Capital flows and sovereign bond spread divergence in the European Monetary Union

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May 1, 2015

Abstract

This paper shows that cross-border capital flows within the EMU may have contributed up to 370 basis points to sovereign spreads during the crisis. Mechanisms through which these capital flows can have affected sovereign bond yields include changes in sovereign fiscal positions, the tight link between banking and sovereign health, the lack of domestic monetary policy tools and the lack of a country-specific exchange rate mechanism.

Index terms - Euro-area, sovereign spread, financial crisis, capital flows, TARGET2.

1 Introduction

This paper sheds some light on the role of cross-border capital flows in the post-2008 divergence of sovereign bond yields within the European Monetary Union (EMU). I identify a fragility of monetary union sovereign debt, focusing on the inability of sovereign nations to control their own currency in combination with a large capital outflow.

The relevance of this research is found when looking at the evolution of sovereign bond spreads in current Euro-countries from the beginning of the EMU. The first decade of the EMU showed a sharp decline in intra-Euro-area sovereign risk premium differentials (Kilponen et al., 2012, Beirne and Fratzscher, 2013). Despite significant differences in country-specific government finances, sovereign yields had been contained within a 50 basis point range from 2002 onwards, and remained very stable until the recent financial crisis. Reasons for this convergence are usually found in a common and stable monetary policy, the elimination of exchange rate risk, and a credibly stable expected inflation rate (Ehrmann et al., 2011). However, during the crisis the intra-Euro-area government bond spreads have diverged; where core countries saw their yields decrease (especially Germany), peripheral countries experienced large yields. Some Euro area countries dealing with elevated government-borrowing costs did so in spite of being in much sounder positions than for instance the US or the UK. The Eurozone saw a risk transfer from private to public, putting pressure on several Euro-countries, and raising the question of preservation of the Euro in the financial market. Finally, after mid-2012, sovereign spreads have started to decline; fundamentals had been improved, but also the European Central Bank (ECB) had credibly expressed its determination to preserve the Euro with the announcement of Outright Monetary Transactions (OMTs) in the secondary market for EMU sovereign bonds.

The developments of these bond yields are interesting for multiple reasons. First from a monetary policy perspective, as the monetary transmission mechanism may be disturbed by excessive volatility or disorder on the sovereign bond market. Also, a crisis of such depth and length may be avoided in the future if drivers of the debt crisis are known. Finally, for the further shaping of the EMU it may be important to identify some fragilities of the relatively new currency area.

Since the introduction of the Euro, some degree of detachment from fundamentals was observed. First by strongly converging bond yields despite large differentials in fundamentals, and second by strongly diverging bond yields without proportional changes in underlying fundamentals. Research on the reasons behind these bond yield developments is extensive, and has not reached consensus yet. Some argue that the large post-crisis volatility of spreads in the Euro-area is a rational reaction of the financial markets to changes in risk and uncertainty. The increased spread during the crisis would thus be due to increased global risk aversion, political uncertainty and deteriorated fundamentals (Aizenman et al., 2011, D'Agostino and Ehrman, 2013). Beirne and Fratzscher (2013) use a panel data set with a regime switching model to argue that the sensitivity of financial markets to country-specific fundamentals has increased

during the crisis, and also that pre-crisis sovereign bond yields poorly reflected these fundamentals. Other views argue that since the crisis government bond yields in the EMU no longer reflected fundamentals, which translates in overshooting or undershooting of pricing. These are either attributed to global panic and increased risk aversion (Caceres et al., 2010, Aizenman et al., 2011), contagion (Forbes, 2012) and the lack of a lender of last resort (De Grauwe, 2012, Lane, 2012), or the existence of redenomination risk (D'Agostino and Ehrman, 2013, ECB 2012). The question whether sovereign bonds were fairly priced in the EMU is put in perspective by de Haan, Hessel and van den End (2014), who argue that the answer to this question highly relies on the model, sample and methods used for empirical analysis. One point of consensus is that sovereign bond pricing in the EMU has not been constant over time; generally the start of the sovereign debt crisis is used as a break date. Also, empirics show a consistent pattern that sovereign bond yield volatility has been larger for members of the EMU than for countries with their own currency when looking at yield differentials compared to fundamentals (among many others: De Grauwe and Ji, 2013, Poghosyan, 2012).

My contribution to this literature is the notion that large capital flows during the crisis from the periphery to the core have contributed to the divergence of sovereign bond yields in the EMU. First of all, financial integration in the Euro-area facilitated large capital outflows from the periphery during the crisis. Second, these large capital reallocations have caused divergence of sovereign bond yields through different macro-economic channels. The empirical results indeed point to a significant divergence of sovereign bond yields as a result of large capital movements. Estimates show a ceteris paribus increase in sovereign bond yields of almost 100 basis points per 100% of GDP capital outflow in the periphery, and a decrease of sovereign bond yields of 70 basis points per 100% of GDP capital inflow in the core. With capital outflow in Ireland ranging up to 330% of GDP (the largest EMU capital outflow), and Germany's capital inflow to 100% of GDP (the largest EMU capital inflow), capital flows have increased bond spreads in my sample by up to 370 basis points. These capital flows can have brought about such yield changes through changes in sovereign fiscal positions, the tight link between banking and sovereign health, the lack of domestic monetary policy tools and the lack of a country-specific exchange rate mechanism. With these results this paper adds to the existing literature on determinants of EMU sovereign spreads during the recent financial crisis.

This paper is structured as follows: In section 2 I give an overview of capital flows within the EMU, and relate these movements to sovereign bond yields. In section 3 I set up our model, based on existing literature and including capital flows. Section 4 introduces the data used and pretesting on this dataset, section 5 shows the results, section 6 discusses some limitations, and section 7 concludes.

2 Capital flows and sovereign bond yields in the EMU

This section elaborates on cross-border capital flows within the EMU, and the possible connections between those capital flows and sovereign bond yields.

2.1 Capital flows

The elimination of exchange rate risk within the Euro-area, paired with a global financial boom greatly increased the intra-Euro-area degree of financial integration. In the years following 1999 the largest increases in net foreign liabilities amongst advanced economies occurred in the periphery of the EMU (the only country having a larger foreign capital inflow in this period was Iceland)(Hargreaves, D. and Watson, E., 2011). Gross capital flows as well as net capital imbalances increased far beyond the level of capital flows between stand-alone countries (Valiante, 2014) and so did the capital dependency of peripheral countries. Large deficits and surpluses emerged between the EMU's core and periphery countries, to an extent that financial risk for both the surplus and the deficit countries increased (Lane, 2013). Surplus countries are very exposed to declining value of external assets, while the deficit countries run the risk of a sudden stop in capital, leading to a decline in asset prices, financial distress and recession (Obstfeld and Rogoff 2005, Mendoza 2010) and face the risk of credit rationing in both the public and private sector (Arteta, 2008). When the financial crisis set in, this is exactly what happened; much of the surpluses were pulled back by core countries and financial institutions in search of safe havens and liquidity, creating a liquidity-run in the peripheral banking and public sector (Valiante, 2014). Silvia Merler and Jean Pisani-Ferry (2012) show that this outflow of capital in the periphery qualifies as a sudden stop, and also that the capital was pulled out from both the public and the private sector. The liquidity gap that arose in the EMU in peripheral countries due to capital outflows was largely filled up by the ECB through the TARGET2 payment system of the Eurozone. Central bank funding replaced private market funding, supporting the liquidity of peripheral banks. This prevented a collapse of the banking sector and mitigated the downturn on the supply of credit to households and firms during the sudden stop. However, the reliance on the central bank exposed the weakness of the private banking sector. At the same time, the lack of an exchange rate mechanism or independent monetary policy did not allow periphery countries to adjust accordingly.

Looking at the United States, which is a monetary union while also a political union, we see similar capital mobility between states as between Euro members but less fragility associated with it. There are significant differences between a large monetary union that is also a political union (like the United States) and the EMU. First, the lack of political unification in the EMU creates different incentives for individual countries, and a stronger home bias of investment in periods of high turmoil (Valiante 2014). Second, in the US the failure of private banks is a carried by the federal government, while in the EMU this burden is for the domestic government. And finally, since the Unites States have one central government and states have fairly modest budgets, a default of a state

is relatively easy to overcome with federal financing.

2.2 The links between capital flows and sovereign bond yields

Whereas financial integration is generally beneficial for the economy, I hypothesize that the high level of financial dependence within the EMU has to some extent backfired during the financial crisis. This hypothesis is two-sided. First: the large dependence of the periphery on the core in the EMU made the periphery more vulnerable to a sudden stop in capital. Second: an EMU member's debt is more vulnerable compared to a stand alone country's debt in the case of a sudden stop. Due to the lack of independent domestic monetary policy tools and an exchange rate mechanism, EMU countries have very little instruments at hand to cope with a contraction of capital inflow. This contributed to the divergence of sovereign bond spreads within the EMU through the needed fiscal support to the private sector, decreasing tax revenues, the inability of the country to mitigate the effects on the economy through the exchange rate mechanism, and the inability to pursue independent monetary policy. Below I elaborate on these channels through which the capital flows may have affected sovereign bond spreads.

Sovereign fiscal position: An outflow of capital from the private sector may affect government finances through declining income (decrease in GDP) and increasing expenses (the need for capital injections in the private sector). As Obstfeld and Rogoff (2005) showed, a sudden stop of capital leads to declining asset prices, financial distress and recession. As capital flows are pro-cyclical (Stiglitz, 2000) they may have been fueling the crisis in the periphery. The exacerbated recession in the periphery resulted in declining tax income[1], and also the need for fiscal support in the private sector resulting from financial distress deteriorated the sovereign fiscal position. This relationship between capital flows and the sovereign fiscal position is supported by the strong correlation between TARGET2 balances and government debt[2], and also by earlier crises where (non-EMU) countries experienced a sudden stop. One example is the 1994 crisis in Turkey; after a credit-rating downgrade resulting from high debt and deficit, Turkey experienced a large-scale capital flight. As a result Turkey saw a large drop in investment and business confidence and increased monetary tightening to control the currency. This led to a large decline in economic activity and a decrease in real GDP of 5% (Altinkemer, 1995). Some other examples are found in Latin-America, such as Brazil in 2001-2002 (Garcia, 2008). This fiscal deterioration translates into higher sovereign yields through decreased creditworthiness (Cantor and Packer, 1996).

Banking sector: There exists a tight two-directional link between banking sector health and sovereign health. First, several studies show that banking crises directly increase the likelihood of a sovereign default, even if this bank-

[1] The average annual decline in tax income over the period 2008-2010 was 4.2% for peripheral countries in our sample. For core countries and non-EMU countries this was 0.7% and 0.8% respectively. Source: Worldbank and own calculations.

[2] Appendix 8.4. TARGET2 balances are used as an estimate of cross-border EMU capital flows.

ing crisis has a purely private origin (Gennaioli, N. et al 2014, Reinhart and Rogoff, 2008). A weak banking sector means that the smooth flow of credit to the economy is no longer ensured. Also, as in the EMU the rescuing of private banks is the responsibility of the sovereign state, private sector distress may increase expected sovereign fiscal deterioration: the need for capital injections becomes more likely to arise in the future. Second, sovereign creditworthiness also affects banking sector health, as it represents a credible guarantee for the financial system. The large amount of banking sector investment in government bonds strengthens this relationship. Especially for EMU countries this cross-dependence is significant. Rough figures show that whereas domestic bank holdings of government debt in countries like the US and the UK is between 5% and 10%, within the EMU these figures range between 10% and 30% (Pisani-Ferry, J. 2012). Therefore, weakness in either sector can give rise to a vicious circle of uncertainty and distress with highly damaging consequences for the economy (Caruana, J. and Avdjiev, S., 2012). The banking crisis that emerged in the Eurozone after the financial breakdown in 2007 was further intensified in the periphery by the sudden stop of capital and drying up of interbank loans[3], cross-border interbank loans in particular. Summarizing: the sudden stop in the periphery led to worsened sovereign health through worsened financial health of private banks.

Lack of monetary policy tools: A channel most specific for a monetary union is the lack of country-specific monetary policy tools. This includes a domestic central bank with control over the money supply, and a lender of last resort for the government. I will illustrate this with a counterexample of a stand alone country facing the threat of a sudden stop. When this happens, the presence of a central bank with control over its national currency may signal a credible guarantee that the government will be able to commit to its short term liabilities issued in domestic currency, even in the case it is temporarily no longer able to roll over its debt. This credibility comes from two different mechanisms which are present in a stand alone country; the ability to expand money supply as an economic stabilizer, and the central bank providing a financial backstop for the government. Expanding money supply may improve the domestic economy, and thereby income and credit supply for the government. When this is not sufficient, the lender of last resort role of the central bank can be a credible signal to investors that short term liabilities will be met. In the case of severe liquidity stress in the financial sector, a central bank can fill this gap by guaranteeing the purchase of sovereign bonds. This financial backstop that the domestic central bank can offer in case the government runs out of money is taken into account in evaluating governments? creditworthiness, and is therefore priced by financial markets (Pisani-Ferry, J. 2012). A good example of a successful credible backstop is the US Fed. It's goal is "to maintain relatively stable prices and yields for government securities" (Woodford 2009), and during the crisis the US government bond yields have remained low despite large deficits and debt. The ECB in contrast has no clear mandate that could justify intervention to prevent turmoil on the sovereign bond market. Even though the ECB can buy government bonds on the secondary market, this could (especially

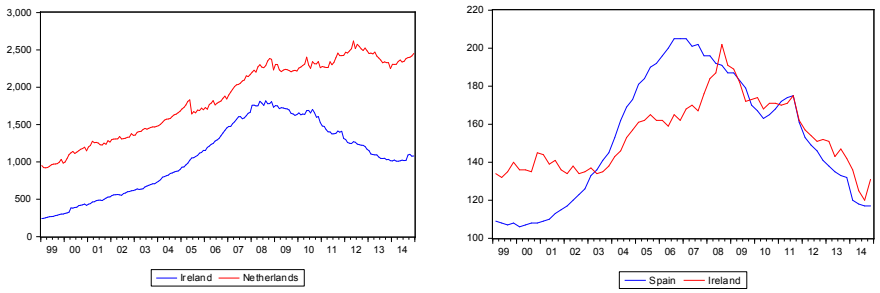
[3]Where interbank money flows were often settled between banks before the crisis through interbank loans, concerns on private banking sector health caused financial institutions to be unwilling to lend amongst each other.

before mid-2012) not be done for other reasons than the monetary transmission, and was not perceived as a credible or sufficient backstop. This means that -all else equal- in the case of a large capital outflow, a stand alone country like the US will have a higher (perceived) creditworthiness than EMU countries, resulting in a larger upward pressure on bond yields in EMU countries than non-EMU countries.

Deleveraging in a monetary union: During non-crisis periods, banks have a number of options to settle (cross-border) capital outflows and deal with the corresponding reserve loss. It can attract new deposits to take the place of the previous one, borrow in the interbank market, go to the central bank for funding or sell assets. Before the Euro-crisis, international flows of money and capital were often settled in the interbank market. The ECB and the national central banks had no specific role in this kind of transactions, which were simply cross-border capital account transactions (Cecchetti et al, 2012). But with the drying-up of interbank loans within the Euro-area (Iyer, R. et al, 2013) this became increasingly difficult. As it is also difficult for a financial institution to attract new deposits during a sudden stop, only two options remain: borrowing from the central bank, or shrinking the balance sheets. The ECB acted on this situation with fixed-rate full-allotment refinancing operations, which increased the possibilities for private institutions to borrow from the central bank, the only limit being the available collateral. However, to the extent that banks choose to reduce the size of their balance sheets in order to deleverage and to deal with the large scale capital outflows, the country experiencing the sudden stop will face amplified credit rationing (see figure 1a). On average, the peripheral area in our sample saw a balance sheet size decrease of 5% since the crisis, while the core area saw an increase of 6,3%. For Ireland this decrease has been nearly 50% (ECB). An outflow of market funding from the peripheral banks (see figure 1b) forced banks to either increase household deposits (stable funding) or decrease loans (credit rationing)(Van den End (2013). The difficulties to obtain household deposits forced banks to decrease credit to borrowers.

The banking sector in a stand alone country with a floating exchange rate is less likely to experience a liquidity crisis as a result of a sudden stop, because adjustment will occur through a depreciation of the currency. The proceeds from asset sales cannot be invested abroad without converting the currency. When nominal interest rates are acceptably high and banks acceptably solvable, this means the depreciated currency may end up back in the banking system. Therefore capital outflow will not necessarily result in a decrease in bank funding (Kopf, 2011). This will keep the economy and the government provided with credit. In the extreme case of a bank run there is always still the central bank, to act as a lender of last resort (Hargreaves, D. and Watson, E. 2011). In short, compared to a stand-alone country, cross-border capital flows have a larger impact on bank deposits in an EMU-country. As adjustments run through forced changes in volume -such as bank deleveraging or debt defaults- instead of external prices, there is a larger need for deleveraging in the EMU country. This results in credit rationing, limiting the supply of money to both the public and the private sector.

Figure 1

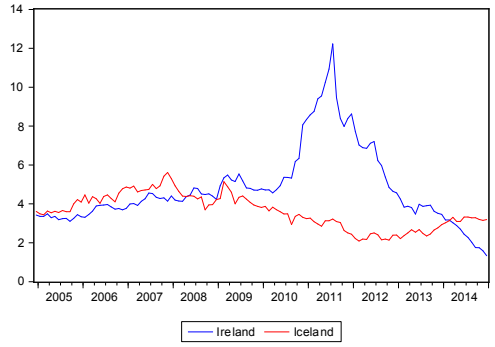


(a) Aggregate MFI balance sheet size (b) Loan to deposit ratio's in the periphery

Exchange rate mechanism: When an outflow of foreign capital and deposits occurs in a stand alone country, the capital outflow's worth of local currency will be sold on the market. This will lead to a depreciation, and thus automatically to a more competitive foreign trade position. This could increase domestic output and result in a natural demand for the currency and foreign money inflow. This counterbalancing effect of the exchange rate on international competitiveness means that when large capital outflows occur, the depreciation of the currency will boost the economy, improving the fiscal position of the sovereign[4]. One good example of this exchange rate mechanism at work is Iceland during the credit crunch in 2008. The highly leveraged country experienced a sudden stop, in response to which the currency lost nearly half its' value (Worldbank), but sovereign bond yields were barely affected (see figure 2). Iceland's quick recovery after the sudden stop is often attributed to the large decrease in value of the Icelandic Krona (among others, Krugman, P.). The absence of the adjustment mechanism of exchange rates in a currency area means that due to the contraction of capital the country must regain competitiveness while experiencing volume rationing of money in their economy. To affect the real exchange rate, they must rely on internal devaluation, requiring significant deflation. With downward wage rigidity this inevitably leads to a painful process of large scale unemployment. Summarizing: contrary to a stand-alone country, a Euro-member must rely on internal devaluation during a capital outflow. This essentially means deflation, recession and unemployment, increasing both nominal debt (through worsening fiscal positions) and real debt (through deflation).

[4]There are two important assumptions underlying this statement. First: the stand-alone country issues debt in it's own currency, and therefore does not experience an increase in real debt due to the depreciating currency (especially for developing economies this is often not the case). Second: the currency area of a currency should approximately be equal to the country. When a currency is widely accepted in many countries (such as the Dollar), the currency will not necessarily depreciate with a capital outflow, as the currency does not necessarily have to be sold on the market.

Figure 2: 10 years sovereign bond yields of Iceland and Ireland.



Self fulfilling prophecies: Assuming some part of this vulnerability of monetary union countries with respect to capital in- and outflow is known by investors, I expect some degree of a self fulfilling prophecy. When investors know the amplified effects of a capital outflow on their investments and deposits, they are likely to avoid this risk by retracting their stakes. This causes (or at least worsens) the capital outflow they feared in the first place.

To conclude, capital flows and sovereign bond yields might reinforce each other, causing countries to be driven either into a good or a bad equilibrium. This paper only focuses on the effects of capital flows on sovereign spreads[5]. This direction of causality is also shown empirically[6].

3 Model

The hypothesis to be tested in empirical analysis is: Large cross-border capital flows have contributed to sovereign bond yield divergence in the EMU. To test this hypothesis I estimate both a linear and a non-linear model with OLS. As some variables are trend-stationary, a time trend is included in the model. Also, country fixed effects are included. The basic linear model thus takes the following form:

$$ytm_j = \alpha_{(0,k)} + \alpha_{(1,k)}t + \sum_{i=2}^{n} \beta_{(i,k)} X_{ij} + \beta_{(n+1,k)} t2_j + \epsilon_j$$

j takes values $(1, .., 14)$ and represents individual countries, k takes values $(1, 2, 3)$, indicating the group of countries; non-EMU (Canada, Sweden, Switzerland, The United Kingdom, The United States), core-EMU (Austria, France, Finland, Germany, The Netherlands) and periphery-EMU (Italy, Ireland, Portugal, Spain)[7]. Parameters will be estimated for these groups individually, and

[5] This possibly produces an endogeneity problem in empirical analysis due to simultaneity.
[6] See appendix 8.2
[7] Greece is deliberately left out of the periphery sample, despite its extreme increase in sovereign bond yields. Due to the fiscal issues that were already present in Greece before the crisis, it is doubtful whether the reaction of financial markets to events in Greece as being

country-specific effects are allowed. The dependent variable ytm represents sovereign bond yields, X control variables, and $t2$ an estimate for capital flows. The control variables include indicators based on previous empirical studies concerning sovereign bond pricing (such as Arslanalp and Poghosyan, 2014; Baldacci and Kumar, 2010; De Haan et al, 2014), and reflect country-specific credit- and liquidity risk, and a short term rate which reflects monetary policy. Even though each country is assumed to be a price-taker on the sovereign bond market, governments do have to some extent control over their effective costs of borrowing, which relates to their national debt, inflation and economic growth (Woglom, 1991). These fundamentals are determining factors for a country's solvency and liquidity, and form a theoretical basis for sovereign bond pricing.

In the non-linear specification I use a dummy variable for the crisis-period, splitting the data set into three subsets. One period of financial integration within the EMU and convergence of sovereign spreads, next a period where capital was pulled back from the periphery to the core and divergence of sovereign spreads, and finally the period after mid-2012 when financial markets seemed to calm down and fundamentals started to improve. This dummy will be interacted with all explanatory variables, to allow for instability in the parameters over time; a semi regime-switching model.

$$ytm_j = \alpha_{(0,k)} + \alpha_{(1,k)}t + \sum_{i=2}^{n} \beta_{(i,k)} X_{ij} + \beta_{(n+1,k)} t2_j + \sum_{i=2}^{n} \gamma_{(i,k)} X_{ij} \times D^c + \gamma_{(n+1,k)} t2_j \times D^c + \epsilon_j$$

By estimating both the linear and the non-linear form, one can easily see the change in bond pricing during the crisis with respect to the pre-crisis level. To clarify, the non-interacted variables provide parameters for the entire sample, including the crisis period. The parameters that correspond to the interaction variables thus show a change in the behavior of financial markets towards certain fundamentals during the crisis. Beirne and Fratzscher (2013) refer to this change in the behavior of financial markets towards certain fundamentals as 'wake-up-call contagion'. Significant parameters for the interaction variables support the 'wake-up-call contagion' hypothesis.

In both the linear and the non-linear model, the coefficients corresponding to capital flows are once restricted to 0, and once unrestricted. This way the robustness of the fundamentals is implicitly tested, and the explanatory power of capital flows can be estimated.

4 Data and pre-testing

4.1 Data

To analyze whether reallocation of capital within the EMU has caused divergence of sovereign bond yields, I have constructed a panel data set consisting of 14 EMU- and non-EMU countries. The data ranges from 1999Q1 until and

representative for other periphery monetary union countries. However, I have performed some robustness tests including Greece. The results can be found in appendix 8.6

including 2014Q3, in a quarterly frequency. Summary statistics can be found in appendix 8.1.

- The variable to be explained is the nominal yield to maturity for 10 year sovereign bonds ytm_j. These bond yields are known to have diverged considerably within the Euro area; the periphery experienced large increases in their sovereign yields as a result of the global financial crisis, whereas the core countries benefited from low yields.

- The variable of interest is cross-border capital flows. As within-EMU capital flows are difficult to identify, I use TARGET2 balances as an approximation of capital and deposit flows between EMU member states. TARGET2 balances in itself should have no effect on economic variables, however, they are a good indicator of cross-border EMU capital flows during the crisis (S. Verkaart, DNB, 12-1-2015). TARGET2 is the payment system for intra-Euro-area payments, with the TARGET2 claims and liabilities of EMU-countries being the net of cross-border payments that are settled through this payment system. The balances reflect a capital account reversal (Buiter et al (2011), Mody and Bornhorst (2012), Bindseil and Konig (2012), and Cecioni and Ferrero (2012)), which means that the large balances have been led by the shifting of financing stocks within the Euro-area by private creditors, of which also commercial banks. The fear of redenomination and panic caused private creditors to seek protection by rearranging their books within the EMU; decreasing assets in some countries, while increasing them in others. This shifting in private capital flows is through TARGET2 compensated by central bank funding.

Control variables used in the regressions are:

- The debt to GDP ratio $debt_j$. Debt to GDP should have a positive effect on sovereign bond yields, as higher government debt increases solvency- and liquidity-risk, leading to higher risk premia. Some existing literature includes a non-linear form of debt in their analysis, as higher debt is associated with stronger reaction to changes in debt (Paesani et al, 2006; Conway and Orr, 2000).

- The short term rate used is the 3-months interest rate sr_j. This is a money-market rate, reflecting the monetary policy stance and including a risk premium. This rate thus co-moves with financial market risk indices to some extent. Rational expectations theory states that the long-term interest rate is a weighted average of short-term rates, where investing in one 10-year bond should yield the same return as rolling over ten 1-year bonds subsequently. Even though this equality does not fully hold empirically, the expected coefficient is positive and between 0 and 1.

- For the inflation rate i_j CPI is used.[8] Two opposing effects of inflation on sovereign bond yields exist. The first one is positive, as explained by the Fisher equation; $r^n = r^r + i$ (Fisher, 1930). When inflation rises, investors demand higher nominal interest rates to compensate for the decrease in

[8]To check for robustness, I also estimated the equations with core inflation, excluding energy prices. The results did not change.

real return. Theoretically, this relationship should be one to one, which would give us a coefficient of 1. Empirical results rarely show this one to one relationship, often attributed to the difficulties in estimating realized and expected inflation rates, together with irrational financial market behavior (Poghosyan, 2014). Also, in areas with high inflation, concerns about monetization of debt increase the inflation premiums embodied in the nominal rates. The second effect of inflation on bond yields is negative, as inflation decreases the real debt burden of the sovereign and thus reduces solvency risk (Keynesian economics, Aizenman and Marion, 2011). Finally, very high or very low inflation may generate macroeconomic uncertainty leading to higher country risk premia (Baldacci, Gupta, and Mati, 2010).

- In order to measure output growth I use the GDP growth rate Δgdp_j relative to the same quarter in the previous year[9]. The effect of GDP growth on sovereign yields can be either positive, negative or zero based on economic theory. A cyclical increase in the output growth is expected to decrease sovereign bond yields, as tax capacity of the country increases, and therefore credit and liquidity risk decreases (Cottarelli and Jaramillo, 2012). However, when the increase in output growth is due to a shift in potential output this would lead to re-optimization of the intertemporal budgets and be associated with increased interest rates (Euler equation).

I have not included any volatility or global risk measures such as credit-ratings or volatility indices. Those variables are not considered 'fundamentals', and are most likely not exogenous. The volatility index may simply be the market sentiments with respect to the crisis, which is what the model tries to explain. Second, the credit-ratings are to some extent based on movements in spreads; the endogeneity problem here is evident. Arghyrou and Kontonikas (2012) do include such financial indices, and find no significant results.

4.2 Pre-testing

4.2.1 Testing for stationarity

Upon first inspection of the variables, I found that results from unit root tests differed substantially between the non-EMU sample and the EMU sample. For this reason I elaborate in this section on reasons why this is the case, and the implications for empirical research. For non-EMU members nearly all of the variables are stationary in levels, whereas for EMU-countries many variables are non-stationary, both for the core and the periphery[10]. Summarizing: The inflation rate is non-stationary in each different panel set. In the Euro-area the debt ratio and sovereign bond yields also contain a unit root, and for the peripheral area specifically it was also not possible to reject the presence of a unit root in Δ GDP.

This large persistence in multiple economic variables can possibly be attributed to the Euro-zone as such, in the sense that large scale and long term

[9]To check for robustness, I also estimated the equations with GDP growth relative to the previous quarter. The results did not change.

[10]See appendix 8.3 Unit root tests

developments associated with the realization of the Euro induced permanent changes in the distribution of fundamental variables. The first decade of the Euro was characterized by convergence of several economic and financial indicators, reducing not only averages, but also variances[11]. The external shock of becoming a Euro-member thus caused a persistent change in the economy and the financial market. Second, the crisis has had a longer lasting effect on Euro countries than it had on non-Euro countries, again causing persistence in the fundamentals. The crisis in the EMU was not only a financial crisis, but also a sovereign debt crisis. This, combined with fiscal adjustment programs, led to many EMU countries experiencing prolonged periods of recession. In our short sample data this may show up as non-stationarity in GDP growth, bond yields, inflation and government debt. Existing literature generally implicitly rejects the possibility of truly non-stationary economic variables, as infinite variances are implausible.

The non-stationarity of EMU variables gives some valuable insights in the evolution both bond yields and fundamentals in the monetary union. However, it leads to some problems concerning estimation of the model. My results in the next section are two-fold. First, I investigate the role of capital flows on sovereign bond yields with a standard model in levels, as it is done in nearly all economic research on the topic. In doing so I ignore the results from the unit root tests, and assume that the variables are not truly non-stationary. To test if those non-stationary variables produce spurious regression results, I test for a unit root in the residuals. If the residuals are stationary, the results may reflect a long-run relationship between the variables and give us consistent estimates. I use a standard unit root test, but adjusted critical values by MacKinnon. For any sample size T, the critical value is calculated as $\beta_\infty + \frac{\beta_1}{T} + \frac{\beta_2}{T^2}$, where all β_i are given by MacKinnon (1994) for different numbers of regressors in the equation used. The results of these tests are shown in the appendix, and suggest that there exits a cointegrated relationship and the results may not be spurious.

Second, to be certain of the unbiasedness of the results, I also estimate the model in first differences. The presence of a unit root is ruled out for all variables, irrespective of the test/specification used. Also the existence of co-integration is further explored which can be added as an error correction term for deviation from the long run relationship. As the first difference models only exploit short run dynamics between the variables, I try to add a long run relationship between variables in the form of an error correction term. This error correction term is constructed as the stationary linear combination of several non-stationary variables. Due to the need for I(1) variables to estimate the co-integrating relationship, I am only able to do so for the EMU countries.

The final model will look as follows:

$$\Delta ytm_j = \alpha_{(0,k)} + \sum_{i=2}^{n} \beta_{(i,k)} \Delta X_{ij} + \beta_{(n+1,k)} \Delta t2_j + \sum_{i=2}^{n} \gamma_{(i,k)} \Delta X_{ij} \times D^c + \gamma_{(n+1,k)} \Delta t2_j \times D^c + \beta_{(n+2,k)} ECM + \epsilon_j$$

[11] In our sample spreads increased from max 30 basis points between 1999 and 2007 to 1130 basis points between 2007 and 2014. Variances increased from 0.4 in the core and 0.7 in the periphery to 0.9 in the core and 3.9 in the periphery.

Again the coefficient $\beta_{(n+1,k)}$ and $\gamma_{(n+1,k)}$ are for each model once restricted to 0, and once unrestricted.

4.2.2 The debt-yield relationship

For a proper understanding of the results in section 4, I discuss the relationship between sovereign debt and sovereign yields in this section. The theoretical relationship between debt to GDP and sovereign bond yields of a country is positive. Some discussion exists on the form of this relationship (linear or non-linear), but there is no theoretical basis for a negative causal effect between sovereign bond yields and debt to GDP in either direction. However, when looking at figure 3, one does observe a negative relationship in many cases. From a theoretical perspective I reject the possibility of a truly negative causal relationship between debt to GDP and sovereign bond yields, which means some exogenous explanation must exist for this phenomenon. Below I have chosen two representative countries from each subgroup; non-EMU, core-EMU and periphery-EMU.

The relationship between debt and yields in non-EMU countries is ambiguous. For Canada I observe the expected pattern, where bond yields increase with the debt level. For the United States however, yields decrease in increasing debt. This may be due to large scale quantitative easing in the United States or investors seeking safe havens. Also the absence of a positive relationship may to some extent be due to the non-linear behaviour of financial markets to fundamentals: as long as fundamentals stay within certain bounds, financial markets do not take them into account in bond pricing. Only when fundamentals exceed some risk-barrier investors start to reassess their portfolios (Paesani et al, 2006; Conway and Orr, 2000). The debt-levels in the non-EMU sample countries may be interpreted by investors as not alarming.

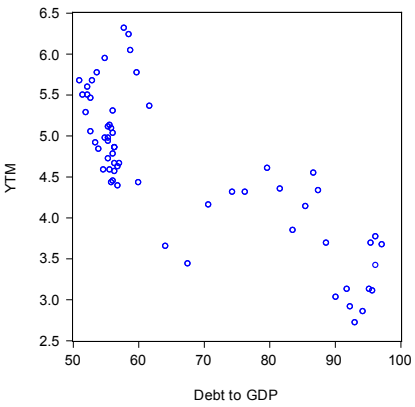
In the core EMU countries, the graphs show a consistent pattern of negative relationships between debt and bond yields. We know that the higher debt levels occurred during and after the crisis.[12] This may indicate a reallocation of investment within the Euro-zone, in the direction of the core: a within-EMU capital flight to safe havens. Also, despite the increase in debt levels, they have still not reached concerning levels[13]. Again, the non-linear behavior of financial markets to sovereign debt may be a reason for the absence of a positive relationship.

Finally, in the periphery I observe the expected positive relationship until around 2012. This relationship seems in some cases exponential (for example Portugal). After mid-2012 the graphs show a sharp negative relationship between debt and bond yields for all peripheral countries included in the sample. Increased confidence as a results of the ECB's OMT announcements may be one of the reasons for this decline in bond yields despite increasing debt.

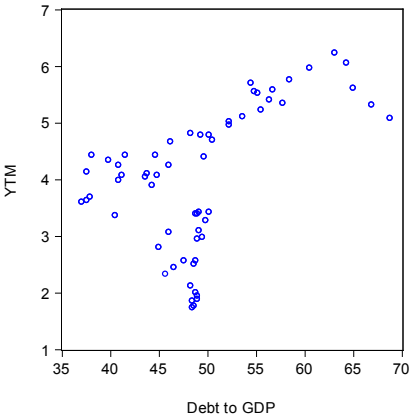
[12] For the countries in the sample debt has nearly monotonically increased since the crisis

[13] The pre-crisis debt to GDP levels of core-EMU countries was contained within 26% and 60%. Post-crisis these have increased to between 48% and 85%. For the periphery the pre-crisis levels were between 31% and 96% of GDP, and post-crisis between 87% and 138%

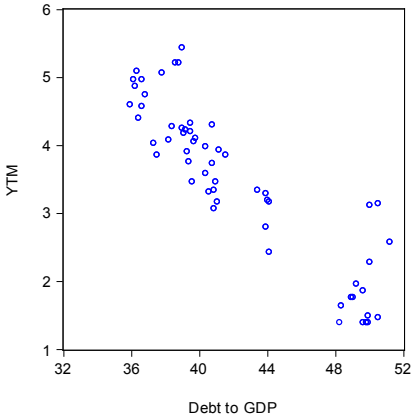
Figure 3: The debt yield relationship



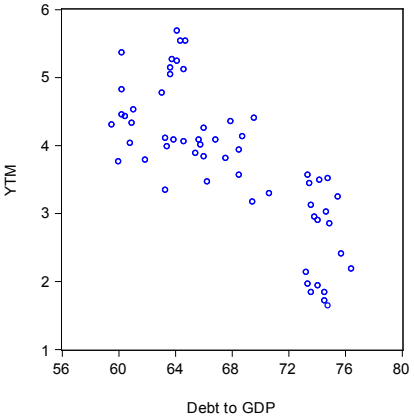
(a) United States



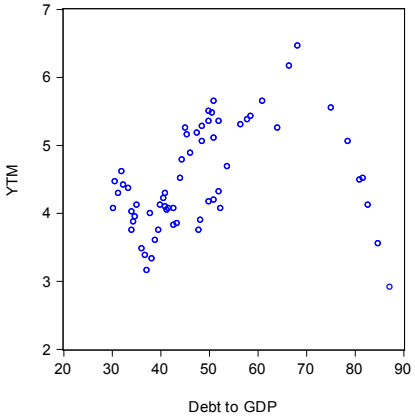
(b) Canada



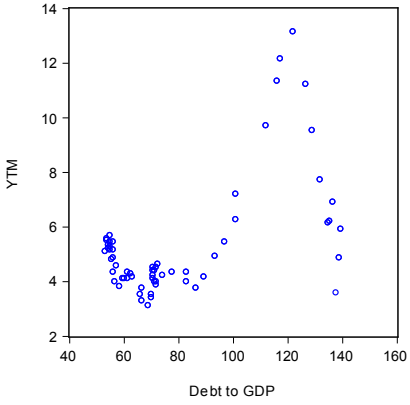
(c) Germany



(d) Austria



(e) Spain



(f) Portugal

These results are compatible with existing literature; earlier research showed a non-linear relationship between bond yields and debt, which appears to be stronger for countries or periods with higher debt (Paesani et al, 2006). Also, a crisis may make investors more sensitive to fundamentals in the form of a 'wake up call' (Giordano et al, 2013). For this reason, I will enter sovereign debt in a non-linear way into our yield equation. More specifically, I use $(\frac{1}{100})(\frac{debt}{GDP})^2$. This way the variable is squared to allow exponential behavior towards debt. To maintain the correct sign when taking the first difference I use $\frac{\Delta debt}{GDP} \times |\frac{\Delta debt}{GDP}|$.

4.2.3 Unbiasedness and efficiency

The models have been adjusted for the residuals to satisfy all necessary assumptions; $\epsilon \sim E[\epsilon] = 0, E[\epsilon^2] = \sigma^2 I$. In the periphery sample a White period covariance matrix is applied[14]. Also, in all samples I found serial correlation. To account for this I have included lags dependent variable.

5 Results

5.1 Models in levels

I first analyze the models in levels, for several reasons. First of all, despite the non-stationarity of many variables in the models, estimation in levels still prevails in the existing literature on sovereign bond yields. To make a better comparison with those estimations I include the levels models in the output. Second, since the residual terms of the models are stationary using MacKinnon adjusted critical values, I have some reason to believe that the results are consistent. The linear combination of the variables is stationary, indicating cointegration. Finally, there are some variables of which I believe not the change but the level determines sovereign bond pricing. For example, changes in government debt and TARGET2 balances are not expected to have much effect when their absolute levels are low, but are expected to have an effect when they are high. For interpretation purposes it makes more sense to use a model in levels than a model in first differences. The results of these regressions are shown in table 1 and table 2.

The most important result to draw from the levels models is that a very large and significant result is found with respect to our variable of interest: TARGET2. I thus find some supporting evidence for the positive (negative) effects of capital inflow (outflow) on sovereign bond yields. In economic terms: on average an aggregated capital outflow of 100% of GDP in the periphery results in an approximately higher yield of 90 basis points. In the core the effect of an aggregated capital inflow of 100% of GDP results approximately in lower yields of 40 basis points. In the samples used, the maximum of aggregated capital outflow amounted to about 3.3 times GDP for Ireland, and the maximum of aggregated capital inflow amounted to about 1 times GDP for Germany. From our levels models I thus find that capital flows have diverged bond yields by up to 350 basis points.

[14] As heteroskedasticity serial correlation tests for panel data are not standard in the Eviews package, self specified heteroskedasticity tests for all samples can be found in appendix 7.5

Table 1: Regressions in levels, no crisis interaction dummies

	Core-EMU	Core-EMU T2	Periphery-EMU	Periphery-EMU T2	Non-EMU
ytm_{-1}	1.0675***	1.0113***	1.4686***	1.3973***	1.0781***
ytm_{-2}	-0.4808***	-0.4457***	-0.5747***	-0.5261***	-0.3510***
ytm_{-3}	0.1614***	0.1478**			
c	5.3215***	5.2508***	4.5251***	4.9246***	5.3946***
	(0.3036)	(0.2787)	(0.5201)	(0.4336)	(0.2646)
$trend$	-0.0429***	-0.0396***	-0.0089***	-0.0231***	-0.0467***
	(0.0045)	(0.0041)	(0.0022)	(0.0026)	(0.0036)
ΔGDP	0.0006	0.0011	0.0045**	0.0041**	0.0099**
	(0.0032)	(0.0032)	(0.0018)	(0.0019)	(0.0045)
$inflation$	0.0701**	0.0750**	0.0857	0.1085**	0.1024***
	(0.0355)	(0.0353)	(0.0527)	(0.0420)	(0.0251)
$shortrate$	0.2103***	0.2001***	0.0367	0.0398	0.1577***
	(0.0404)	(0.0391)	(0.0570)	(0.0453)	(0.0352)
$debt$	-0.0010	-0.0033	0.0059	0.0046	0.0055*
	(0.0060)	(0.0059)	(0.0052)	(0.0053)	(0.0029)
$TARGET2$		-0.4507***		-0.9286***	
		(0.1634)		(0.1471)	
SE of regr.	0.2375	0.2351	0.4277	0.4077	0.2425
R^2	0.9500	0.9511	0.9177	0.9256	0.9680

N=298, 244, 305, T=62. Cross-section fixed effects
***, **, * indicate significance at the 1%, 5% and 10% level respectively.

Table 2: Regressions in levels, with crisis interaction dummies

	Core-EMU	Core-EMU TARGET2	Periphery-EMU	Periphery-EMU TARGET2	Non-EMU
ytm_{-1}	0.9425***	0.8982***	1.4853***	1.3874***	1.0880***
ytm_{-2}	-0.4553***	-0.4357***	-0.5837***	-0.5142***	-0.3759***
ytm_{-3}	0.0946	0.0851			
c	4.7840***	4.8251***	3.1380***	3.5792***	5.4146***
	(0.2255)	(0.2112)	(0.4115)	(0.3563)	(0.2683)
$trend$	-0.0391***	-0.0375***	0.0053	-0.0119**	-0.0467***
	(0.0028)	(0.0026)	(0.0042)	(0.0057)	(0.0043)
ΔGDP	-0.0013	-0.0016	0.0022***	0.0018**	0.0076**
	(0.0044)	(0.0045)	(0.0007)	(0.0007)	(0.0030)
$inflation$	0.0589*	0.0649*	0.1525***	0.1729***	0.1449***
	(0.0340)	(0.0348)	(0.0245)	(0.0333)	(0.0099)
$shortrate$	0.3176***	0.2958***	0.2262**	0.2301***	0.1383***
	(0.0331)	(0.0327)	(0.0404)	(0.0248)	(0.0456)
$debt$	-0.0006	-0.0029	0.0045*	0.0057**	0.0039
	(0.0050)	(0.0048)	(0.0027)	(0.0025)	(0.0031)
$TARGET2$		-0.3649***		-0.8346***	
		(0.1312)		(0.3109)	
$GDP{*}D^c$	0.0095	0.0106*	0.0208	0.0196	0.0047
	(0.0063)	(0.0063)	(0.0174)	(0.0210)	(0.0042)
$inflation{*}D^c$	-0.1592***	-0.1336**	-0.2880***	-0.2305***	-0.1342***
	(0.0515)	(0.0588)	(0.0540)	(0.0431)	(0.0403)
$shortrate{*}D^c$	0.2569***	0.2614***	0.4214***	0.4401***	0.0048
	(0.0791)	(0.0785)	(0.0940)	(0.0912)	(0.0659)
$debt{*}D^c$	0.0109***	0.0096***	0.0046***	0.0028	0.0060***
	(0.0028)	(0.0029)	(0.0007)	(0.0027)	(0.0009)
$TARGET2{*}D^c$		-0.0345		-0.1263	
		(0.1312)		(0.1738)	
SE of regr.	0.2222	0.2192	0.4120	0.3917	0.2395
R^2	0.9568	0.9583	0.9249	0.9328	0.9692

N=298, 244, 305, T=62. Cross-section fixed effects
***, **, * indicate significance at the 1%, 5% and 10% level respectively.
The top results are regressed over the entire sample period. The crisis interactions only generate values during the crisis-period (2009q1-2012q2) on top of the existing effect.

Furthermore, the coefficients of the lagged dependent variables is consistent with what was expected from the unit root tests. For the periphery the joint coefficient is close to one, while it is smaller for both the core- and the non-EMU countries. For debt some kind of wake-up-call effect is observed, where the reaction of financial markets to debt strengthens during the crisis. This is the case for each sample. Output growth has very small effects. The inflation rate has an intuitive effect, when inflation increases, investors demand higher nominal yields to compensate for their decline in real yield. During the crisis this effect reduces to around 0. The coefficient for the short rate is positive as expected, which remains unchanged for non-EMU countries during the crisis period. In EMU countries however, the responsiveness of bond yields to short rates increased during the crisis.

5.2 First difference and error-correction models

I have estimated the same models also in first differences (see table 3 and table 4). The variables used in the first difference models are all stationary, so in essence I can see whether the results from the levels specifications are robust after eliminating the possibility of spurious relations.

Overall I have again found supporting evidence of the importance of capital flows in explaining the divergence of government bond yields in the EMU. Our proxy variable TARGET2 has the expected sign, and especially in the periphery adds a lot of explanatory power to the models. The proportion of variance explained in the periphery models including TARGET2 is around 15% higher than the models without TARGET2. Translating the size of the coefficient into more economic terms, on average a 100% of GDP capital outflow results in an approximate increase in yields of 90 basis points in the periphery. In the core a 100% of GDP capital inflow results in an approximate decrease in yields of 80 basis points. This means that capital flows have caused divergence of bond spreads by up to 370 basis points during the crisis. The effects of capital flows found in the models in levels appear to be robust when estimating in first differences.

Furthermore, for the non-EMU countries the results are for most variables as expected. The effects of an increase in output on the bond yields are only visible during the crisis. The effect is small and negative, pointing to cyclical movements in the economy. The inflation rate also has an intuitive effect: when inflation increases, investors demand higher nominal yields to compensate for their decline in real yield. During the crisis this effect weakens, but remains slightly positive. The coefficient for the short rate is positive, as expected, and does not change during the crisis. Debt is not significant at all. This is not very surprising. For all countries in the sample, debt has been contained within 95% of GDP for the United States and the UK, and even lower for the remainder of the sample (below 50% during the crisis). These debt levels are not very alarming, and may have been too low for investors to act.

For the core-EMU countries, no results are observed for output growth and similar results for inflation as observed for the non-EMU area. Again, the inflation rate positively affects bond yields, while during the crisis this effect weakens

to around 0. There is a significant positive effect of changes in the short rate to bond yields. Also this effect weakens during the crisis, but remains positive. This decrease in the effect can be explained by the risk premium that the short rate contains. In this period of financial turmoil, an increase in general risk premiums can pressure down sovereign bond yields of countries, which are perceived to be safe. There is no effect of a change in debt on the bond yields, both before and during the crisis. This can be explained by the low absolute levels of debt over the entire sample period (so the absence of a 'wake up call' to investors) and by the safe haven status in times of financial distress. There is a large and significant effect of capital flows on the sovereign bond yields. Large inflows of capital lead to decreasing yields. This effect only occurs during the crisis.

In the periphery changes in output growth have no effect at all. There is a notably large coefficient for the lagged dependent variables compared to the other two areas. The short rate is significantly positive in the non-crisis period, but in this cases decreases to being negative during the crisis. I suspect this indicates some disturbance of the monetary transmission. The ECB decreasing the money market rate did not translate to lower yields. Inflation rates have the expected positive effect, and do not change much during the crisis. Debt has the expected effect during the crisis, but no effect before and after the crisis. Some explanations for this can be found in section 3.1.2. The non-crisis periods in the periphery have been characterized first by low yields despite a wide variety of debt levels. Second, after mid-2012 yields have started to decline as a result of increased confidence and the OMT announcement. One thus observes declining yields while debt is still rising in many cases. Also, a very strong effect of capital flows on sovereign bond yields is observed. The variable is significant for the periphery over the entire sample period, and the size of the effect does not change during the crisis (as the interaction term with the crisis-dummy is not significant).

The error correction term is only added for the periphery area, since I was not able to find a cointegrating relationship in the other areas (non-EMU does not have sufficient non-stationary variables, and for the core-EMU these variables were not significantly cointegrated). This term specifically equals : $(ytm_{(-1)} - 0.0239 * debt_{(-1)} - 1.2617 * i_{(-1)} - 0.0740)$ This shows a long-run positive relationship between sovereign bond yields, the sovereign debt level and inflation. The lack of this relationship in the core again points to non-linear behavior to debt (wake-up call contagion) or safe haven flight, such that even in the long run there seems to be no relationship between the debt levels and bond yields. Excluding the ECM parameter does not alter our results for other parameters. Only our explanatory power improves.

The largest differences between the levels and the first difference models are: the short rate during the crisis period, and the significance of debt during the crisis period. The relationships obtained for those variables in the levels models may thus be spurious.

Table 3: Regressions in first differences, no crisis interaction dummies

	Core-EMU	Core-EMU T2	Periphery-EMU	Periphery-EMU T2	Non-EMU
Δytm_{-1}	0.1532***	0.0917***	0.5635***	0.4628***	0.2326***
Δytm_{-2}	-0.3615***	-0.3604***			-0.2798***
Δytm_{-3}					
Δytm_{-4}			-0.1413**	-0.2163***	
Δytm_{-5}	-0.2255***	-0.2297***			-0.1948***
c	-0.0478***	-0.0496***	-0.0491	-0.0498	-0.0564***
	(0.0127)	(0.0123)	(0.0514)	(0.0383)	(0.0188)
ΔGDP	-0.0008	0.0012	0.0030	0.0019	0.0050
	(0.0046)	(0.0046)	(0.0024)	(0.0017)	(0.0062)
$\Delta inflation$	0.0517	0.0528	0.1378**	0.1671***	0.0950***
	(0.0341)	(0.0338)	(0.0629)	(0.0508)	(0.0245)
$\Delta shortrate$	0.2071***	0.1847***	0.0305	0.0369	0.1149***
	(0.0341)	(0.0440)	(0.0516)	(0.0416)	(0.0418)
$\Delta debt$	-0.0007	-0.0008	0.0008	0.0005	0.0029
	(0.0012)	(0.0012)	(0.0015)	(0.0016)	(0.0030)
$\Delta TARGET2$		-0.5388***		-0.9270***	
		(0.1939)		(0.1970)	
ECM			-0.0628**	-0.0387**	
			(0.0285)	(0.0145)	
SE of regr.	0.2382	0.2355	0.4383	0.4187	0.2563
R^2	0.2667	0.2859	0.3455	0.4052	0.2234

N=298, 244, 305, T=61. Cross-section fixed effects
***, **, * indicate significance at the 1%, 5% and 10% level respectively.

Table 4: Regressions in first differences, no crisis interaction dummies

	Core-EMU	Core-EMU T2	Periphery-EMU	Periphery-EMU T2	Non-EMU
Δytm_{-1}	0.1856***	0.1205**	0.6097***	0.4785***	0.2298***
Δytm_{-2}	-0.3564***	-0.3387***			-0.2573***
Δytm_{-3}					
Δytm_{-4}			-0.1368***	-0.2305***	
Δytm_{-5}	-0.3153***	-0.3353***			-0.2194***
c	-0.0536***	-0.0443***	-0.0354	-0.0421	-0.0574***
	(0.0120)	(0.0127)	(0.0074)	(0.0097)	(0.0190)
ΔGDP	0.0012	-0.0006	-0.0021*	-0.0028***	0.0083
	(0.0051)	(0.0052)	(0.0013)	(0.0009)	(0.0066)
$\Delta inflation$	0.1017***	0.0953**	0.1940***	0.1965***	0.1300***
	(0.0376)	(0.0375)	(0.0324)	(0.0383)	(0.0293)
$\Delta shortrate$	0.4315***	0.4339***	0.3155***	0.3494***	0.1223**
	(0.0604)	(0.0593)	(0.0089)	(0.0334)	(0.0498)
$\Delta debt$	0.0006	0.0006	-0.0082**	-0.0068*	0.0038
	(0.0012)	(0.0012)	(0.0042)	(0.0039)	(0.0040)
$\Delta TARGET2$		-0.1120		-0.8606***	
		(0.2853)		(0.0861)	
ECM			-0.0749*	-0.0394	
			(0.0366)	(0.0410)	
$\Delta GDP*D^c$	0.0000	0.0020	0.0018	0.0163*	-0.0163*
	(0.0076)	(0.0076)	(0.0147)	(0.0093)	(0.0094)
$\Delta inflation*D^c$	-0.1660**	-0.1350*	-0.1625*	-0.0707	-0.1128**
	(0.0716)	(0.0698)	(0.0978)	(0.0879)	(0.0565)
$\Delta shortrate*D^c$	-0.2861***	-0.3216***	-0.3587**	-0.4698***	0.0749
	(0.0781)	(0.0766)	(0.0442)	(0.0581)	(0.0801)
$\Delta debt*D^c$	-0.0004	0.0003	0.0095*	0.0078	0.0018
	(0.0032)	(0.0031)	(0.0054)	(0.0051)	(0.0060)
$\Delta TARGET2*D^c$		-0.8010**		-0.0030	
		(0.3585)		(0.1327)	
SE of regr.	0.2217	0.2162	0.4187	0.4033	0.2538
R^2	0.3748	0.4100	0.4132	0.4608	0.2495

N=298, 244, 305, T=61. Cross-section fixed effects
***, **, * indicate significance at the 1%, 5% and 10% level respectively.

5.3 Robustness and extensions

I have applied several robustness checks to test the results. I ran the same regressions, but with core inflation instead of inflation, with GDP growth relative to the previous quarter instead of relative to the same quarter in the previous year, and with fiscal deficit instead of the first difference of debt. Also I have tried including the real exchange rate as an extra explanatory fundamental. None of these slight changes altered the results significantly. Also, I ran regressions with Greece included in the periphery-cluster, the results can be found in appendix 8.6. Greece was left out of the sample due to doubts about Greece being representative for other periphery monetary union countries. I do find some changes in the significance of the short rate (significant when Greece is left out of the sample, but only negatively significant during the crisis period when Greece is included). The significance of our variable of interest; TARGET2, remains unchanged and significant beyond the 1% level. Capital flows remain an important determinant of sovereign bond yields when Greece is included, in fact, the results tend to point to an even stronger relationship. The models have a worse explanatory power when Greece is included, most likely due to the large variance of the dependent variable ytm[15]. The standard error of regression is much larger when Greece is included: around 1 compared to around 0.4 without Greece.

6 Limitations

This research is one step towards a better understanding and knowledge of the role of capital mobility in the sovereign debt crisis. However, there are some limitations to the research and interpretation of the results. One issue is the measurement of capital flows, and our inability to split this in different types of capital and deposits. - For instance, the suppliers of capital may be private or public, but also the destination of this capital may be private or public. - This reduces the insight in the effects of different sorts of capital flows on bond yields, but also disables us from filtering out the disposal of sovereign bonds. By measuring the effects of capital flows through payments that are processed by the TARGET2 payment system, I inevitably include cross-border (but within EMU) payments, which are related to the sale and purchase of financial assets, such as government bonds. That is, for some part the effect of large capital flows on sovereign bond yields is much more basal than the structure laid out in section 2.2. As earlier research showed that the sudden stop in the periphery was much larger than the disposal of government bonds, I still carefully conclude that the capital flows within the EMU contributed to the divergence of yields. Another limitation is that part of the connection between capital flows and sovereign spreads remains anecdotal. The unique nature of the EMU makes it difficult to make accurate comparisons with historic events. More detailed research would be needed to quantify diverging pressures through different channels.

[15]The variance for ytm in the periphery is 2.1795 when Greece is excluded, and 11.0005 when Greece is included.

7 Conclusion

This paper contributes to the existing literature by adding one more driver of the large divergence of sovereign bond yields in the EMU: large cross-border capital flows. I found that before the crisis, financial integration caused large amounts of capital to flow from the core to the periphery, increasing the core's stake in the periphery, but also the capital dependence of the periphery to the core. This facilitated a large scale capital flight when the financial crisis hit the Eurozone. A causal relationship is found between the amount of capital outflow (inflow) and the increase (decrease) of sovereign bond yields. Possible channels through which this effect runs are: the sovereign fiscal position, the tight link between banking sector stress and sovereign stress, the lower creditworthiness of EMU countries due to the lack of a credible backstop, the liquidity crises due to the need for deleveraging, and internal devaluation because of the lack of an exchange rate mechanism. The size of this effect ranges up to about 370 basis points in sovereign spreads between the countries in our sample. On average an aggregated capital outflow of 100% of GDP in the periphery results in an approximately higher yield of 90 basis points. In the core the effect of an aggregated capital inflow of 100% of GDP results approximately in lower yields of 70 basis points.

This result is potentially very interesting for monetary policy makers. As the monetary transmission in the Eurozone is disturbed by disorder on the sovereign bond market it is of importance to keep sovereign bond yields contained within reasonable bounds. This paper emphasizes the need for policymakers to take into account large capital flows as drivers of sovereign bond yield divergence. Also for domestic policy makers it is relevant to be aware of the vulnerabilities of their sovereign debt. Their inability to control their own currency in combination with a large capital outflow has shown to be very harmful for the economy. Awareness of these effects of capital flows is a first step towards preventive policies. Further research would be needed to identify possible policy to minimize the risk of such a crisis happening again in the future.

8 Appendix

8.1 Summary statistics

Variable	Description		Mean	Variance	Source
YTM	Yield to maturity	non-EMU	3.7234	1.8078	Bloomberg
	10 years sovereign	core	3.7154	1.2221	
	bond spreads	periphery	4.7976	2.1795	
Debt	Central government	non-EMU	49.1730	348.2079	OECD
	debt as % of	core	52.7851	171.6336	
	GDP	periphery	73.2962	1062.0234	
ΔGDP	GDP growth rate	non-EMU	2.1328	8.4896	OECD
	over the same	core	1.5078	12.8418	
	quarter of last year	periphery	1.5631	26.0258	
$Inflation$	Inflation growth	non-EMU	1.6975	1.5063	OECD
	rate over the same	core	1.7862	0.8547	
	quarter of last year	periphery	2.3422	2.9108	
Shortrate	Short term	non-EMU	2.5058	3.4995	OECD
	interest rate	core	2.4105	2.2728	
		periphery	2.4105	2.2746	
$TARGET2$	Cumulative net				IFS
	payments through	core	0.0463	0.0956	
	T2 ,% of GDP	periphery	-0.4014	0.4724	
crisis	Dummy variable 1				
	for 2009Q1-2012Q2				
	0 elsewhere				

8.2 Causality

The results of the Granger causality test are in line with the hypothesis that the TARGET2 balances cause bond yield changes, and not the other way around.

Pairwise causality test, YTM and $TARGET2$

	P-value
Ho: $TARGET2$ does not homogeneously cause YTM	0.0639
Ho: YTM does not homogeneously cause $TARGET2$	0.2956

8.3 Unit root tests

8.3.1 Unit roots in the variables

The results of the LLC unit root tests are shown below. All variables are either stationary or I(1). The bold results are the results used, their selection based on the characteristics of the specific variables.

Levin, Lin and Chu unit root test, **non-EMU countries**, p-values

Ho: Panels contain unit roots Ha: Panels are stationary			
Panel means: Time trend:	Included Included	Included Not included	Not included Not included
YTM	**0.0049**	0.9250	0.0059
Debt to GDP	**0.0079**	0.0907	0.2494
ΔGDP	0.0000	**0.0000**	0.0000
$Inflation$	0.0590	**0.2219**	0.0039
Shortrate	**0.0130**	0.1741	0.0004

Levin, Lin and Chu unit root test, **EMU core countries**, p-values

Ho: Panels contain unit roots Ha: Panels are stationary			
Panel means: Time trend:	Included Included	Included Not included	Not included Not included
YTM	**0.0376**	0.4560	0.0066
Debt to GDP	**0.2021**	0.9831	0.9877
ΔGDP	0.0000	**0.0000**	0.0000
$Inflation$	0.9859	**0.7647**	0.0221
Shortrate	**0.0921**	0.3443	0.0008
$TARGET2$	0.2122	0.2217	**0.0531**

Levin, Lin and Chu unit root test, **EMU periphery countries**, p-values

Ho: Panels contain unit roots Ha: Panels are stationary			
Panel means: Time trend:	Included Included	Included Not included	Not included Not included
YTM	**0.7990**	0.4610	0.0439
Debt to GDP	**0.1590**	0.1875	0.8921
ΔGDP	**0.1566**	0.1586	0.0077
$Inflation$	0.2562	**0.3628**	0.0019
Shortrate	**0.0520**	0.4421	0.0063
$TARGET2$	0.3649	0.4213	**0.0458**

8.3.2 Unit roots in the residuals

Critical values are calculated using MacKinnon tables for unit root testing in residuals.

Levin, Lin and Chu unit root test, **Residuals**

Ho: Residuals contain unit roots
Ha: Residuals are stationary

	t-Stat	Critical Value	Obs	Variables
Core	-14.8406	-4.7739	298	5
Core T2	-14.7637	-5.0467	298	6
Core interaction	-14.5301	-5.7945	298	9
Core interaction T2	-14.7277	-6.2364	298	11
Periphery	-9.2224	-4.7858	248	5
Periphery T2	-8.8167	-5.0646	248	6
Periphery interaction	-10.3865	-5.8147	248	9
Periphery interaction T2	-10.8619	-6.2616	248	11

8.4 Correlations

Correlations core-EMU

	YTM	$DebtGDP$	ΔGDP	$Inflation$	$Shortrate$	$TARGET2$
YTM	1.0000					
$DebtGDP$	−0.2859	1.0000				
ΔGDP	0.1739	−0.0135	1.0000			
$Inflation$	0.1583	−0.0080	−0.0939	1.0000		
$Shortrate$	0.8356	−0.3734	0.0893	0.3764	1.0000	
$TARGET2$	−0.4414	−0.3212	−0.1207	0.0477	−0.3107	1.0000

Correlations periphery-EMU

	YTM	$DebtGDP$	ΔGDP	$Inflation$	$Shortrate$	$TARGET2$
YTM	1.0000					
$DebtGDP$	0.3282	1.0000				
ΔGDP	−0.1494	−0.2596	1.0000			
$Inflation$	0.1177	−0.3934	0.1552	1.0000		
$Shortrate$	−0.1065	−0.4992	0.1757	0.5843	1.0000	
$TARGET2$	−0.5844	−0.4519	0.1896	0.3387	0.5533	1.0000

Correlations non-EMU countries

	YTM	$DebtGDP$	ΔGDP	$Inflation$	$Shortrate$
YTM	1.0000				
$DebtGDP$	0.3024	1.0000			
ΔGDP	0.1716	0.0486	1.0000		
$Inflation$	0.4135	0.3898	−0.0842	1.0000	
$Shortrate$	0.7395	−0.0.653	0.0410	0.3829	1.0000

8.5 Heteroskedasticity tests

Test for heteroskedasticity: Self-specified Breusch-Pagan
Auxiliary regressions: $e_i^2 = \sum_i \beta_i x_{in} + \epsilon_i$

Model	Distribution $\chi^2(p-1)$	Test statistic $n \times R^2$	Critical value at 5%
Difference models			
Core	$\chi^2(5)$	2.7249	11.070
Core with TARGET2	$\chi^2(9)$	2.1275	16.919
Periphery	$\chi^2(6)$	31.5248	12.592
Periphery with TARGET2	$\chi^2(10)$	33.8672	18.307
Non-EMU	$\chi^2(5)$	0.9150	11.070
Level models			
Core	$\chi^2(6)$	5.4832	12.592
Core with TARGET2	$\chi^2(10)$	8.4036	18.307
Periphery	$\chi^2(6)$	38.0432	12.592
Periphery with TARGET2	$\chi^2(10)$	61.9256	18.307
Non-EMU	$\chi^2(6)$	9.3620	12.592

8.6 Break date models

As the equations for EMU sovereign bond yields contain multiple non-stationary variables, the model may pick up a spurious correlation. I considered multiple options to deal with this problem, one of which is a regime switching model. This makes sense given the obvious break date in the Euro-zone data.

$ytm_{(j,t)} = f(debt_{(j,t)}, i_{(j,t)}, \Delta gdp_{(j,t)}, sr_{(j,t)}, t2_{(j,t)})$
for t=(1999Q1-2008Q2, 2008Q3-2014Q3)

However, only ΔGDP is a stationary series when considering the pre- and post-crisis period separately. Other variables remain non-stationary, so I do not consider this an optimal option. The results of those regressions are found in the table below.

Breakdate Core- and Periphery-EMU

	Core-EMU	Core-EMU TARGET2	Periphery-EMU	Periphery-EMU TARGET2	Non-EMU
Δytm_{-1}	0.9482***	0.8811***	1.4711***	1.3759***	1.1455***
Δytm_{-2}	-0.3489***	-0.3022***	-0.5631***	-0.4912***	-0.2789***
Δytm_{-3}	-0.0548	-0.0629			
Pre- and post-crisis period					
c	4.7472***	4.7864***	3.4331***	3.8678***	5.0702***
	(0.1959)	(0.1882)	(1.1468)	(0.9350)	(0.4350)
trend	-0.0415***	-0.0402***	-0.0027	-0.0142	-0.0507***
	(0.0026)	(0.0025)	(0.0191)	(0.0157)	(0.0070)
ΔGDP	-0.0095*	-0.0093*	0.0024	0.0019	0.0042
	(0.0047)	(0.0048)	(0.0031)	(0.0031)	(0.0053)
Inflation	0.3128***	0.1302***	0.1654***	0.1744***	0.1185***
	(0.0346)	(0.0337)	(0.0564)	(0.0555)	(0.0295)
Shortrate	0.2940***	0.2834***	0.1793	0.1926*	0.2434***
	(0.0319)	(0.0323)	(0.1172)	(0.1099)	(0.0398)
Debt	0.0035	0.0010	0.0036	0.0047	0.0201***
	(0.0024)	(0.0027)	(0.0047)	(0.0041)	(0.0045)
TARGET2		-0.2933**		-0.8492***	
		(0.1237)		(0.2544)	
Crisis period					
c	12.1912***	9.9916***	-1.1052	0.0186	4.8229***
	(1.4007)	(1.4950)	(4.2537)	(4.3871)	(1.0625)
trend	-0.1386***	-0.0989***	0.0657	0.0378	-0.0463***
	(0.0203)	(0.0232)	(0.0608)	(0.0641)	(0.0160)
ΔGDP	0.0025	0.0046	0.0231**	0.0223**	0.0181**
	(0.0047)	(0.0048)	(0.0099)	(0.0100)	(0.0086)
Inflation	0.1400**	0.1140*	-0.1736**	-0.0930	0.0294
	(0.0687)	(0.0675)	(0.0880)	(0.0927)	(0.0421)
Shortrate	-0.7886***	-0.6649***	0.9238***	0.9304***	-0.1418
	(0.1488)	(0.1471)	(0.3381)	(0.3262)	(0.1110)
Debt	0.0101***	-0.0022	0.0076	0.0079*	0.0234***
	(0.0034)	(0.0052)	(0.0049)	(0.0044)	(0.0050)
TARGET2		-0.6112***		-0.9299***	
		(0.1908)		(0.1778)	
R^2	0.9564	0.9583	0.9248	0.9325	0.9670
SE of regression	0.2201	0.2161	0.4116	0.3916	0.2471

8.7 Robustness test including Greece

Determinants of bond yields with Greece included
Cross-section fixed effects

	Periphery-EMU	Periphery-EMU TARGET2	Periphery-EMU	Periphery-EMU TARGET2
$\Delta ytm_{-1})$	0.3714***	0.3020***	0.3100***	0.2594***
Δytm_{-4}	-0.3157***	-0.3941***	-0.3485***	-0.4220***
c	0.0353	0.0021	-0.0296	-0.0896
	(0.0706)	(0.0601)	(0.0685)	(0.0605)
ΔGDP	-0.0181	-0.0191*	-0.0092	-0.0036
	(0.0124)	(0.0115)	(0.0137)	(0.0128)
$\Delta inflation$	0.4176***	0.4556***	0.3023**	0.3575**
	(0.1155)	(0.1109)	(0.1429)	(0.1382)
$\Delta shortrate$	-0.0826	-0.0261	0.2779	0.2953
	(0.1766)	(0.1109)	(0.2407)	(0.2243)
$\Delta debt$	-0.0176	-0.0130	-0.0461	-0.0328
	(0.0168)	(0.0160)	(0.0414)	(0.0317)
$\Delta TARGET2$		-2.3911***		-1.1454
		(0.3913)		(0.7028)
ECM	-0.0170***	-0.0168***	-0.0170***	-0.0178***
	(0.0060)	(0.0052)	(0.0056)	(0.0049)
ΔGDP*crisis			-0.0850**	-0.1026***
			(0.0378)	(0.0346)
$\Delta inflation$*crisis			0.3619*	0.3029
			(0.2173)	(0.2034)
$\Delta shortrate$*crisis			-0.5904*	-0.4395
			(0.3542)	(0.3269)
$\Delta debt$*crisis			0.0358	0.0221
			(0.0385)	(0.0364)
$\Delta TARGET2$*crisis				-1.7781**
				(0.8094)
SE of regression	1.0629	1.0109	1.0507	0.9869
R^2	0.2732	0.3536	0.2996	0.3948

N=300, T=62
The top results are regressed over the entire sample period. The crisis interactions only generate values during the crisis-period (2009q1-2012q2) on top of the existing effect.

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