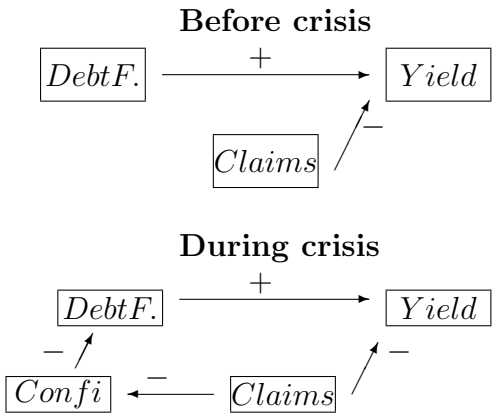


Figure 7: Potential omitted variable Claims to GDP ratio

## 6.2 Overview robustness checks

For the robustness checks 2010Q4 has been used has breakdate[47]. The robustness checks have been performed for both the estimation in levels (see table 16 on page 46 for the the Spain and Italy sample and table 18 on page 48 for the Ireland and Portugal sample) as the estimation in first differences (see table 17 on page 47 for the the Spain and Italy sample and table 19 on page 49 for the Ireland and Portugal sample).

### 6.2.1 Debt to GDP ratio

Using the debt to GDP ratio instead of the debt to GDP ratio forecast shows no big differences. The main difference is that the effect of the debt to GDP ratio is smaller than the effect of the debt to GDP ratio forecast. So there is even less evidence for wake-up-call contagion.

### 6.2.2 Bid-Ask Spread

Including the Bid-Ask spread of the different government bonds instead of the volume of outstanding debt gives the following results. The most interesting changes in the levels estimation are the debt to GDP forecast and inflation. For Spain and Italy the sign of the debt to GDP forecast for the entire sample period changes (it still does not significantly differ from zero however) and for Ireland and Portugal the wake-up-call contagion coefficient from debt to GDP forecast becomes smaller so that it gets insignificant. The coefficient of the inflation variable increases so that it gets significant on the 10% significance level for Italy and Spain while for Ireland and Portugal the sign for inflation changes from a + into a - although in both cases the estimate of the inflation coefficient does not significantly differ from zero for Ireland and Portugal. The rest of the coefficients remain similar in the estimation in levels. The most interesting insight from the estimation in first differences is that including the Bid-Ask spread instead of volume of outstanding debt causes that that for Spain and Italy the debt to GDP forecast in the entire sample gets significant on the 5% significance level (with the wrong sign) but that the coefficient of wake-up-call contagion from debt to GDP forecast slightly increases and remains signifcant on the 10% significance level. So including

[47]The same robustness checks have been performed with 2009Q4 as break-date. From the robustness checks with 2009Q4 as break-date similar conclusion can be drawn.

the Bid-Ask spread instead of the amount of outstanding debt as a proxy for liquidity risk did not change the output much which means that it likely that the amount of outstanding debt is a good proxy for liquidity.

### 6.2.3 US Corporate Bond AAA Spread

The most remarkable insight from using the US corporate AAA spread instead of the VIX as a proxy for global risk aversion of financial markets is that the impact of risk aversion of financial markets gets much smaller in both the estimation in levels as the estimation in first differences. All estimations for Spain and Italy where VIX is used as a proxy show a significant impact on the 1% significance level of risk aversion on government bond yield spreads which even gets stronger due to shift contagion during the crisis (also on the 1% significance level). If the US Corporate Bond AAA Spread has been used instead then in the estimation in levels there is no significant effect during the entire sample period and a significant shift contagion effect on the 5% significance level. In the estimation in first differences the opposite is the case: there is a significant effect during the entire sample period on the 10% significance level and no significant shift contagion effect. The rest of the output remains similar. This robustness checks casts some doubt on the validity of VIX as a proxy for risk aversion of financial markets. Klepsch (2011) found the same: if the corporate spread has been used instead of VIX as a proxy for global risk aversion the large impact of global risk aversion on EMU government bond spreads disappears. She argues however by looking at the behaviour of the VIX variable and the US corporate bond spread variable that the VIX variable is likely to catch a positive impact since in the case of unrest during the European sovereign debt crisis the VIX increases. For the US corporate bond spread the opposite is true: it decreases during the European sovereign debt crisis. This does not solve the question whether VIX is a good proxy however. However as Klepsch (2011) argues theoretically it makes more sense that VIX is a better proxy for global risk aversion of financial markets because it is plausible that the European sovereign debt crisis changed risk appetite of global financial markets since it is a large crisis in the world economy.

### 6.2.4 MFI debt to GDP ratio

Including the MFI debt to GDP ratio does not show many changes for the estimations in levels and first differences for both Spain and Italy as Portugal and Ireland. The only remarkable change is that VIX is not significant anymore on the 10% significance level in the estimation in levels for Ireland and Portugal. So in the two samples no evidence has been found that the MFI debt to GDP ratio is an omitted variable for GDP growth.
A side benefit of including the fundamental MFI debt to GDP ratio is that it also possible to see whether there is wake-up-call contagion from this variable. For Ireland and Portugal (both in the estimation in levels as in first differences) both the entire sample period coefficient as the contagion coefficient of the MFI debt to GDP ratio have the expected sign[48]. The coefficients do not differ significantly from zero however. For Spain and Italy the coefficients of MFI debt to GDP do not have the expected sign (excep for the entire sample period coefficient in the estimation in levels). The coefficients do also not differ significantly from zero however. So for both Italy and Spain as Ireland and Portugal no evidence for an impact of an indebted banking sector on goverment bond yield spreads has been found.

[48]If the amount of debt in the banking sector relative to GDP increases, this involves more risk which leads theortically into an increase in the government bond yield spread.

### 6.2.5 Claims to GDP ratio

As is the case for the MFI debt to GDP ratio, it is also possible to see whether there is an impact of the fundamental international claims to GDP ratio on government bond yield spreads. In the entire sample period the expectation is to find a negative sign which is offset by a positive contagion coefficient during the crisis (see figure 7 for an explanation). In general the theory does not hold. All contagion coefficients from the claims to GDP ratio are negative instead of positive (although all of them are not significantly different from zero) and there is only one significant entire sample period coefficient on the 10% significance level (for Ireland and Portugal in the estimation in first differences).

Adding the claims to GDP ratio does not change the output much except for a greater wake-up-call contagion effect from debt to GDP forecast in the estimation in first differences for Italy and Spain which becomes significant on the 5% significance level. So for the Spain and Italy sample the claims to GDP ratio was a omitted variables which caused the the impact of the debt to GDP forecast had been underestimated in the regression [49]. A problem with this way of reasoning one would also expect a significant effect from the claims to GDP ratio which is not the case. Still although not significant it might slightly change the estimates so it is might be an explanation [50]. For Ireland and Portugal the coefficient of the debt to GDP ratio is still not significantly different from zero after the claims to GDP ratio has been included. So the evidence that the claims to GDP ratio is an omitted variable is weak.

## 6.3 Summary robustness checks

In general the robustness checks do not change the output. The main exception is using the US corporate bond spread instead of VIX. If the US corporate bond spread is used the impact of risk aversion on government bond spreads becomes much smaller. Klepsch (2011) explained the reason for this finding. This does not (statistically) answer the question which proxy is better but theoretically it makes sense to accept VIX as being the better proxy for risk aversion during the crisis.

# 7 Conclusion

The aim of this thesis is to research the impact of contagion on government bond markets of the EMU periphery. There are four kinds of contagion: wake-up-call-, regional-, shift- and pure contagion. In the literature many research approaches and research specifications have been used to tackle this research question. The contribution of this thesis is that it shows that the literature does not take into account two factors sufficiently. If the literature would do this properly it will probably change the results.
First, many macroeconomic variables contain a unit root. In variables which contain a unit root shocks persist forever and the variable does not revert back to its' long term mean. In pure timeseries approaches doing regressions with variables which contain a unit root has the danger of spurious regression because the significant relationship has been driven by a

[49] A higher claims to GDP ratio increases the debt to GDP forecast through the confidence channel. If one does not control for the claims to GDP ratio it might cause that the contagion effect from the debt to GDP forecast had been underestimated

[50] The P-value from contagion effect of the debt to GDP ratio forecast changes from 0.06 to 0.03.

random shock which persist forever in the nonstationary variables instead of an actual causal relationship. Summarizing, one cannot simply rely on the output based on regressions with nonstationary variables. Some academics use the argument that they use a panel data approach which means that if the cross-section dimension goes to infinity unit roots do not play a role anymore which is based on the influential paper from Phillips and Moon (1999). Since in macroeconomic panel datasets the time dimension often is larger than the cross-section dimension (and according to Baltagi (2008) unit roots get more important if the time dimension increases) it is often advisable to also run the regression in first differences. If the output is similar, then it is possible to trust the output. This thesis shows that if the first differences are used to check whether the output is robust that the coefficient estimates are often not robust for some variable which casts some doubt on the research of academics who did not check this. Second, many researches simply pool the data of different cross-section unit together with the assumption that the different cross-section will respond in the same way on the different variables. If this homogeneity does not hold in combinatation with a dynamic model it causes inconsistent estimates of the coefficients of even the mean group estimator which means that the coefficient cannot even be interpreted as the effect for the average cross-section unit (Pesaran and Smith, 1995). This thesis shows that the homogeity assumption does not even hold for the complete EMU periphery countries. If seperate regression are used for the group Spain and Italy and the group Ireland and Portugal the regression output shows that the government bonds yields of these country respond completely different on the different independent variables.

So, did contagion have an impact on the government bond markets of the periphery? After separating Spain and Italy in group 1, Ireland and Portugal in group 2 and dropping Greece the following conclusions can be drawn. Since most variables contain a unit the estimation output of the estimations in first differences are most reliable. For both the group Spain and Italy as the group Ireland and Portugal very limited evidence on wake-up-call contagion has been found. The literature often found evidence for wake-up-call contagion but the literature does not seem to take into account unit roots in a sufficient way since their conclusion are often based on regression specifications in levels. This thesis shows that this effect disappears after taking the first differences. In none of the specifications regional contagion has been found. The opposite is even true. During the crisis there seems to be a dampening effect of the average government bond yield spread on the government bond yield spread of the periphery. Shift contagion however seems robust for Spain and Italy. The regression specifications in first differences show a strong impact of risk aversion of financial markets on Spanish and Italian government bond yield spreads with an additional effect during the crisis. An economic interpretation of this finding is the flight-to-safe-havens hypothesis. Because of for example a bad government reputation financial markets withdraw money from Spain and Italy in times of economic unrest (in times of economic unrest financial markets get more risk averse). For Ireland and Portugal no significant shift contagion has been found in the estimations in first differences. After taking the first differences it was not possible to measure pure contagion anymore since the crisisdummy without interaction drops more or less out. Another interesting finding is that conventional monentary policy seems to succesful in Ireland and Portugal but not succesful in Spain and Italy.

# 8 Further research

This thesis did not successfully find a proper regression specification for Greece. Since their is a lot to be explained about the Greek government bond markets it would be a good idea in further research to focus on the situation in Greece. It is not wise to draw conclusion for Greece on base of the other countries in the periphery because the situation is different in Greece and the homogeneity assumption will probably not hold. Another useful thing to research is to get a better view of what is happening in the Irish and Portuguese government bond markets. Some intuitive findings have been found for these countries but the adjusted $R^2$ is approximately 10 percent lower than the adjusted $R^2$ of the regression of Spain and Italy which means that it is somewhat less succesful. Another difference with the situation of Spain and Italy is that the difference between the Irish and Portuguese spread is greater than between the spread of Spain and Italy. So it might be true for Spain and Italy that a common factor drives their bond almost completely with the same impact this is however not the case for Ireland and Portugal. Either there should be a significant country specific variable or the countries respond differently on the common factors. Because if there is only a common factor driving the yield spreads of Ireland and Portugal with the same impact then their spreads would me equal. So in the future more research on this topic is needed.

This thesis focuses on contagion and for wake-up-call contagion there are several country-specific factors which might suffer from contagion. There is further research needed for other country-specific factors. These countries might also have a contagion effect. It might also be that some factors influence government bond yields spreads in a non-linear way[51].

Another interesting thing to research would be the presence of cointegration. In that case there would be a long run relationship between two variables which contain a unit root. For the question of the impact of contagion it might not be very relevant since contagion is probably a temporarily phenomenon instead of a long run phenomenon. From the point of view to get to know the determinants of government bond yield spreads it might be relevant though. Intuitively it also makes sense that there is a long run relationship between better country-specific fundamentals and lower government bond yield spreads. If that is the case fundamentals play a larger role in explaining government bond yield spreads in the long run while risk aversion is more a short run phenomenon. This is out of the scope of this thesis however.

[51] In some specifications of this thesis a squared debt to GDP ratio has been included to verify whether the relationship between the debt GDP ratio and government bond yield spreads is non-linear. No evidence has been found for such a non-linear relationship.

# 9 Figures

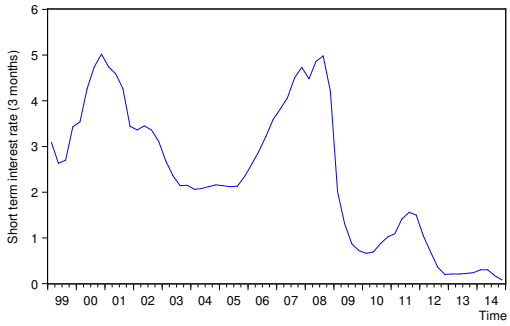


Figure 8: Short term interest rate (3 months)

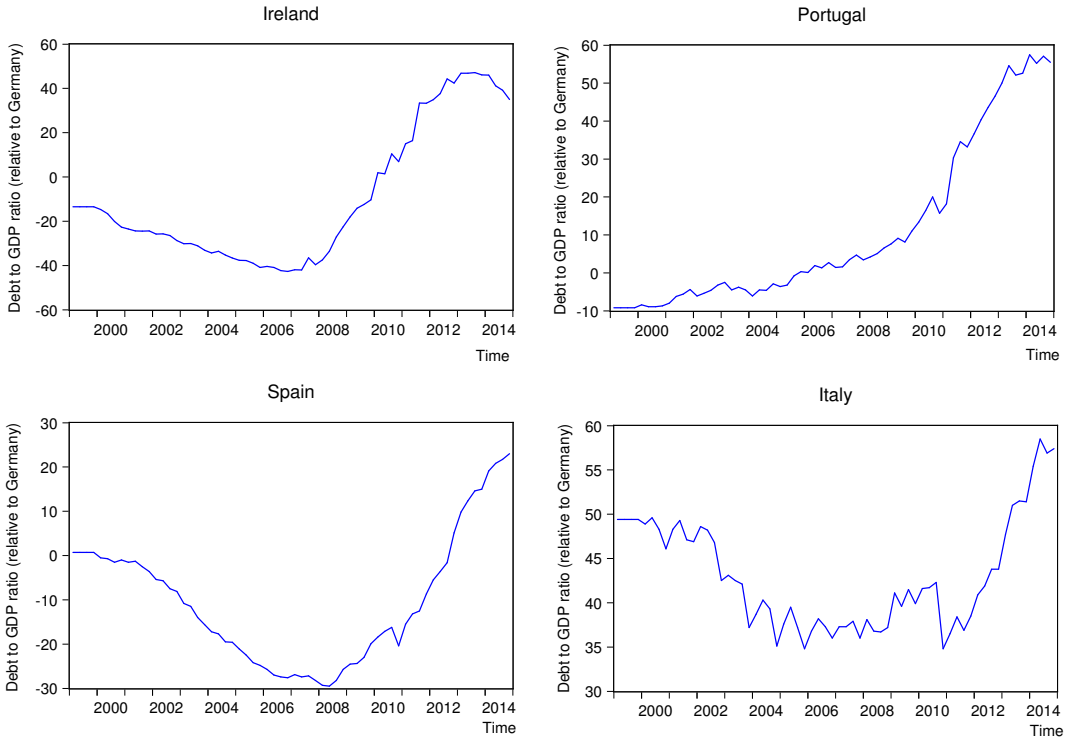


Figure 9: Debt to GDP ratio (relative to Germany) periphery, period 1999-2014

# 10 Tables

| Variables main regression | | | |
|---|---|---|---|
| Variable | Source | Frequency | Modification |
| Government bond yield | Datastream | Quarterly | |
| Debt to GDP ratio forecast | Economic Forecasts European Commission | Bi-annual | Cubic Interpolation |
| GDP growth | Eurostat | Quarterly | |
| Regional yield | Own Calculation | Quarterly | |
| Amount outstanding debt (government) | ECB Monetary Financial Statistics | Monthly | Aggregation |
| VIX | Federal Reserve Bank of St. Louis | Quarterly | |
| Inflation | OECD | Quarterly | |
| Short term interest rate (3 months) | Eurostat | Quarterly | |
| Variables robustness checks | | | |
| Variable | Source | Frequency | Modification |
| Debt to GDP ratio | Eurostat | Quaterly | |
| Bid-Ask spread | Bloomberg | Daily | Aggregation |
| US corporate bond AAA spread | Federal Reserve Bank of St. Louis | Quarterly | |
| MFI debt to GDP ratio | Datastream | Quarterly | |
| Claims to GDP ratio | Bank for International Settlements | Quarterly | |

Aggregation means that aggregation is performed by the author. Datastream for example also aggegates the data automatically if asked (which is the case for the government bond yield spread and the MFI debt to GDP ratio).
To calculate a GDP ratio both data on the level of the variable as data on the level of GDP is needed. Data on the GDP level has been collected from Eurostat on quarterly basis.

| Variables main regression | | |
|---|---|---|
| Variable | Measurement unit | Relative to Germany |
| Government bond yield | Percentage | Yes |
| Debt to GDP ratio forecast | Percentage | Yes |
| GDP growth | Percentage | Yes |
| Regional spread | Percentage | Yes |
| Amount of outstanding debt | Billions | Yes |
| VIX | Index | No |
| Inflation | Percentage | Yes |
| Short term interest rate | Percentage | No |
| Variables robustness checks | | |
| Variable | Measurement unit | Relative to Germany |
| Debt to GDP ratio | Percentage | Yes |
| Bid-Ask spread | Percentage | Yes |
| US coprorate Bond AAA spread | Percentage | No |
| MFI debt to GDP ratio | Percentage | Yes |
| Claims to GDP ratio | Percentage | Yes |

Table 9: Overview variables and data source

| Dependent variable: Government bond yield | | | |
|---|---|---|---|
| Independent Variable | Levels | 1st dif | Long term av. relationship |
| Constant | -0.280824*** | | -1.674232*** |
| Yield(-1) | 1.356732*** | 0.622525*** | |
| Yield(-2) | -0.552649*** | -0.201374*** | |
| Debt to GDP ratio forecast | 0.00521** | 0.007689 | 0.034333*** |
| GDP Growth | -0.014778*** | -0.003773 | -0.002544 |
| Regional yield | 0.017916 | 0.680127*** | 0.871702*** |
| Amount of outstanding debt | -0.000467** | -0.000937 | -0.003454*** |
| VIX | 0.00469* | 0.002535* | -0.003296 |
| Inflation | 0.012053 | 0.030899 | 0.083785* |
| Crisis | -0.45164*** | | -1.979125*** |
| Debt to GDP ratio forecast*crisis | 0.006296*** | -0.035854 | 0.029616*** |
| GDP Growth*crisis | -0.092006** | -0.011611 | -0.433942*** |
| Regional yield*crisis | 0.013231 | -0.346975** | -0.544948*** |
| VIX*crisis | 0.019745** | 0.006607 | 0.059248*** |
| Adjusted $R^2$ | 0.97 | 0.45 | 0.81 |
| Observations | 682 | 671 | 704 |
| Durbin Watson Statistic | - | - | 0.46 |

White cross-section standard errors. * significant at 10% level; ** significant at 5% level *** significant at 1% level
All variables are relative to Germany except for VIX.

Table 10: Regression results, sample: all countries, crisis dummy: 2009Q4

| Dependent variable: Government bond yield | | | |
|---|---|---|---|
| Independent Variable | Levels | 1st dif | Long term av. relationship |
| Constant | -0.479223* | | -1.876066*** |
| Yield(-1) | 1.316175*** | 0.649686*** | |
| Yield(-2) | -0.544127*** | -0.218329*** | |
| Debt to GDP ratio forecast | 0.004151 | 0.010357 | 0.028235*** |
| GDP Growth | -0.01488 | -0.006171 | 0.010883 |
| Regional yield | -0.018105 | 0.711002*** | 0.36855* |
| Amount of outstanding debt | -0.000722 | -0.001114 | -0.00357*** |
| VIX | 0.009358*** | 0.003268 | 0.013093 |
| Inflation | 0.009186 | 0.046941 | -0.036588 |
| Crisis | -0.763817** | | -4.61749*** |
| Debt to GDP ratio forecast*crisis | 0.011311*** | -0.042942 | 0.056196*** |
| GDP Growth*crisis | -0.123993** | -0.022404 | -0.541885*** |
| Regional yield*crisis | 0.053629 | -0.393125* | 0.066328 |
| VIX*crisis | 0.026636 | -0.004452 | 0.080867** |
| Adjusted $R^2$ | 0.97 | 0.45 | 0.82 |
| Observations | 310 | 305 | 320 |
| Durbin Watson Statistic | - | - | 0.57 |

White cross-section standard errors. * significant at 10% level; ** significant at 5% level *** significant at 1% level
All variables are relative to Germany except for VIX.

Table 11: Regression results, sample: periphery, crisis dummy: 2009Q4

| Dependent variable: Government bond yield | | | |
|---|---|---|---|
| Independent Variable | Levels | 1st dif | Long term av. relationship |
| Constant | -0.455728*** | | -1.323143*** |
| Yield(-1) | 1.206634*** | 0.352212*** | |
| Yield(-2) | -0.436033*** | -0.066987 | |
| Debt to GDP ratio forecast | 0.005358** | 0.016497 | 0.029721*** |
| GDP Growth | -0.009521 | 0.0009 | 0.01307 |
| Regional yield | 0.099264 | 0.753864*** | 0.653856*** |
| Amount of outstanding debt | -0.000785 | -0.002484*** | -0.003*** |
| VIX | 0.00538** | 9.22E-06 | -0.000705 |
| Inflation | 0.045274 | 0.076687* | 0.110091** |
| Crisis | -0.504649 | | -2.497081*** |
| Debt to GDP ratio forecast*crisis | 0.00326 | 0.005712 | 0.024289*** |
| GDP Growth*crisis | -0.121286*** | -0.01014 | -0.453234*** |
| Regional yield*crisis | -0.07425 | -0.500296*** | -0.332098** |
| VIX*crisis | 0.029028* | 0.043355*** | 0.069996** |
| Adjusted $R^2$ | 0.97 | 0.51 | 0.86 |
| Observations | 248 | 244 | 256 |
| Durbin Watson Statistic | - | - | 0.56 |

White cross-section standard errors. * significant at 10% level; ** significant at 5% level *** significant at 1% level
All variables are relative to Germany except for VIX.

Table 12: Regression results, sample: periphery without Greece, crisis dummy: 2009Q4

| Dependent variable: Government bond yield | | | | | | |
|---|---|---|---|---|---|---|
| Sample | Periphery excl. Greece | | Spain and Italy | | Ireland and Portugal | |
| Independent Variable | Levels | 1st dif | Levels | 1st dif | Levels | 1st dif |
| Constant | -0.302726** | | -0.242823** | | -0.165795 | |
| Yield (-1) | 1.176526*** | 0.346329** | 0.490399*** | 0.234529 | 1.132971*** | 0.393672** |
| Yield (-2) | -0.436272** | -0.099161 | -0.186077 | -0.096694 | -0.532279** | -0.20176 |
| Yield (-3) | 0.054376 | 0.092211 | 0.285009*** | 0.352137*** | 0.109024 | 0.018271 |
| Debt to GDP forecast | 0.00531** | 0.014775 | 0.007024** | 0.007107 | -0.005719 | 0.013911 |
| Growth | -0.014775 | 0.001518* | -0.021501* | 0.001757 | -0.019048 | -0.010576 |
| Regional Yield | 0.103697 | 0.731998*** | 0.285094*** | 0.58179*** | 0.34257 | 1.009616*** |
| Outstanding Debt | -0.0005** | -0.001773*** | -0.00102* | -0.002547*** | 2.98E-05 | -0.001345 |
| VIX | 0.004976* | 0.000357 | 0.003807 | 0.002925*** | 0.005717** | -0.003111 |
| Inflation | 0.033111 | 0.063216 | 0.0317 | 0.06891** | 0.006166 | -0.008579 |
| Interest rate | -0.001964 | -0.001886 | 0.000389 | 0.043381* | -0.011369 | 0.00897 |
| Crisis | -0.365544 | | -1.110595 | | 0.539256*** | |
| Debt to GDP forecast*crisis | 0.004292** | 0.012806 | 0.002898 | 0.015082 | 0.016934 | 0.000327 |
| Growth*crisis | -0.102547** | -0.033319 | -0.039452 | -0.056901 | -0.112865** | -0.018486 |
| Regional Yield*crisis | -0.100098 | -0.507209*** | -0.095503 | -0.393572*** | -0.295501 | -0.627191** |
| VIX*crisis | 0.002772 | 0.029084** | 0.057094*** | 0.064066*** | -0.05735 | -0.022954 |
| Interest rate*crisis | 0.625938** | 0.958655** | -0.420185* | -0.270578 | 1.667966*** | 2.218009*** |
| Adjusted $R^2$ | 0.97 | 0.53 | 0.98 | 0.73 | 0.98 | 0.61 |
| Observations | 244 | 240 | 120 | 122 | 120 | 122 |

White cross-section standard errors. * significant at 10% level; ** significant at 5% level *** significant at 1% level
All variables are relative to Germany except for VIX and the short term interest rate.

Table 13: Regression results, short term interest rate included, crisis dummy: 2009Q4

| Dependent variable: Government bond yield | | | | |
|---|---|---|---|---|
| Sample | Spain and Italy | | Ireland and Portugal | |
| Independent Variable | Levels | 1st dif | Levels | 1st dif |
| C | -0.207283* | | -0.110102 | |
| Yield(-1) | 0.507857*** | 0.213648 | 1.131502*** | 0.416148** |
| Yield(-2) | -0.162833 | -0.090587 | -0.540311** | -0.221199 |
| Yield(-3) | 0.219137*** | 0.355045*** | 0.121655 | 0.011744 |
| Debt to GDP ratio forecast | 0.001903 | -0.010449 | -0.004096 | 0.006581 |
| GDP Growth | -0.015862 | 0.010387 | -0.019813* | -0.0073 |
| Regional Yield | 0.220097*** | 0.380895*** | 0.293991** | 0.705956*** |
| Amount of outstanding debt | -0.000594 | -0.002319*** | 4.39E-05 | 0.000235 |
| VIX | 0.00662*** | 0.00637*** | 0.005735* | 0.001433 |
| Inflation | 0.026051 | 0.067206*** | -0.002442 | -0.041929 |
| Interest Rate | 0.009385 | 0.006256 | -0.007845 | -0.033963 |
| Crisis | -0.783139** | | 0.209418 | |
| Debt to GDP forecast*crisis | -0.000631 | 0.037498* | 0.023326** | 0.024477 |
| GDP Growth*crisis | -0.020861 | -0.054079 | -0.129327* | -0.012551 |
| Regional Yield*crisis | -0.045192 | -0.182471* | -0.248101* | -0.296383 |
| VIX*crisis | 0.070372*** | 0.062342*** | -0.068012 | -0.045178* |
| Interest Rate*crisis | -0.631867* | -0.241377 | 1.860853*** | 2.55562*** |
| Adjusted $R^2$ | 0.98 | 0.72 | 0.98 | 0.62 |
| Observations | 122 | 120 | 122 | 120 |

White cross-section standard errors. * significant at 10% level; ** significant at 5% level *** significant at 1% level

All variables are relative to Germany except for VIX and the short term interest rate.

Table 14: Regression results, short term interest rate included, crisis dummy: 2010Q4

| Correlation entire sample | | | | | |
|---|---|---|---|---|---|
| | Yield | D/GDP | Growth | MFI | Claims |
| Government Bond Yield Spr. | 1 | | | | |
| Debt to GDP Forecast | 0.41 | 1 | | | |
| GDP Growth | -0.54 | -0.46 | 1 | | |
| MFI Debt to GDP | 0.34 | -0.01 | -0.38 | 1 | |
| Claims to GDP | -0.03 | -0.38 | 0.19 | 0.62 | 1 |
| Correlation during crisis, breakdate 2009Q4 | | | | | |
| | Yield | D/GDP | Growth | MFI | Claims |
| Government Bond Yield Spr. | 1 | | | | |
| Debt to GDP Forecast | 0.09 | 1 | | | |
| GDP Growth | -0.42 | 0.32 | 1 | | |
| MFI Debt to GDP | 0.27 | -0.03 | -0.48 | 1 | |
| Claims to GDP | 0.02 | 0.00 | 0.11 | 0.57 | 1 |
| Correlation during crisis, breakdate 2010Q4 | | | | | |
| | Yield | D/GDP | Growth | MFI | Claims |
| Government Bond Yield Spr. | 1 | | | | |
| Debt to GDP Forecast | -0.10 | 1 | | | |
| GDP Growth | -0.49 | 0.35 | 1 | | |
| MFI Debt to GDP | 0.59 | 0.21 | -0.57 | 1 | |
| Claims to GDP | 0.13 | 0.25 | 0.41 | 0.14 | 1 |

Table 15: Overview Correlation Robustness Checks

| Dependent variable: Government bond yield spread (relative to Germany) | | | | | | |
|---|---|---|---|---|---|---|
| Independent Variable | Standard | Debt to GDP | Bid-ask Spread | US C. AAA | MFI D. to GPD | Claims to GDP |
| Constant | -0.207283* | -0.106761 | -0.130149*** | -0.151521 | -0.227849** | -0.189267* |
| Yield(-1) | 0.507857** | 0.513655*** | 0.347144** | 0.57635** | 0.505761*** | 0.496015*** |
| Yield(-2) | -0.162833 | -0.162251 | -0.038155 | -0.347694* | -0.160867 | -0.160911 |
| Yield(-3) | 0.219137*** | 0.21702*** | 0.194356*** | 0.252271* | 0.221118*** | 0.241387*** |
| Debt to GDP Forecast | 0.001903 | | -0.002033 | 0.004789 | 0.002163 | 0.001592 |
| Debt to GDP | | -0.003209 | | | | |
| GDP Growth | -0.015862 | -0.016451 | -0.017801 | -0.023321 | -0.01433 | -0.015657 |
| Reg. Yield | 0.220097*** | 0.222046*** | 0.236877*** | 0.217943** | 0.217693*** | 0.219036*** |
| Outstanding Debt | -0.000594 | 1.50E-05 | | -4.52E-04 | -0.00056 | -0.000585 |
| Bid-Ask-Spread | | | 6.106052*** | | | |
| VIX | 0.00662*** | 0.00676*** | 0.007066*** | | 0.006457*** | 0.006568*** |
| US Corporate Bond AAA spread | | | | 0.092785 | | |
| Inflation | 0.026051 | 0.022612 | 0.036948* | -0.005968 | 0.029722 | 0.026515 |
| Interest Rate | 0.009385 | 0.013504 | 0.012201 | 0.004885 | 0.010582 | 0.009941 |
| MFI Debt to GDP | | | | | 0.021288 | |
| Claims to GDP | | | | | | 0.000351 |
| Crisis | -0.783139** | -0.602836* | -0.297509 | -2.122309** | -0.784551** | -1.258061** |
| Debt to GDP Forecast*crisis | -0.000631 | | -0.002327 | 0.001492 | 0.000465 | 0.004132 |
| Debt to GDP | | -0.003575 | | | | |
| GDP Growth*crisis | -0.020861 | 0.003966 | -0.019617 | -0.047554 | -0.035866 | -0.008344 |
| Reg. Yield*crisis | -0.045192 | -0.044704 | -0.058045 | -0.014196 | -0.038822 | -0.049593 |
| VIX*crisis | 0.070372*** | 0.071606*** | 0.047452*** | | 0.068896*** | 0.070818*** |
| US Corporate Bond AAA spread*crisis | | | | 1.147077** | | |
| Interest Rate*crisis | -0.631867* | -0.661087** | -0.583163** | -0.246535 | -0.604498* | -0.547732 |
| MFI Debt to GDP*crisis | | | | | -0.077644 | |
| Claims to GDP*crisis | | | | | | -0.008991 |
| Adjusted $R^2$ | 0.98 | 0.98 | 0.99 | 0.98 | 0.98 | 0.98 |
| Observations | 122 | 122 | 122 | 122 | 122 | 122 |

White cross-section standard errors. * significant at 10% level; ** significant at 5% level *** significant at 1% level
All variables are relative to Germany except for VIX, the US corporate bond AAA spread and the short term interest rate.

Table 16: Ro bustness check, levels estimation, sample: Italy and Spain, crisis dummy: 2010Q4

| Dependent variable: Government bond yield spread (relative to Germany) | | | | | | |
|---|---|---|---|---|---|---|
| Independent Variable | Standard | Debt to GDP | Bid-ask Spread | US C. AAA | MFI D. to GPD | Claims to GDP |
| Yield(-1) | 0.213648 | 0.231855 | 0.129651* | 0.174007 | 0.220751 | 0.203347 |
| Yield(-2) | -0.090587 | -0.10545 | 0.006653 | -0.220886* | -0.089213 | -0.081504 |
| Yield(-3) | 0.355045*** | 0.319342*** | 0.323217*** | 0.334778*** | 0.356067*** | 0.366869*** |
| Debt to GDP Forecast | -0.010449 | | -0.01688** | -0.012161 | -0.010885 | -0.011322 |
| Debt to GDP | | 0.014552 | | | | |
| GDP Growth | 0.010387 | 0.010882 | 0.007487 | 0.013765 | 0.010502 | 0.01073 |
| Regional Yield | 0.380895*** | 0.361174*** | 0.379801*** | 0.368049*** | 0.379942*** | 0.382956*** |
| Outstanding Debt | -0.002319*** | -0.003421*** | | -2.70E-04 | -0.002248*** | -0.002098*** |
| Bid-Ask Spread | | | 5.081317*** | | | |
| VIX | 0.00637*** | 0.005897*** | 0.0072*** | | 0.006214*** | 0.006275*** |
| US Corporate Bond AAA Spread | | | | 0.102448* | | |
| Inflation | 0.067206* | 0.053328* | 0.062188* | 0.069692 | 0.06698* | 0.066277* |
| Interest Rate | 0.006256 | 0.008602 | 0.021697 | 0.008315 | 0.004586 | 0.0087 |
| MFI Debt to GDP | | | | | -0.051769 | |
| Claims to GDP | | | | | | -0.000642 |
| Debt to GDP Forecast*crisis | 0.037498* | | 0.041818* | 0.067545** | 0.03668* | 0.042796** |
| Debt to GDP | | -0.007393 | | | | |
| GDP Growth*crisis | -0.054079 | -0.03654 | -0.031038 | -0.312716*** | -0.058602 | -0.066367 |
| Regional Yield*crisis | -0.182471* | -0.189466* | -0.144595* | -0.133191 | -0.181293* | -0.189336* |
| VIX*crisis | 0.062342*** | 0.068149*** | 0.044539*** | | 0.061825*** | 0.061688*** |
| US Corporate Bond AAA Spread*crisis | | | | 1.003082 | | |
| Interest Rate*crisis | -0.241377 | -0.55403 | -0.214748 | 0.417037 | -0.237607 | -0.142509 |
| MFI Debt to GDP*crisis | | | | | -0.038504 | |
| Claims to GDP*crisis | | | | | | -0.008059 |
| Adjusted $R^2$ | 0.72 | 0.71 | 0.78 | 0.58 | 0.71 | 0.71 |
| Observations | 120 | 120 | 120 | 120 | 120 | 120 |

White cross-section standard errors. * significant at 10% level; ** significant at 5% level *** significant at 1% level
All variables are relative to Germany except for VIX, the US corporate bond AAA spread and the short term interest rate.

Table 17: Robustness check, first differences estimation, sample: Italy and Spain, crisis dummy: 2010Q4

| Dependent variable: Government bond yield spread (relative to Germany) | | | | | | |
|---|---|---|---|---|---|---|
| Independent Variable | Standard | Debt to GDP | Bid-ask Spread | US C. AAA | MFI D. to GPD | Claims to GDP |
| Constant | -0.110102 | -0.021108 | -0.116283 | 0.046603 | 0.091010 | 0.014154 |
| Yield(-1) | 1.131502*** | 1.15863*** | 1.053468*** | 1.028371*** | 1.153577*** | 1.136442*** |
| Yield(-2) | -0.540311*** | -0.565973** | -0.544489** | -0.365863* | -0.570961** | -0.58168** |
| Yield(-3) | 0.121655 | 0.139408 | 0.202509 | 0.040665 | 0.151824 | 0.152412 |
| Debt to GDP Forecast | -0.004096 | | -0.00321 | -0.003793 | -0.002997 | 8.46E-05 |
| Debt to GDP | | -0.003419 | | | | |
| GDP Growth | -0.019813* | -0.02239** | -0.020708** | -0.022976** | -0.020421** | -0.02689** |
| Regional Yield | 0.293991** | 0.35292*** | 0.356583*** | 0.411105*** | 0.347305*** | 0.326696*** |
| Outstanding Debt | 4.39E-05 | 1.16E-04 | | 1.84E-04 | 0.000283 | 2.45E-05 |
| Bid-Ask-Spread | | | 1.540217** | | | |
| VIX | 0.005735* | 0.00411 | 0.004309 | | 0.004254 | 0.004009 |
| US Corporate Bond AAA Spread | | | | 0.023841 | | |
| Inflation | -0.002442 | 0.001266 | -0.008581 | -0.002882 | -0.001536 | -0.000389 |
| Interest Rate | -0.007845 | -0.011246 | -0.005229 | -0.003214 | -0.011231 | -0.007715 |
| MFI Debt to GDP | | | | | 0.023273 | |
| Claims to GDP | | | | | | -0.000251 |
| Crisis | 0.209418 | 0.756892 | 1.176782 | -1.408675 | 0.781798 | 0.304072 |
| Debt to GDP Forecast*crisis | 0.023326** | | 0.003882 | 0.012305 | 0.011843 | 0.018716 |
| Debt to GDP | | 0.014126 | | | | |
| GDP Growth*crisis | -0.129327* | -0.11045* | -0.087096 | -0.124276* | -0.110795 | -0.108832 |
| Regional Yield*crisis | -0.248101* | -0.330699*** | -0.357054*** | -0.422459*** | -0.317601*** | -0.272253** |
| VIX*crisis | -0.068012 | -0.078992 | -0.077247* | | -0.072422 | -0.079897* |
| US Corporate Bond AAA Spread*crisis | | | | 0.894788 | | |
| Interest Rate*crisis | 1.860853*** | 1.96764*** | 1.695936*** | 1.276007** | 1.835824*** | 2.104024*** |
| MFI Debt to GDP*crisis | | | | | 0.007331 | |
| Claims to GDP*crisis | | | | | | -0.002279 |
| Adjusted $R^2$ | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 |
| Observations | 122 | 122 | 122 | 122 | 122 | 122 |

White cross-section standard errors. * significant at 10% level; ** significant at 5% level *** significant at 1% level
All variables are relative to Germany except for VIX, the US Corporate Bond AAA Spread and the Short Term Interest Rate.

Table 18: Robustness check, levels estimation, sample: Ireland and Portugal, crisis dummy: 2010Q4

| Dependent variable: Government bond yield spread (relative to Germany) | | | | | | |
|---|---|---|---|---|---|---|
| Independent Variable | Standard | Debt to GDP | Bid-ask Spread | US C. AAA | MFI D. to GPD | Claims to GDP |
| Yield(-1) | 0.416148** | 0.45623** | 0.41079* | 0.334037** | 0.410462** | 0.418902** |
| Yield(-2) | -0.221199 | -0.220286 | -0.224527 | -0.075214 | -0.231834 | -0.195684 |
| Yield(-3) | 0.011744 | 0.020266 | 0.020221 | -0.068879 | 0.00736 | 0.008605 |
| Debt to GDP Forecast | 0.006581 | | 0.006247 | 0.008776 | 0.009102 | 0.00534 |
| Debt to GDP | | -0.015795 | | | | |
| GDP Growth | -0.0073 | -0.011157 | -0.00772 | 0.000968 | -0.005475 | -0.01423 |
| Regional Yield | 0.705956*** | 0.762925*** | 0.711345*** | 0.696211*** | 0.706411*** | 0.714341*** |
| Outstanding Debt | 0.000235 | -0.00148 | | 0.001381 | 0.000179 | 0.000985 |
| Bid-Ask-Spread | | | 0.12852 | | | |
| VIX | 0.001433 | 0.001698 | 0.001402 | | 0.001767 | 5.44E-05 |
| US Corporate Bond AAA Spread | | | | 0.023522 | | |
| Inflation | -0.041929 | -0.046655 | -0.045165 | 0.009652 | -0.038206 | -0.053747 |
| Interest Rate | -0.033963 | -0.033183 | -0.030239 | -0.078184* | -0.026138 | -0.011546 |
| MFI Debt to GDP | | | | | 0.116568 | |
| Claims to GDP | | | | | | -0.001777* |
| Debt to GDP Forecast*crisis | 0.024477 | | 0.02305 | 0.03394 | 0.024712 | 0.002878 |
| Debt to GDP | | 0.024076 | | | | |
| GDP Growth*crisis | -0.012551 | -0.010583 | -0.009351 | -0.00276 | -0.010753 | -0.006602 |
| Regional Yield*crisis | -0.296383 | -0.417236** | -0.305079 | -0.298621* | -0.282708 | -0.329739 |
| VIX*crisis | -0.045178* | -0.048189 | -0.044803* | | -0.046252 | -0.035694 |
| US Corporate Bond AAA Spread*crisis | | | | 1.358853 | | |
| Interest Rate*crisis | 2.55562*** | 2.517328*** | 2.508407*** | 1.939181** | 2.537522*** | 2.440082*** |
| MFI Debt to GDP*crisis | | | | | 0.079506 | |
| Claims to GDP*crisis | | | | | | -0.002939 |
| Adjusted $R^2$ | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 | 0.63 |
| Observations | 120 | 120 | 120 | 120 | 120 | 120 |

White cross-section standard errors. * significant at 10% level; ** significant at 5% level *** significant at 1% level
All variables are relative to Germany except for VIX, the US corporate bond AAA spread and the short term interest rate.

Table 19: Robustness check, first differences estimation, sample: Ireland and Portugal, crisis dummy: 2010Q4

# 11 Appendix

## 11.1 Breakpoint test

The most straightforward structural breaktest is the Chow break test (Chow, 1960). The assumption of the Chow break test is that the breakdate is known beforehand.

$$y_t = \beta x_t + c_t \gamma x_t \tag{4}$$

The variable $c_t$ takes value 0 before the breakdate and value 1 after the breakdate. By simply doing an F-test which compares a restricted model (without $c_t \gamma x_t$) and a unrestricted model (with $c_t \gamma x_t$) it is easy to verify whether there is a significant break in the equation.
A disadvantage of the Chow breaktest is however that one has to know the breakdate before performing the test. Hansen (2001) mentions two disadvanteges for the fact that the breakdate has to be known beforehand. First, the researcher can miss the breakdate by selecting a wrong date beforehand. Secondly, an endogeneity problem might arises if the researcher selcts the breakdate on base of the residuals. In that case the residuals are correlated with the $c_t \gamma x_t$ term which is an endogeneity problem. Quandt (1960) came up with the idea to perform a Chow breaktest for all possible breakdates in the dataset. The date with the largest F-statistic is most likely to be the breakdate. The F-statistics are easy to compute the distribution of the statistics is different in this case is however, which means that the critical values are not valid (Quandt, 1960; Verbeek, 2012). Andrews (1993) calculated new critical values which makes it possible to interpret the Quandt-statistics.
Breakpoint tests are mainly used for timeseries and not for panel data. Therefore the i subscript has been dropped in equation (4).

## 11.2 Homogeneity assumption and dynamic panel data approaches

If the homogeneity assumption holds then all cross-section units have the same $\beta$ in equation (5):

$$y_{i,t} = \alpha_i + \beta X_{i,t} + \epsilon_{i,t} \tag{5}$$

However if the homogeneity assumption does not hold and the cross-sections have been pooled anyway then there is an additional term ($\beta X_{i,t}(\beta_i - \beta)$) in the error term:

$$y_{i,t} = \alpha_i + \beta X_{i,t} + \beta X_{i,t}(\beta_i - \beta) + \epsilon_{i,t} \tag{6}$$

In the static panel regression a false homogeneity assumption provide consistent estimates for for the individual cross-section unit since the country-specific $\beta$ might be higher or lower than the estimated $\beta$ from the panel regression. The estimate for the average cross-section unit (or mean group estimate) however is still consistent as can be seen from equation (6). Keep autocorrelation in mind however. After lagging the dependent variable it is easy to see that their is a high degree of autocorrelation. The error term of $y_{i,t-1}$ consists of $\beta X_{i,t-1}(\beta_i - \beta)$ and the error term of $y_{i,t}$ consists as said of $\beta X_{i,t}(\beta_i - \beta)$. Since those two terms are very similar autocorrelation is evident. In the static panel regression autocorrelation does not cause inconsistency in the mean group estimator there is no correlation between an independent

variable and the error term. This is not the case in a dynamic panel setting for the following reason.

$$y_{i,t} = \gamma y_{i,t-1} + \alpha_i + \beta X_{i,t} + \beta X_{i,t}(\beta_i - \beta) + \epsilon_{i,t} \tag{7}$$

Since in the dynamic setting one of the error terms ($\beta X_{i,t-1}(\beta_i - \beta)$) is in a independent variable ( $y_{i,t-1}$) there is correlation between an independent variable and the error term. So in the case of a dynamic panel setting a false homogeneity assumption causes an endogeneity problem which makes also the mean group estimator inconsistent.

## 11.3 Nickell bias in dynamic panel data models

$$y_{i,t} = \alpha_i + \gamma y_{i,t-1} + \beta X_{i,t} + \epsilon_{i,t} \tag{8}$$

Lagging equation (8) gives:

$$y_{i,t-1} = \alpha_i + \gamma y_{i,t-2} + \beta X_{i,t-1} + \epsilon_{i,t-1} \tag{9}$$

Substituting equation (9) into equation (8) gives:

$$y_{i,t} = \alpha_i + (\alpha_i + \gamma y_{i,t-2} + \beta X_{i,t-1} + \epsilon_{i,t-1}) + \beta X_{i,t} + \epsilon_{i,t} \tag{10}$$

$\alpha_i$ is by construction correlated with $y_{i,t}$ and $y_{i,t-1}$. Since there is an error term ($\epsilon_{i,t-1}$)) in $y_{i,t-1}$ (see equation (8)) there is correlation between $\alpha_i$ and $\epsilon_{i,t-1}$) which is an endogeneity problem. This causes that OLS (or LSDV) is not a consistent estimator for the $\gamma$ coefficient (Verbeek, 2012).
So both the fixed effects estimator as the random effects estimator have an endogeneity problem in a dynamic panel specification. The solution seems straightforward: get rid of $\alpha_i$ by using the within transformation.

$$(y_{i,t} - y_{i,t-1}) = \gamma(y_{i,t-1} - y_{i,t-2}) + \beta(X_{i,t} - X_{i,t-1}) + (\epsilon_{i,t} - \epsilon_{i,t-1}) \tag{11}$$

In static panel data models the within transformation procedure is a reliable method which still yields consistent estimates. For dynamic panel data model this is not the case because in the dynamic panel data case there is also the term $y_{i,t-1} - y_{i,t-2}$ which has correlation with $\epsilon_{i,t} - \epsilon_{i,t-1}$. Because $y_{i,t-1}$ and $\epsilon_{i,t-1}$ are correlated by construction. Again, endogeneity causes that the Least Squares procedure causes inconsistent estimates. The bias which arises from this endogeneity is in the literature known as the Nickell bias.
A said in the main text, Nickell (1981) shows that the Nickell bias disappears if the time dimension of the panel data set converges to infinity.

## 11.4 Potential solution to Nickell bias

Several methods have been used to avoid the Nickell bias. As common in the case of endogeneity biases instrumental variables or GMM methods are used to solve these biases. The approach Andersen and Hsiao (1981) use is an easy applicable solution. Hsiao used the within transformation and as an instrument for the differenced lagged dependent variable he used either ($y_{i,t-2} - y_{i,t-3}$) or just the level of $y_{i,t-2}$. Arellano and Bover (1995) show however that the level version of the Andersen-Hsiao estimator yields large biases and large standard errors in case of (potential) unit root of the dependent variable . Arellano and Bond (1991)

build on the Andersen-Hsiao approach by adding additional instruments. Take for example $t = 3$ is in the within transformed equation:

$$(y_{i,3} - y_{i,2}) = \gamma(y_{i,2} - y_{i,1}) + \beta(X_{i,3} - X_{i,2}) + (\epsilon_{i,3} - \epsilon_{i,t-2}) \tag{12}$$

$y_{i,1}$ could serve as an instrument now because of its' high correlation with $(y_{i,2} - y_{i,1})$ but no correlation with the error term. If t is large it is necessary to restrict the number of instruments to avoid computational problems (Judson and Owen, 1996). If $t = 4$ both $y_{i,1}$ as $y_{i,2}$ could be used as instruments for $(y_{i,3} - y_{i,2})$. So the higher t the more instruments the Arellano-Bond Estimator can use[52]. However, like all GMM methods also the Arellano-Bond Estimator suffers if the instruments are weak (Verbeek, 2012). Although the GMM method holds (given that instruments are strong) consistent results the LSDV estimator estimates have a lower variance. So there is trade-off between consistency and efficiency by choosing between LSDV estimators and GMM estimators.

[52]the numerical example is from Baltagi (2008)

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