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Is there a Long-Term Relationship among European Sovereign Bond Yields?

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By

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Abstract

The integration of financial markets has been a recurring theme in academic and financial research. The majority of the literature has focused on equity markets. Literature on the integration of international bond markets is not as common, specifically regarding that of European bonds since the beginning of the common currency area.

This thesis will first estimate a fixed effects pooled model and then proceed to undertake panel unit root and cointegration tests to determine the degree of comovement of European sovereign bond yields. If this thesis determines that yields move together over time, the benefits of diversification in European government bond portfolios may be limited. The results will also have implications for monetary policy. If it is evident that economic shocks (e.g. inflationary shocks) are transmitted quickly from country to country, then it will complicate the task of monetary policy when it comes to pursuing an independent policy with respect to domestic monetary conditions in the presence of asymmetric economic shocks.

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Introduction

Over the past few decades, the global liberalization of financial markets has resulted in increased interdependence among international markets. A prime example of interdependence among international markets exists on the European continent. The European Monetary Union has played a huge role in the integration of Europe's capital and money markets. As a result of this integration, European government bond markets accounted for over 55% of all withstanding bonds in the Euro area in the years following the implementation of the monetary union (Pagano and Von Thadden 2004).

Recent years have seen the global financial crisis spawn a sovereign debt crisis within Europe. Since 2009, European government bond markets have been shaken, resulting in multiple rescue packages from the International Monetary Fund and a debate on everything from the best short-term response to the long-term stability and sustainability of the euro area (Arghyrou and Kontonikas 2011; and Andreas, 2014).

This thesis explores the long-term relationship among European sovereign bond yields in order to evaluate the benefits of diversification in a government bond portfolio and the complications for European monetary policy. The empirical analysis focuses on twelve countries, eleven of which currently use the euro as their national currency and a twelfth which has its own currency and monetary policy. Panel data from 12 countries are examined using stacked regressions, fixed effects models, and seemingly unrelated regressions. Finally, this thesis uses the Pedroni cointegration test to investigate the presence of long-run relationships among bond yields. Since the previous work related to this topic focuses on both different sets of countries and different time periods, this thesis presents a positive contribution to the extant literature by providing updated empirical tests and evidence.

The chapters of this thesis are structured as follows: The next chapter gives a brief history of the formation of the euro area. The third chapter continues with a discussion of the many economic and political institutions of Europe and the economic convergence of the European economies before and after the implementation of the common currency. Chapter four reviews the extant literature and past research regarding testing for long-term relationships among variables. The fifth chapter introduces the theoretical model and discusses the sample data. Chapter six discusses the empirical model and presents the estimates generated by the various models as well as various econometric tests. Finally, chapter seven presents the conclusions of this thesis.

A Brief History of the Euro Area

The European Monetary Union is one of the great economic experiments of our time. The EMU is arguably the most important development in the international financial markets since the Bretton-Woods system and the gold standard. In effect, the EMU has created the largest fully connected economy in the world in terms of nominal GDP, if the Eurozone is considered one economy. Before the implementation of this euro area, countries throughout Europe were subject to exchange rate risk; the common currency eliminated this key obstacle to efficient economic integration. Now, financial assets and claims can be traded swiftly at identical (or near identical) prices within the EMU member states. The history of the economic integration of the European continent can be traced back more than half a century.

The concept of the economic (and political) integration on the European continent was designed during an era when both World Wars were still fresh in the minds of all Europeans. In many ways, economic and political integration of Europe was a remarkable feat given the suffering Europe endured through the devastation of the three wars of the previous hundred years. Namely, the Franco-Prussian War, World War I, and World War II exposed the deep divides between European states. In particular, the fact that France and Germany could stand together so soon after WWII to unify Europe served as a historical achievement given that they had been bitter rivals and enemies for the past century. Nevertheless, Europe eventually succeeded in its endeavor to achieve unity.

The first move towards economic (and political) convergence came with the integration of the coal and steel industries in the early 1950s, an early effort to secure lasting peace on the continent (Moghadam 2014). Next, the treaty of Rome established the European Economic

Community and the European Atomic Energy Community in 1957. By 1969, the European Economic Community decided to make economic and monetary union a goal of European integration. A precursor to the European Monetary Union, The European Monetary System was created ten years later, based on fixed yet adjustable exchange rates. The exchange rates were based on a weighted average of the currencies of countries participating in the European Monetary System (with the exception of the United Kingdom who didn't participate in the exchange rate mechanism until 1990). The exchange rates were maintained by the Exchange Rate Mechanism (ERM) and most currency fluctuations stayed within 2.25% of the central rates. The Italian lira, the Portuguese escudo, the Spanish peseta, and the British pound sterling were all allowed to fluctuate by 6% in either a positive or negative direction.

On February 7, 1992, the signing of the Maastricht Treaty laid the foundations for European economic and political unity. Its three-stage process, which involved numerous setbacks and currency crises, involved various measures to bring about economic integration. The first stage dealt with eliminating restrictions on capital movements. The second stage established the European Monetary Institute (the precursor of the European Central Bank). Additionally, the second stage secured two main criteria for convergence: (1) a cap on the public deficit at 3% of GDP and (2) a limit on government debt at 60% of GDP. The third and final stage involved more convergence criteria including a cap on inflation rates (set at 1.5% above the inflation rate of the three countries with the lowest inflation) and a cap on the long-term nominal interest rate (equal to 2% above the average of the aforementioned three countries). The Maastricht Criteria, as they are known, aimed to bring about economic convergence and the introduction of a common currency. The new currency, the euro, was launched on January 1, 1999 and officially replaced the national currencies of the member states on January 1, 2002.

The Institutions of the European Union and the European Monetary Union

The European Union (EU) is a mainly political entity that comprises of 28 member countries with several candidate countries located primarily in Europe. The European Monetary Union (EMU) is an economic union that essentially coordinates economic policy-making among member states. Notably, all 28 EU member states are part of the single market framework which includes the free movement of goods, services, and capital. All members of the EU are also members of the EMU. The key caveat here is that many, but not all, member states have adopted the euro. This common currency is in circulation in 19 member states. The remaining 9 member states either have opt-out clauses (The United Kingdom and Denmark) or need to meet certain fiscal and/or monetary convergence requirements in order to join the common currency area, or Eurozone. The economic convergence policies of the EMU cover all states in the Eurozone and all states in the EU that are not in the common currency area.

The institutions of the European Union and the European Monetary Union are deeply intertwined. The EU is comprised of numerous institutions governing on the supranational level. There are several key institutions that make up the European Union: (1) the European Council consists of European heads of state who come together to set the EU’s political agenda, (2) the European Parliament consists of directly-elected members who are responsible for passing EU laws, establishing the EU budget, and supervising and scrutinizing other EU institutions, (3) the Council of the European Union (comprised of government ministers) negotiates and adopts laws and the EU budget jointly with the European Parliament, and (4) the European Commission composed of one commissioner from each member state proposes new and enforces current EU legislation. The exact law-making process within the EU is very drawn-out and beyond the scope of this thesis.

A final key institution is the European Central Bank or ECB. The ECB is responsible for managing the common currency and developing and implementing monetary policy for the member states. Managed jointly by the Executive Board, the Governing Council, and the General Council, the ECB acts as an independent central bank that is theoretically insulated from political pressure. The Executive board consists of the President, the Vice-President, and four members from the national central banks of countries within the EU. The Governing Council comprises the governors of the national central banks that have met the convergence criteria according the Maastricht Treaty plus the six components of the Executive Board. The General Council is made up of the president, the vice-president, and all governors of the national central banks. All the components of the Executive Board are appointed for a single eight-year term in order to protect these decision-makers from outside political pressure. Both the ECB and national governments respect the independence of policy decisions. The decisions regarding all policy are made in autonomy, without any recommendations or instructions from national governments or supranational EU authorities (Gandolfo 2002, 358).

Each of the three elements of the ECB has individual responsibilities. The Governing Council formulates monetary policy including changes to the interest rate and the reserves of the ECB and the national banks. The Executive Board implements monetary policy according to the decision of the Governing Council through instructing the national central banks. The General Council has relatively minor responsibilities which include collecting statistical information, preparing ECB reports, and contributes to the preparation of fixing the exchange rates of countries that have met the convergence criteria as defined in phase III of the Maastricht Treaty.

Contrary to its American counterpart, the ECB has a singular main goal of price stability. The American Federal Reserve has a dual mandate of both price stability and maximum employment. The ECB has several tools at its disposal. First and foremost, the ECB controls the Eurozone-wide interest rates. The ECB also manages the foreign currency reserves of the Eurozone, thus enabling it to buy or sell currencies to balance exchange rates. Additionally, the ECB controls the printing of euro banknotes in member states.

The ECB coordinates economic policy with the national central banks of all EU countries, regardless of their participation in the common currency area. This cooperative group is called the European System of Central Banks or ESCB. In coexistence with the ESCB, the Eurosystem comprises of the ECB and the national central banks of all countries that have adopted the euro. The group of countries that have adopted the euro is known as the euro area.

The Maastricht Treaty, signed in 1992 and implemented in 1993, made it clear that Europe did not intend to stop with the creation of a common market. The Maastricht Treaty not only strengthened the economic ties between nations, it also brought the political hopes and aspirations of the European continent to light. The treaty essentially created the European Union. Apart from the political side, the treaty provided certain economic requirements that countries would need to follow in order to join the EU; inflation and interest rates would need to be maintained below a specific level, and caps on government debt were issued. In addition to these requirements, those countries that wished to join the common currency area would need to, obviously, universally adopt the euro. The existence of exchange rate differentials affected each country differently. Those countries which have a large trading industry with countries outside of the European continent were more impacted by changes in the exchange rate system.

Additionally, the peripheral countries of Europe (i.e. the relatively weaker economies) felt a stronger structural shock than that of the more stable core countries such as Germany and France.

The Stability and Growth Pact (or SGP) of 1997 details the economic restraints placed on member nations. The SGP is an implementation of the Excessive Deficit Procedure of the Maastricht Treaty. The SGP is essentially a set of rules and/or guidelines that set out to coordinate fiscal policies and sound public finances across the European Union. For example, the SGP has rules regarding the prevention of excessive public debt burdens and budget deficits. Specifically, the SGP requires all member states to limit the government deficit to 3% of annual GDP and limit government debt to 60% of GDP (or at least have a debt to GDP ratio that is not increasing and is approaching 60%).

The economic rationales behind the deficit and debt criteria are highly related. Gandolfo (2002) provides a thorough explanation of the convergence criteria. Regarding the debt to GDP ratio, Gandolfo lets g, D, and Y denote the budget deficit, the stock of public debt, and nominal GDP, respectively. The sustainability condition requiring member states to have decreasing levels of debt is therefore $\Delta(D/Y) \leq 0$ and can be rewritten as $\Delta D/D \leq \Delta Y/Y$ since a fraction remains constant when the numerator changes in the same proportion as the denominator. Multiplying the equation by D/Y gives $\Delta D/Y \leq (\Delta Y/Y)(D/Y)$and then $g/Y \leq (\Delta Y/Y)(D/Y)$after substituting g for ΔD due to the prohibition of financing the public deficit through the issuance of new money. Therefore, the equation $g/Y = (\Delta Y/Y)b$ gives the boundary of the level of sustainability of the debt to GDP ratio, where b represents the constant D/Y value. Additionally, equilibrium in the current account (CA = 0) stipulates that the budget deficit plus the excess of private savings (savings minus investment) must equal zero. It follows that the deficit to GDP ratio is equal to the ratio of excess private saving to GDP. In the early nineties, the excess private savings to GDP ratio averaged 3 to 4 percentage points. So, a 3% deficit to GDP ratio was reasonable. It then follows that b = 60% given the growth and inflation targets put forward by Gandolfo (2002).

In addition to the criteria surrounding the limits on debt and public deficits, there were also stipulations regarding inflation and interest rates. Namely, the inflation of any member must not exceed by more than 1.5 percentage points the inflation rate of the three countries with the lowest inflation levels and the long-run interest rate of any member must not exceed the average of the same three countries by more than 2 percentage points. As in the case of caps on government debt and public deficits, the criteria for inflation and interest rate levels have economic rationale behind them. For inflation, a frequent cause of trade-balance disequilibria is change in the terms-of-trade due to inflation differentials. It follows that similarity in inflation levels is a reasonable assumption in the theory of optimum currency areas (Gandolfo 2002). Regarding long-term interest rates, the two percentage point margin accounts for the fact that some member states will have different levels of inherent risk. According to the uncovered interest parity condition, a risk premium makes up for interest rate differentials under perfect capital mobility and fixed exchange rates.

According to Gandolfo (2002) the enforcement and application of the two fiscal components of the Maastricht criteria varied.

> "As regards the two fiscal criteria, the one concerning the deficit/GDP ratio was applied *strictly*, while the criterion of the debt/GDP ratio was interpreted *dynamically*, in the sense that a country to qualify should have shown a consistently decreasing trend towards the 60% reference value, even if the current debt/GDP ratio was actually higher" (Gandolfo 2002: 366).

During the early stages of the creation of the monetary union, Gandolfo argues that the guidelines and regulations concerning membership were not strictly enforced. While some of the stronger European economies held up to these criteria, other countries did not. For example, in 1997 Italy had debt to GDP ratio of 121.6%, more than twice the limit stated in the Maastricht criteria. Nevertheless, Italy still proceeded with the process of joining the monetary union. During the 2008 economic crisis, there are even more instances during which member states failed to follow these limitations. For example, the average euro area budget deficit in 2010 was equal to 6.0% of GDP as average public level debt reached 85% of GDP. In fact, this debt ratio exceeded 100% in five member countries at the time. Clearly, the enforceability of certain requirements is in question.

While some of these fiscal imbalances have improved over the past years, they still pose a threat to the stability of growth, employment, and the overall sustainability of the common currency area. Despite the strength of the Maastricht Treaty, the Stability and Growth Pact, and two rounds of reforms in 2003-05 and 2010-11, skepticism prevails (see Schuknecht, Moutot, Rother, and Stark 2011; and Andreas, 2014). The shortcomings of fiscal policy in the euro area must be addressed. Not only must government budget deficits be kept in check, but the lack of a fiscal transfer system (such as that in the United States) wherein the stronger countries prop up the weaker ones poses a serious concern to the long-term sustainability of the monetary union.

Literature Review

There have been numerous studies examining the relationship of European economies over the past decades. Many of these studies have detailed the relationship among European financial markets in order to demonstrate the integration of the economies of Europe and the role of the monetary union. The examination of the financial markets commonly analyzes the stock market; literature on the relationships among bond markets is not as prevalent. However, investigating the relationship among sovereign bond markets could yield interesting results and implications, especially given that the monetary authorities at the European Central Bank (ECB) have the ability to directly participate in the sovereign bond markets. Various authors have examined the sovereign bond markets over the past few decades; most have focused on the bond markets of large economies such as that of the United States, Japan, and Germany. Literature focusing on the European sovereign bond markets is not as abundant, particularly when it comes to recent time periods.

Literature discussing European sovereign bond market integration is rare in the post-2008 period. The vast majority of previous literature focuses on the time period just before or just after the establishment of the monetary union and the European Central Bank. While there has been a limited amount of theoretical work done on the subject of European financial integration since 2008, there has been even less empirical analysis on the topic. This thesis will attempt to expand on the current state of empirical analysis by looking at the long-term relationship among European sovereign bonds including data from the 1990s to the aftermath of the 2008 economic crisis.

Over a multiple-year period of negotiations, one dozen European countries signed the Maastricht Treaty on February 7, 1992. This treaty established a rough timeline for the construction and implementation of the European Economic and Monetary Union (EMU). On January 1, 1999, the exchange rates of all participating countries were fixed and all financial markets were switched to the common currency, the euro. Exactly three years later, the euro entered the economies in the form of euro notes and coins, completing the phasing in of the common currency. Swanson (2008) shows that during the period between the Maastricht Treaty and the inception of the common currency, euro area bond yields converged greatly with the anticipation of monetary union and the credibility of the yet-to-be-formed European Central Bank (ECB). From 1999 until mid-2008, 10-year bond yields across the euro area converged even more. However, once the 2008 financial crisis hit, this story of yield convergence takes a turn for the worse.

There is some existing literature on the long-term relationships among European sovereign bonds over the past few decades. The numerous empirical and theoretical works has mixed results, with some studies pointing to a lack of integration among bond markets and others pointing to either weak or strong integration over various time periods. Clare, Maras, and Thomas (1995) present a study on the integration of the bond markets of the United Kingdom, the United States, Germany, and Japan from 1978 to 1990. Using the Engle and Granger methodology instead of the "more usual" correlation tests (which may indicate a lower degree of integration if short-run deviations lead markets away from their long-run cointegrated path), the authors find low correlations between the mentioned bond markets in the long run compared to stock market returns. These results point to diversification benefits derived from investing in the bond markets during this time period. In contrast, Taylor and Tonks (1989) use similar cointegration techniques and Granger causality tests to examine stock market integration in the United Kingdom, West Germany, the Netherlands, Japan, and the United States, from 1973 to 1986. Their evidence suggests that the stock market of the United Kingdom is cointegrated with German, Dutch, and Japanese stock markets. These results yield the implication that the reduction in long-run risk from diversification will be slight.

By contrast, Mills and Mills (1991) examine the 5-year government bonds of the US, the UK, West Germany, and Japan from 1986 to 1989. They conduct cointegration analysis using the more powerful Johansen and Juselius approach. They find that bond yields are determined by their own domestic fundamentals in the long run, i.e. bond yields are not cointegrated. Mills and Mills also conduct impulse response tests, which measure the response of each variable to a unit innovation in the other variables. They find that shocks in one bond market are quickly transmitted to other bond markets. This suggests that yield movements in the bonds of one country contribute to and affect yield movements in other countries.

Clare and Lekkos (2000) examine the globalization of financial markets in the context of the efficacy of an independent monetary policy. Monetary policy typically affects the short end of the term structure of government bonds. However, if we assume that rates on the long end of the structure are determined by short term interest rate expectations, then monetary policy would affect the entire term structure. If the long-term relationship (cointegration) among government bonds is significant, then the ability of monetary policy makers to influence the term structure may be put in jeopardy. Clare and Lekkos find that during periods of extreme financial turmoil (such as the 1992 sterling exchange rate crisis, the 1997 Asian crisis, and the 1998 Russian debt crisis) yields respond primarily to international factors. This would suggest that international economic crises will need to be controlled for in any long-term relationship analysis of bond yields. The authors' examination of US, German, and UK government bond markets also suggest that risk premia (both temporary and permanent) and contagion effects played an important role in influencing yields from 1990 to 1999. These results suggest that some fundamental factors may need to be controlled for in the long-term relationship analysis of this thesis.

The cointegration of international bond markets within Europe has implications for monetary and fiscal policy. The monetary union of the European economies differs from the monetary union of the United States in that the American states benefit from the system of fiscal transfers. If, for example, a U.S. state is prospering while another state is in economic decline, the more prosperous state can use the system of fiscal transfers (such as unemployment insurance or Medicaid) to support the weaker state. Europe does not have a similar system. Over the past few years, while European countries like Greece have experienced severe economic decline, unemployment, and IMF bailout packages, more prosperous countries like Germany have not sent economic aid due to the lack of a fiscal transfer system. While most of Europe is a monetary union, the continent still has far to go to become a fiscal union. Implementing some form of fiscal union is critical for the success and long-term viability of a monetary union.

The lack of a fiscal transfer system means that monetary policy is more important to the economic union. If bond markets are cointegrated, the task of monetary policy makers becomes more complicated. Under cointegrated sovereign bond markets, bond yields (and prices) move together over time. Therefore, economists and policy makers may find it difficult to distinguish between yield movements caused by internal forces versus those caused by external forces. Under cointegrated bond markets, it will be difficult to determine the exact origin of a cataclysm in the financial markets since all the various sovereign bond yields move together. Monetary policy makers will therefore have the complicated task of developing an accurately targeted monetary policy for the entire economic union.

Baele et al. (2004) present work on the integration of EMU financial markets up until 2004. The authors argue that there are natural demand and supply-driven considerations that have affected the euro area sovereign bond markets. On the supply side, increased competition among government debt managers has led to increased liquidity and government bond issue volumes across the euro area. Additionally, issuance of sovereign debt has become more regular and predictable through a series of pre-announced auction calendars. On the demand side, increased market liquidity has encouraged investors to take a euro-wide perspective rather than a national perspective when deciding their portfolio allocations.

In terms of measuring bond market integration, Baele et al. also provide some useful insights. Yields on European bonds of the same maturity should be identical if the degree of systematic risk (and therefore risk premia) is identical across countries. Yields should also react solely to news common to all euro area markets since risk factors can be diversified away by investing in bonds in different regions, assuming constant systematic risk. Unfortunately, this conclusion is implausible due to credit and liquidity differences among countries; therefore, it becomes necessary to analyze what caused yield differentials in the euro area. The authors argue that yield differentials may be caused (or enhanced) by multiple factors, such as varying levels of credit risk, liquidity levels, availability of developed derivatives markets, and yield movements caused by local or country-specific news. De Santis (2012) confirms these factors and adds aggregate risk as a factor, namely changes in monetary policy, global uncertainty, and risk aversion. Ideally, it would be appropriate to compare local yields with the yield in a perfectly integrated market. However, given the lack of such a market, the 10-year German bund serves as a second-best alternative given its high liquidity and well-developed derivatives market, according to Baele et al.

De Santis (2012) builds a model to analyze bond yields over the period 1 September 2008 to 4 August 2011. His model controls for current and forecasts of government budget deficits (controls using the issuance of long-term government bonds on a monthly basis), government public debt (credit ratings), consensus forecast of inflation and real GDP growth (employs the one-year-ahead consensus forecast of inflation and real GDP growth), liquidity risk factors (bond-specific bid-ask spreads of the corresponding maturity), and regional and international aggregate risk factors (spread between U.S. triple-B corporate bond and U.S. treasury of the identical maturity). The author finds that credit risk is statistically significant, economically sizable, and contributes to higher yield spreads in Greece, Ireland, Portugal, and Spain. Additionally, liquidity risk played a minor role and international risk factors were not a variable that could explain the crisis. De Santis also finds significant spillover effects among countries, particularly when the effect originates from Greece.

Pagano and Von Thadden (2004) compare yield differentials (and simple statistics such as the average and standard deviations of sovereign bond yield differentials compared to the German 10-year benchmark bond) on European sovereign debt from both before and after the inception of the common currency. They conclude that the persistence of yield differentials under the EMU for sovereign debt signifies that euro area bonds are not perfect substitutes. However, they note that this persistence in yield differentials is not a reflection of continued market segmentation but rather differing fundamental risks, such as default risk or the possibility of the collapse of the EMU exchange risk.)

> “Even in an integrated market, differentials may persist to the extent that they are a reflection of the various bonds’ different risk, maturity, or cash-flow characteristics, rather than stemming from trading costs, taxes, clearing and settlement costs, or other institutional barriers to trade” (Pagano and Von Thadden 2004: 546).

Despite further expected European economic integration, they note the yield differentials will persist to some degree. On the other hand, Ehrmann et al. (2011) concludes that the monetary union has effectively created a unified euro area bond market, despite the fact that there are varying credit risks and liquidity characteristics among sovereign bonds. Laopodis (2008) suggests that since these differences in bond market liquidity or default risk among countries cause yield differentials, benefits from portfolio diversification are possible within the monetary union. Ehrmann et al. (2011) analyzes raw correlations and individually regresses a variety of 10-year sovereign bond yields from European countries against that of Germany. In other words, Germany serves as the baseline for this analysis.

Laopodis (2008) uses the Johansen and Juselius approach to test for long-term relationships, or cointegration, among euro area bond yields. He finds no long-term relationship among euro area bond markets in the pre-euro time period (1 January 1995 to 1 December 2000) but does find evidence of a “weak” long-term relationship during the post-euro period (1 January 2001 to 27 July 2006). However, it should be noted that Laopodis does not test for structural breaks in the data using the Gregory-Hansen ADF test. Laopodis details the meanings and implications of his cointegration analysis results:

> “If two or more shared common stochastic trends in a given group of countries exist, then it must be the case that some countries’ government bond markets behave independently of the others in the long run… By contrast, if we find only one shared common stochastic trend in a given group, then it would mean that these bond markets have a single common long-run path and any one market may

> be representative of the behavior of the group. Therefore, an investor should only invest in one of these markets and not in all of them" (Laopodis 2008: 64-65).

Additionally, Laopodis uses the Granger causality test to determine if there is any unidirectional or bidirectional causality among European bonds. He uses an error-correction term in the post-euro and without an error-correction term in the pre-euro period in these tests. He finds a higher degree of bivariate linkages among all euro area bond markets during the post-euro period compared to the pre-euro period. Additionally, he finds that the UK sovereign bond markets do not have Granger-causality influences on the euro area bond markets in both specified time periods.

Laopodis notes that yield differentials among euro area government bonds are likely to decrease as the euro area becomes more and more integrated over time. However, Laopodis did not anticipate the severity of the 2008 economic downturn in his claim (as many others also failed to do). Nevertheless, it should be noted that yield differentials will decrease given increased European economic integration. For policymakers in Europe, higher correlations among government bonds will lead to a greater transmission of economic shocks according to Laopodis. This increased risk could lead to adverse consequences for the stability of the monetary union. Laopodis asserts that this will complicate the task of monetary policymakers in influencing long-term interest rates and maintaining/achieving price stability. De Santis (2012) adds on to this argument by introducing varying idiosyncratic and fundamental problems among countries.

> "Separating the liquidity explanation and contagion risk from aggregate risk and sovereign default is very important from a policy making perspective, because an intervention by the central bank can be successful if financial markets face technical liquidity problems or subject to contagion. If, on the contrary, the rise in

spreads is due to aggregate factors and sovereign default then a central bank has only little room for manoeuvre" (De Santis 2012: 2-3).

The arguments of De Santis and Laopodis will be explored thoroughly in this thesis. This thesis will also use the results of the cointegration analysis and Granger causality tests to determine the implications on monetary policy. As De Santis notes, "To safeguard the stability of the euro area financial system, the highest priorities are to reduce the sovereign solvency risk and to tackle contagion" (De Santis 2012: 27).

Arghyrou and Kontonikas (2011) develop an econometric model comparing the 10-year bund yield with selected countries over the time period January 1999-February 2010. The authors find that (1) a majority of EMU countries were affected by Greece during the 2008 crisis through contagion (the coefficient of the variable representing the spread of Greek bonds versus German bonds is positive and significant for most countries), (2) the markets did price macro-fundamentals and international risk during the crisis period but failed to do so in the years leading up to the crisis, and (3) that speculation did not have significant effects on EMU yield spreads. The authors also note that the EMU crisis is driven by more than economic and fiscal problems in Greece; other countries in similarly dire economic troubles (Ireland, Portugal, etc.) began to contribute to the crisis more and more.

Abad et al. (2009) analyze the impact of the monetary union on euro area debt market integration in a European Central Bank working paper. Using Bekaert and Harvey's CAPM-based model (1995) the authors analyse the differences in importance of idiosyncratic and systemic risk over the time period 1999 to June 2008. Note that this data sample stops just before the onset of the financial crisis. The research of Abad et al. provides three main results. First, local instruments (i.e. variables using data from within European economies) offer good predictive power in terms of bond returns apart from world and regional instruments; this indicates incomplete market integration. Second, EMU and US government bond markets exhibit a fairly low degree of integration, suggesting that domestic risk factors drive returns in the euro area countries rather than international risk factors. The authors follow the lead of Bekaert and Harvey (1995) in using a methodology based on a capital asset pricing model (CAPM) to determine the degree of integration among bond markets. Third, the returns on euro area government bonds are more influenced by euro area risk factors whereas non-euro area bond markets are more influenced by worldwide risk factors, indicating a higher vulnerability to external risks.

In addition to the previous literature on the integration of bond markets, it is also important to bring attention to the previous literature regarding the econometric tests that will be carried out in this thesis. Ramirez and Komuves (2014) use unit root and cointegration analysis with structural breaks in their analysis of the relationship between economics infrastructure, gross fixed capital formation, and foreign direct investment inflows to Hungary over recent years. Specifically, the following tests, which are detailed by Ramirez and Komuves, will be particularly useful in the econometric analysis of this thesis: Granger causality tests, Gregory-Hansen single-break cointegration test, Johansen cointegration tests, Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests, and Zivot-Andrews single-break unit root tests.

The contribution of this thesis to the literature will be three-fold: (1) this thesis will include data from the 2008 financial crisis onwards, (2) it will also include data from a variety of European countries, which will entail using data from countries with varying liquidity and default risks; and (3), this thesis will examine the policy implications of the results for fiscal and monetary policy, portfolio diversification, and European economic integration as a whole.

Theoretical Model

This thesis will use panel data to analyze the long-term relationship among government bonds in the euro area and the United Kingdom. Since the analysis will be over a period of nineteen years, simple correlation coefficients will not be appropriate nor sufficient measurements. Therefore, this thesis will use cointegration analysis to test for long-term relationships. Additionally, this thesis will need to account for numerous factors that could affect the relationship among bond yields. For example, differences in liquidity may cause an underlying difference in bond yields among countries, and certain exogenous or idiosyncratic shocks may cause bond yields to exhibit greater volatility or move erratically for short periods of time, possibly skewing the empirical results of cointegration analysis. For this reason, it may be beneficial to use bond yield data of a lower frequency. Using high frequency data (e.g. daily bond yield data) may lead to the inclusion of short-term shocks. Using data of medium or longer-term frequency may abate this problem by excluding unpredictable yield movements of an extreme short-term nature.

As stated in the historical chapter of this thesis, one of the objectives of establishing the common currency area and ensuing joint monetary policy was the convergence of all economies in the euro area. The European Central Bank's stated goal is to maintain price stability (contrary to the U.S. Federal Reserve's dual mandate including inflation and employment goals) which, especially when combined with the common currency and free movement of capital and labor, all promote the convergence of European economies. Therefore, it would seem logical to presume that European economic integration has occurred under the tenure of the ECB. If integration has occurred, then it follows that sovereign bond yields of all countries in the member nations should have converged for bonds of identical maturities and liquidity. Perfect economic integration would lead to perfectly identical bond yields across countries. However, bond yields have clearly not converged perfectly. This thesis will determine to what degree bond yield integration has occurred in several European economies, what factors have significantly caused convergence, and what factors have impeded yield convergence.

Panel data tend to exhibit either deterministic or stochastic trends over time. Panel data can therefore be non-stationary. Non-stationarity in a data set could lead to the misspecification of results or spurious regressions; the r-squared values and F- and t-statistics may become inflated, resulting in inaccurate and unreliable conclusions. Additionally, the variance and covariance in a non-stationary data set are time variant and approach infinity as time approaches infinity. A non-stationary series also does not have a long-run mean it will revert back to after a shock. Given that this thesis analyzes the long-term relationship among macroeconomic variables, non-stationarity (or unit roots) may be present in the data. Therefore, it will be necessary to test for panel unit roots and non-stationarity before thoroughly developing the appropriate panel data model. This thesis will carry out various econometric analyses to test for the presence of unit roots, including the Levin, Lin, and Chu test for panel unit roots.

There are two traditional types of panel data models: (1) the fixed effects model and (2) the random effects model. Each type has its own advantages and disadvantages. The fixed effects model treats the constant as group or section specific. Each intercept, while possibly different from all other intercepts, is included to capture time-invariant factors; within-group estimators can solve this issue through the use of the time variation from each cross-sectional unit. The fixed effects model is also called the least squares dummy variable model for its use of dummy variables in accounting for separate constants for each group. The downside to the use of dummy variables is that each additional dummy variable uses one more degree of freedom. Therefore, using too many dummy variables could leave too few observations. The inclusion of too many dummy variables may also lead to multicollinearity, making the estimation of the model difficult to interpret.

The random effects model includes constants for each section as a random variable. Of course, this involves making assumptions about the distribution of the random component of the model. Compared to the fixed effects model, the random effects model has two main advantages: (1) the random effects model includes a smaller number of parameters to estimate, and (2), the random effects model allows for the addition of variables that have equal explanatory power for all observations in a group. Additionally, the random effects model assumes that the sample is from a larger universe of data.

Essentially, the fixed effects model assumes that each group differs in the intercept terms, while the random effects model assumes each group has its own error term. The Hausman Test can aid in determining which model best suits a set of panel data. This thesis will go into more detail on the Hausman Test in the methodology section.

Given that this study will encompass a variety of countries each with individual fundamental factors and differing yet time-invariant cultures, histories, and economies, it would be logical to assume that the fixed effects model would be the more appropriate among the two possible choices. Additionally, since all data from this study will be macroeconomic data that is well-documented, it is safe to assume that the data will be balanced, meaning that data is available for all time periods. The fixed effects model accounts for the invariable factors of each country, namely the fact that each country has its individual history, economy, government, et cetera that does not change over time. Therefore, the fixed effects model would be:

$$\boldsymbol{y_{it} = \beta x_{it} + \alpha_{it} + D_i + \varepsilon_{it}}$$

where there are *k* regressors in x_{it} excluding the constant term and D_i represents dummy variables. The fixed effects model assumes that differences across units can be captured in the differences in the group-specific constant term α_i (Greene 2002). The fixed constant here is time-invariant; the term "fixed" does not necessarily imply that the constant is nonstochastic. Each constant term is treated as an unknown parameter.

The data will consist of 12 cross-sectional regressors for i=1, …, 12 and monthly observations from 1995 through 2013 resulting in 228 time periods for each variable, t=1, …, 228 for a total of 2,736 observations. European 10-year sovereign bond yields from 12 countries will be the dependent variables, which will be a function of numerous independent variables. Following the lead of Laopodis (2008) and Arghyrou and Kontonikas (2011), the formulation of the stacked regression model is as follows:

$$\boldsymbol{(Y)_{it} = f[(CR)_{it}, (BAS)_{it}, (INF)_{it-1}, (IR)_{it}, (VOL)_{it}\ ; D_i] + \varepsilon_{it}}$$

where the regressand, Y, is the sovereign bond yield for the 10-year maturity segment. Bond yield data is provided by the St. Louis Federal Reserve. The model includes the following regressors: the credit rating (CR) as a proxy of differences in default risk among countries, the bid-ask spread of each country compared to the 10-year German bund (BAS) to account for varying levels of liquidity and resulting risk, the rate of inflation (INF), the interest rate (IR), a measure of market volatility (VOL), and dummy variables$(D_i)$to account for various exogenous variables. ε_{it} is a normally distributed error term.

The credit rating (CR) serves as a direct indicator of default risk for each country, which will impact bond yields. As the default risk increases or overall financial stability of a country decreases, the credit rating will go down. The expected sign of the CR variable is negative, indicating a negative relationship between credit rating and bond yields; as the credit rating of an economy decreases, the sovereign bond yields of that economy should increase because investors will demand a higher premium for the added risk of investment. The credits ratings in this model are provided by Fitch, which provides the most number of years of data on European credit ratings out of the big three credit agencies (the other two being Standard & Poor’s and Moody’s). The CR variable is constructed through the creation of an index series ranging from zero to one hundred with one hundred being a AAA rating. Each one-tier decrease in credit rating corresponds to a decrease of five in the constructed index. For example, a credit rating of AAA, AA+, and AA correspond to a 100, 95, and 90 in the index.

A variable (BAS) accounting for the bid-ask spread of sovereign bonds is included to reflect the varying levels of liquidity from country to country. The larger the spread between the bid price and asking price, the lower the liquidity. In turn, lower liquidity represents a greater risk for buyers of sovereign bonds since the investment may not be able to be bought or sold quickly enough to minimize losses. Therefore, the expected sign of the bid-ask spread variable is positive; as the bid-ask spread increases, yields will also increase. The bid-ask spread data is provided by Bloomberg.

The rate of inflation (INF) will be lagged in order to show the effect of shifting expectations on the required return of an investment (yield) of a bond. Inflation is expected to have a positive sign in the model to reflect the fact that as inflation increases, bond yields rise to compensate investors for the loss of purchasing power. Inflation data is provided by the Organization for Economic Cooperation and Development or OECD. The European Central Bank’s interest rate on the deposit facility (the rate at which European banks make overnight deposits) will be used as the interest rate variable (IR) in the model. This data is provided by the ECB Statistical Data Warehouse. The interest rate is expected to have a positive sign in the equation, given that as interest rates rise yields must also rise in order to stimulate demand for bonds via increased returns. It should be noted that data on this interest rate is not available for the entire time period since the ECB was founded around the turn of the millennium. The final independent variable, VOL, uses the Deutsche Borse VDAX Volatility Index. This volatility index measures overall volatility in the German equity markets; this index was chosen for its ample available data (most volatility indices do not cover the entire sample period of this model). The volatility variable is expected to have a negative sign. Heightened or increasing volatility will spur a flight to safety among the markets, leading to investors opting for government bonds as a safer investment over other riskier securities. This will boost demand for bonds causing bond prices to rise and yields to fall, *ceteris paribus*. Data on this volatility index is provided by Bloomberg.

This model intends to account for numerous economic shocks, volatile time periods, and exogenous variables through the use of dummy variables D_i. D_1, D_2, and D_3 are dummy variables accounting for, respectively, the Peso crisis which occurred as a result of the December 1994 devaluation of the Peso via-à-vis the dollar, the Asian debt crisis triggered in July of 1997, and the 1998 Russian debt crisis. All of the crises potentially affected the expected convergence of European sovereign bonds that would accompany the establishment of the euro area in 2000. D_4 accounts for the July/August 2012 time period immediately following the remarks of ECB president Mario Draghi asserting that he will do “whatever it takes” to save the euro. These remarks may have caused unpredictable yield movements during a specific time period.

This model will control for differences in default risk among countries and differences in liquidity levels among countries. This thesis follows De Santis (2012) in using credit ratings as a proxy to control for default risk. To control for liquidity risks, this thesis uses data on bid-ask spreads of the 10-year maturity segment. Controlling for these two exogenous variables is crucial to the estimation of the model as the level of yield convergence may be skewed by fundamental differences in default and liquidity risks.

Figure 1: European 10-year Government Bond Yields

The question that arises is the following: Is the monetary union sustainable? This is one of the questions that this thesis will address through the analysis of the long-term relationship among government bond yields. If this thesis finds that there is a long-term relationship among bond yields, then it would suggest that convergence has occurred in the sample countries. On the other hand, this scenario could also mean that policy-makers such as those in the ECB would have more difficulty in developing and executing a well-targeted monetary policy. If bond yields move together, it will be more difficult to determine the exact origin of changes in yields; if bond yields move similarly across countries, the task of developing a well-targeted policy becomes more complicated because it is more difficult to determine from which country (in the euro area or not) an economic shock originated. Additionally, if bond yields are related over the long run, the benefits of diversification in a portfolio of government bonds will be diminished. If yields across countries move in a similar direction over time, investing in a portfolio of multiple government bonds may not provide much more protection via diversification than a portfolio of only one government bond.

Empirical Results

Preliminary Stacked Regressions

The results for the preliminary stacked regression without including the dummy variables are shown in table 1 in Appendix A. The t-statistics of all independent variables are significant at the 5% significance level. The coefficients of the independent variables are all of the expected sign except for inflation and volatility. The sign for inflation was expected to be positive; however the estimated coefficient is negative indicating that as inflation increases, bond yields decrease. This result is contrary to the theory that as inflation increases, bond yields need to increase in order to compensate bondholders for the negative effects of inflation on purchasing power. The sign for volatility was expected to be negative. Given that the measure of volatility in the data is a measure of stock market volatility, it would be logical to assume that as volatility rises, investors would flee the riskier equity markets in favor of the stable bond markets, particularly government bonds. A positive coefficient on volatility indicates that higher levels of volatility in the stock market do not necessarily prompt a flight to safer assets, at least not immediately.

A major problem with this preliminary regression is the Durbin-Watson Statistic. The Durbin-Watson statistic measures possible serial correlation of the first order. A Durbin-Watson Statistic near 2 indicates no likely serial correlation, while a value near 4 indicates negative serial correlation and a value approaching zero corresponds to positive serial correlation. The Durbin-Watson statistic of 0.159 in this model represents likely positive serial correlation of the first order, which will need to be addressed later in the empirical results.

Table 2 shows the same regression as table 1 while excluding the ECB deposit rate (IR) variable. Data for the ECB deposit rate is only available since December, 1998. The interest rate variable will be included in later regressions spanning a shorter time span. This second regression now has all variable coefficients of the expected sign and also significant at the 10% significance level. Every t-statistic is also significant at the 5% level except for the t-statistic corresponding to the volatility variable (VOL). However, the Durbin-Watson statistic has now moved even closer to 0, indicating that positive serial correlation of the first order is even more likely. In addition, dummy variables D_2, D_3, and D_4 have now been included with the first two being significant at the 5% level. Interestingly, the coefficient for these two significant dummy variables are both positive; this indicates that during the time period of the Asian Crisis and Russian Debt Crisis, European bond yields increased, possibly pointing to spillover effects as yields rose to compensate for greater amounts of risk in the markets.

Hausman Test

The Durbin-Wu-Hausman test determines whether the Fixed Effects Model or the Random Effects Model is more appropriate for a given set of data. The null hypothesis of the test is that the Random Effects Model (REM) is appropriate while the alternative hypothesis is that the Fixed Effects Model is more appropriate. The results of the Hausman test are shown on page 36. The Hausman chi squared statistic is significant at the 5% significance level, indicating that we can reject the null hypothesis and proceed in estimating a Fixed Effects Model.

Figure 2: Hausman Test

Correlated Random Effects - Hausman Test
Pool: COUNTRIES
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	**99.609843**	5	**0.0000**

Cross-section random effects test comparisons:

Variable	Fixed	Random	Var(Diff.)	Prob.
BAS_?	3.049636	3.243263	0.000438	0.0000
CR_?	-0.119262	-0.103293	0.000003	0.0000
INF_?(-1)	-0.029882	-0.055563	0.000021	0.0000
IR	0.553393	0.527350	0.000008	0.0000
VOL	0.016471	0.015339	0.000000	0.0000

Cross-section random effects test equation:
Dependent Variable: Y_?
Method: Panel Least Squares

Sample (adjusted): 1998M12 2013M12
Included observations: 181 after adjustments
Cross-sections included: 12
Total pool (unbalanced) observations: 2133

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	14.20923	0.284514	49.94216	0.0000
BAS_?	3.049636	0.114031	26.74395	0.0000
CR_?	-0.119262	0.003171	-37.61284	0.0000
INF_?(-1)	-0.029882	0.020737	-1.440990	0.1497
IR	0.553393	0.023894	23.16000	0.0000
VOL	0.016471	0.002610	6.309586	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.727389	Mean dependent var	4.540210
Adjusted R-squared	0.725327	S.D. dependent var	2.169183
S.E. of regression	1.136852	Akaike info criterion	3.102341
Sum squared resid	2734.786	Schwarz criterion	3.147493
Log likelihood	-3291.647	Hannan-Quinn criter.	3.118866
F-statistic	352.8730	Durbin-Watson stat	0.161234
Prob(F-statistic)	0.000000		

Fixed Effects Model

In addition to the results of the Hausman test, The Fixed Effects Model (FEM) is also theoretically the appropriate model because, unlike OLS, it accounts for individuality among the various cross-sectional units. Given that we are analyzing 12 countries with unique factors, accounting for individuality in each cross-section will be key for this model. The FEM accounts for the individuality and heterogeneity by giving each country its own unique intercept. Each one of these intercepts is time-invariant. The results of the FEM are shown in Figure 3.

The initial FEM shows that all independent variables are significant and all coefficients are also of the anticipated sign with exception of inflation (INF) and volatility (VOL). This is a curious result given that, theoretically, higher inflation would lead to higher bond yields as investors need to be compensated more and more as inflation rises. The negative inflation coefficient indicates that as inflation rises, bond yields decrease and bond prices increase.

Other variations of this fixed effects model are shown in Appendix C. When the interest rate (IR) variable is removed from the equation, the coefficient for inflation gains the expected positive sign. It is possible that this effect is due to the fact that data on the interest rate only goes back to December of 1998. When IR is included in the FEM, part of the data set is removed. This restriction could affect the coefficient on inflation. The conflicting results regarding the sign of the coefficient of INF could also be due to the fact that the inflation data used is ex-post, not ex-ante. In other words, the inflation data used in this model measures actual inflation levels; inflation is not measured in terms of future expectations.

In addition, dummy variables D_1, D_2, and D_4 corresponding to the Peso crisis, the Asian crisis, and Mario Draghi's July 2012 comments respectively are all significant. The first two significant dummy variables have a positive coefficient, indicating that during those periods of economic crisis, yields increased due to depressed demand for government bonds. This could have been caused by the spillover effects of the unexpected Peso crisis and the Asian crisis. The dummy variable corresponding to the Russian debt crisis is not significant. This could be due to the fact that the Russian debt crisis occurred during the aftermath of the Asian crisis; in other words the Russian crisis did not have as large of a surprise element. The final dummy variable has a negative sign attached to it coefficient. This indicates that Mario Draghi's pledge to save the Eurozone at any cost pushed yields lower. This is particularly evident in Italian and Spanish bonds (see Figure 1) as their yields sharply decreased following Draghi's comments. Once the markets gained confidence in the stability of the Eurozone and the continued inclusion certain economies (namely Spain and Italy) in the common currency area, investors became more willing to buy government debt. As demand for bonds increased, yields decreased. Thus, a negative coefficient for D_4 is logical.

Figure 3: FEM Regression Output with Cross-Section Weights

Dependent Variable: Y_?
Method: Pooled EGLS (Cross-section weights)

Sample (adjusted): 1998M12 2013M12
Included observations: 181 after adjustments
Cross-sections included: 12
Total pool (unbalanced) observations: 2133
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	10.40093	0.292065	**35.61167**	**0.0000**
BAS_?	4.747095	0.211159	**22.48112**	**0.0000**
CR_?	-0.076626	0.003176	**-24.12598**	**0.0000**
INF_?(-1)	-0.126841	0.015149	**-8.372989**	**0.0000**
IR	0.625310	0.014257	**43.86091**	**0.0000**
VOL	0.013601	0.001632	**8.332158**	**0.0000**
Fixed Effects (Cross)				
AT--C	0.134249			
BE--C	-0.441558			
DE--C	-0.226456			
EL--C	-0.192169			
ES--C	0.250212			
FI--C	0.012393			
FR--C	0.040905			
IR--C	0.367807			
IT--C	-0.377354			
NL--C	0.051575			
PT--C	-0.008523			
UK--C	0.396010			

Effects Specification

Cross-section fixed (dummy variables)

Weighted Statistics

R-squared	0.682148	Mean dependent var	6.126975
Adjusted R-squared	0.679745	S.D. dependent var	2.260116
S.E. of regression	1.077324	Sum squared resid	2455.889
F-statistic	283.8246	Durbin-Watson stat	0.164776
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.687905	Mean dependent var	4.540210
Sum squared resid	3130.878	Durbin-Watson stat	0.224811

Correction for Serial Correlation via Autoregressive Process

All of the presented fixed effects models suffer from apparent serial correlation. Given that the Durbin-Watson statistic is consistently low, it is likely that there is positive serial correlation in the model. To correct for serial correlation of the first order, we add an AR(1) process to the model, assuming that there is a common autoregressive process for the various cross-sections over time (see Ramirez, 2010; and Greene, 2003).

Given that in the previous regressions the volatility variable has the opposite anticipated sign, the VOL variable is lagged by one time period in order to explain the possible delay in the effect of heightened levels of volatility on equity markets. The results for this AR(1) process are shown on page 41.

All t-statistics are significant at the 5% significance level and all variables are now of the expected sign. Inflation (lagged by one month) shows a positive coefficient, confirming our theory that as inflation rises yields must also rise in order to give bondholders a higher return on their investment to compensate for the loss due to inflation. The coefficient on VOL is now negative. This indicates that as volatility in the equity markets rises, yields fall as investors shift away from stocks and demand safe haven assets such as government bonds. The lag in this variable also suggests that this effect is not immediate; investors and the markets take time to react to changes in volatility. When the dummy variables are added to the AR(1) process, the sign of the coefficient for D_2 reverses to become negative (see Appendix C) and the t-statistic is significant at any significance level.

Adding an AR(2) process makes the model even stronger. The coefficients are all of the same sign and both AR(1) and the AR(2) processes are statistically significant. The positive coefficient on AR(1) indicates that there is likely positive serial correlation of the first order. The negative coefficient on AR(2) indicates that there is likely negative serial correlation of the second order.

Figure 4: AR(1) Process

Dependent Variable: Y_?
Method: Pooled EGLS (Cross-section weights)

Sample (adjusted): 1999M01 2013M12
Included observations: 180 after adjustments
Cross-sections included: 12
Total pool (unbalanced) observations: 2121
Iterate coefficients after one-step weighting matrix
Convergence achieved after 19 total coef iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.660489	0.676276	**8.370090**	**0.0000**
BAS_?	1.436394	0.149461	**9.610516**	**0.0000**
CR_?	-0.020178	0.006595	**-3.059430**	**0.0022**
INF_?(-1)	0.064899	0.014323	**4.531240**	**0.0000**
IR	0.070773	0.025517	**2.773516**	**0.0056**
VOL(-1)	-0.003368	0.000817	**-4.122785**	**0.0000**
AR(1)	0.985799	0.004411	**223.4902**	**0.0000**
Fixed Effects (Cross)				
AT--C	-0.820241			
BE--C	-0.488708			
DE--C	-0.929507			
EL--C	2.856538			
ES--C	0.395273			
FI--C	-0.704720			
FR--C	-0.492722			
IR--C	-0.226045			
IT--C	-0.126030			
NL--C	-0.759687			
PT--C	1.515632			
UK--C	-0.248899			

Effects Specification

Cross-section fixed (dummy variables)

Weighted Statistics

R-squared	0.971493	Mean dependent var	7.189255
Adjusted R-squared	0.971263	S.D. dependent var	2.734354
S.E. of regression	0.363832	Sum squared resid	278.3815
F-statistic	4215.836	Durbin-Watson stat	1.630814
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.969408	Mean dependent var	4.539673
Sum squared resid	306.5775	Durbin-Watson stat	1.721282

Cross-Section Seemingly Unrelated Regressions (SUR)

Seemingly unrelated regressions consist of several regressions that each have a dependent variable and exogenous independent variables. Each equation can be individually estimated and can stand as an individual linear regression. A seemingly unrelated regression (SUR) system has error terms in the equations that are related; the equations are related through the correlation of the error terms. Since it is assumed that disturbances are correlated across models in a SUR, it would be incorrect to conclude that disturbances act independently. This leads to the necessity of having an efficient estimator (Olamide and Adepoju 2013).

There are two main reasons for using a SUR model (Moon and Perron 2006). First, a SUR system increases efficiency by combining information on different equations. To further increase efficiency in the model, a parametric assumption regarding the disturbance process can be imposed (Greene 2003). Second, using a SUR model allows for the testing of restrictions involving parameters in different equations within the system. In addition, Ramirez (2010) argues that another motivation behind the use of a SUR procedure lies in the theory that economic events and/or shocks affect countries in different ways, therefore generating cross-sectional error term correlation.

A SUR model requires that the panel data be balanced. In others words, all variables must have data for all time periods. In this thesis, data on the ECB interest rate on the deposit facility is not available before 1999, therefore the sample data time period must be adjusted in order to accommodate the lack of interest rate data. The results of the estimated SUR are shown in Appendix D.

All variables are statistically significant except for inflation. In addition, both inflation and volatility are of the unexpected sign. The dummy variable accounting for Draghi's

"Whatever it takes" speech is also statistically significant and of the expected sign. The other three dummy variables are not included because they are not relevant in the new shortened sample period.

The second SUR estimation in Appendix D shows an identical SUR with an AR(1) process to correct for serial correlation. The results of this AR(1) model differ from the previous model in that INF is now statistically significant and the coefficient for both INF and VOL now have the expected sign. In addition, the overall explanatory power of the model according to R^2 has increased considerably.

Unit Root Tests

Before testing for cointegration, it is necessary to determine if all variables are stationary via unit root tests. If a series is shown to contain a unit root (i.e. the series is non-stationary) the series can be rendered stationary through differencing. A series that is stationary after taking the first difference is integrated of order one or I(1). Ideally, all series should be integrated of the same order. However, it is possible to run cointegration analysis even if all variables are not integrated of the same order (Pedroni, 2000).

Pooled time series data tend to exhibit a trend and therefore non-stationarity. It follows that the variables in pooled time series models have means, variances, and covariances that are time varying. Additionally, using OLS or GLS to estimate such models may produce misspecified estimates; this would likely lead to exaggerated R^2values and t-statistics (see Engle and Granger, 1987; Ramirez 2007).

Rather recently, several researchers have developed unit root tests designed for panel data. Notably, the Levin, Lin, and Chu test (2002) the Im, Pesaran, and Shin test (2003) and the

Hadri test (1999) have developed unit roots tests for panel data. These panel unit root tests are more powerful than those carried out on any single series because the information within a time series is strengthened by that contained in the cross section data (Ramirez 2007). In other words, the above researchers have found that type II error (the failure to reject a null hypothesis of non-stationarity) is less likely to occur when using panel unit root tests compared to unit root tests on a single series which are notorious for having low power.

Unit root tests for all variables are shown in the Appendix. The Levin-Lin-Chu test was used for all pooled variables. Three confirmatory tests were also examined for pooled variables: the Im, Pesaran and Shin (IPS) test, the Augmented Dickey-Fuller-Fisher (ADF-Fisher), and the Phillips-Perron Fisher (PP-Fisher) tests. The Augmented Dickey-Fuller (ADF) test, Kwiatkowski-Phillips- Schmidt-Shin (KPSS) test, and/or the Zivot-Andrews unit root test with one structural break were used for all other variables.

The Levin-Lin-Chu test employs a null hypothesis of a unit root with the following (ADF) specification:

$$\Delta \boldsymbol{y_{it}} = \boldsymbol{\alpha y_{it-1}} + \sum \boldsymbol{\beta_{it}} \Delta \boldsymbol{y_{it-j}} + \boldsymbol{X_{it}} + \boldsymbol{v_{it}}.$$

where y_{it} corresponds to the pooled variable, X_{it} refers to the exogenous variables such as the cross section fixed effects and v_{it} represents the independent disturbances or error terms. The Im, Pesaran and Shin test and ADF Fisher chi-square estimates separate ADF regressions for each cross section. This allows for individual unit roots processes.

Maddala and Wu (1999) demonstrate that the IPS test is more powerful than the LLC test. While the null hypotheses are identical (the presence of a unit root) the alternative hypotheses are different. The alternative hypothesis of the LLC test is based on homogeneity of the autoregressive parameter. The alternative hypothesis of the IPS test is based on heterogeneity of that same parameter. In other words, the IPS test does not pool the data while the LLC test is based on regressions with pooled data. In addition, Maddala and Wu note that “when there is no cross-sectional correlation in the errors, the IPS test is slightly more powerful that the Fisher test… Both tests are more powerful than the (LLC) test” (Maddala and Wu 1999: 644).

The summaries of the unit root tests for the pooled variables BAS, CR, and INF are displayed in Appendix E. For BAS, the chi statistic is significant at the 5% level so we therefore reject the null hypothesis and conclude that BAS does not have a unit root. We fail to reject the null hypothesis for CR in level form; however we are able to reject the null hypothesis when CR is differenced and conclude that CR is stationary. For both BAS and CR, all the relevant tests and statistics yield the same conclusion. The unit root tests for INF are contradictory. We fail to reject the null hypothesis in the Levin-Lin-Chu test but do reject the null in the ADF, PP, and Im, Pesaran and Shin tests. Therefore, we can conclude that INF is stationary in level form because the (IPS) test, in particular, controls for both individual fixed effects and individual linear trends.

The results of the unit root tests for the unpooled variables IR and VOL are also in Appendix A. VOL is shown to be integrated of order zero I(0) according to both the ADF and Zivot-Andrews test. IR has contradictory results in that the ADF test indicates that IR is I(1) while the more powerful KPSS test which defaults to a stationary null (no unit root) indicates that IR is stationary in level form.

In conclusion, all variables are stationary in level form except for the credit rating variables. This result was expected as the credit rating for each country does not change frequently and the series may be prone to exhibiting a trend since a credit rating may follow a long-term increase or decrease to reflect a country’s improving or deteriorating economic and/or public finance situation.

Finally, this thesis performed an ADF Fisher unit root test as originally proposed by Maddala and Wu (1999) to examine the stationarity of the residuals of each cross section in stack regression and a SUR model. The null hypothesis in this test is that the residuals of all cross sections over time have a unit root (i.e. no cointegration) and the alternative is that at least some cross sections do not have a unit root. According to the ADF-Fisher test, the error terms of both models do not have a unit root; we can reject the null hypotheses in the ADF-Fisher and Im, Pesaran and Shin tests and conclude that the residuals of the model are stationary. The detailed results are at the end of Appendix E.

The fact that the residuals were found to not contain a unit root suggests that an equilibrium or stable relationship exists that keeps the pooled variables in proportion to each other in the long run. According to Ramirez (2007), this is a key finding because investigators may be prone to erroneously apply the GLS method to relationships that are non-stationary and generate spurious results.

Panel Cointegration Results

The Pedroni (1997, 1999, 2000) cointegration test allows for a considerable amount of heterogeneity in panel data model (see Asteriou and Hall 2011). The null hypothesis of no cointegration differs from that of other cointegration tests (e.g. the McCoskey and Kao test). Pedroni's cointegration tests allow for multiple regressors, varying cointegration vectors across the panel sections, and for heterogeneity in the error terms across cross sections. However, it should be noted that a significant drawback of the Pedroni test is the assumption of a unique cointegrating vector.

The Pedroni test constructs four panel statistics and three group panel statistics to test the null hypothesis. The autoregressive term is assumed to be equivalent across all cross sections in the panel statistics; on the other hand, the parameter can vary over each cross section. In other words, if the null hypothesis is rejected in the panel statistics, the variables are cointegrated for all cross sections (in this case the countries). If the null hypothesis is rejected in the case of the group panel statistics, at least one of the countries is cointegrated.

The results of the Pedroni tests are shown on the following page. Unfortunately, the credit rating variable CR has been omitted due to its inclusion leading to an error in running the test, viz., a singular or non-invertible matrix. It is likely that this error is caused by the very low variance in the credit rating series. It should be noted that the credit ratings for Austria, Germany, and the Netherlands are constant (AAA) throughout the entire sample. The weighted statistics for the panel-PP and panel-ADF are both significant at the 5% level and the group-PP and group-ADF statistics are both significant at the 10% level. Therefore, we can reject the null hypothesis of no cointegration and conclude that there is cointegration in the model.

Figure 5: Pedroni Cointegration Test

Series: INF_? BAS_? Y_?

Sample: 1994M06 2013M12
Included observations: 235
Cross-sections included: 12
Null Hypothesis: No cointegration
Trend assumption: No deterministic trend
Automatic lag length selection based on SIC with lags from 13 to 14
Newey-West automatic bandwidth selection and Bartlett kernel

Alternative hypothesis: common AR coefs. (within-dimension)

	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	4.127097	0.0000	5.211435	0.0000
Panel rho-Statistic	-1.755170	0.0396	-2.732267	0.0031
Panel PP-Statistic	-1.223777	0.1105	**-1.995083**	**0.0230**
Panel ADF-Statistic	-1.235808	0.1083	**-1.754183**	**0.0397**

Alternative hypothesis: individual AR coefs. (between-dimension)

	Statistic	Prob.
Group rho-Statistic	-1.625824	0.0520
Group PP-Statistic	**-1.536428**	**0.0622**
Group ADF-Statistic	**-1.396460**	**0.0813**

Cross section specific results

Phillips-Peron results (non-parametric)

Cross ID	AR(1)	Variance	HAC	Bandwidth	Obs
AT	0.930	0.087005	0.152818	7.00	174
BE	0.925	0.183405	0.258820	5.00	194
DE	0.871	0.097047	0.091128	2.00	227
EL	0.971	0.200858	0.303521	7.00	197
ES	0.949	0.139321	0.236362	5.00	196
FI	0.961	0.104219	0.211221	8.00	210
FR	0.936	0.066518	0.096018	6.00	227
IR	0.985	0.248230	0.891150	9.00	168
IT	0.941	0.050786	0.091935	7.00	169
NL	0.953	0.068599	0.082803	3.00	175
PT	0.973	0.128105	0.197060	5.00	175
UK	0.944	0.093707	0.114558	2.00	227

Augmented Dickey-Fuller results (parametric)

Cross ID	AR(1)	Variance	Lag	Max lag	Obs
AT	0.930	0.087005	0	13	174
BE	0.910	0.177115	1	14	193
DE	0.871	0.097047	0	14	227
EL	0.971	0.200858	0	14	197
ES	0.934	0.129135	1	14	195
FI	0.940	0.096401	3	14	207
FR	0.915	0.045149	12	14	215
IR	0.965	0.179907	3	13	165
IT	0.911	0.046860	2	13	167
NL	0.953	0.068599	0	13	175
PT	0.962	0.122330	1	13	174
UK	0.935	0.092147	1	14	226

Conclusion

This thesis has both analyzed and estimated the long-term relationship among European sovereign bond markets during the 1995-2013 time period, using empirical models similar to those proposed by Arghyrou and Kontonikas (2011), Laopodis (2008), and De Santis (2012). The conceptual model hypothesizes that bond yields were positively or negatively affected by different internal and external factors. Namely, the bid-ask spread, inflation, and the interest rate were expected to be positively related to bond yields while the credit rating and equity market volatility were expected to share a negative relationship with government bond yields. This theory was, for the most part, confirmed by the preliminary regressions and fixed effects models. However, it should be noted that the coefficients of inflation and volatility variables were not of the expected sign in the initial regressions. This thesis argued that the conflicting results regarding the sign of the coefficient for inflation was due to the fact that the inflation data was ex-post; the data measured actual inflation levels rather than an ex-ante measure that would include agents' future expectations about inflation. Similarly, the coefficient for volatility matched expectations only once a lag was introduced to the series. This lag could suggest that the flight from equity markets to bond markets due to heightened equity market volatility is not immediate; investors and the markets take time to react to spikes in volatility.

This thesis also carried out a Hausman test to determine whether a fixed effects model or a random effects model would be more appropriate. Conceptually, this thesis argued that a fixed effects model would be the better choice given that a fixed effect model is more appropriate for a study encompassing multiple cross sections with individual (and sometimes time-invariant) factors. The rejection of the null hypothesis in the Hausman test confirmed this theory.

This thesis proceeded to estimate fixed effects models. The fixed effects models showed dummy variables D_1, D_2, and D_4 to be statistically significant at the 5% level. The only dummy variable that was not significant was that accounting for the Russian debt crisis of 1997; it is possible that this variable was not significant because it did not have the same surprise effect as the other economic crises; in other words the Russian debt crisis may have been expected as a spillover from the Asian crisis of 1998. The two dummy variables that had a positive coefficient were those accounting for the Peso crisis and the Asian crisis. The positive coefficient could suggest that the markets were concerned about spillover effects from Mexico and Asia into the European government bond markets; therefore, during the time of these two crises, demand for government bonds fell and yields increased. Out of the three statistically significant dummy variables, only the one corresponding to Mario Draghi's "whatever it takes" speech in July of 2012 had a negative coefficient. This indicates that yields were pushed lower and prices higher after his comments, suggesting that the markets began to demand more government debt as confidence in the stability of the euro area was restored.

Finally, this thesis undertook multiple panel unit root and cointegration analyses. It found that all variables were stationary in level form with the exception of the credit rating variable, CR. This was somewhat expected since the credit rating of any country in the sample did not change frequently. Therefore, the variance of the credit ratings was relatively low. However, since all other variables were found to be integrated of order zero, this thesis proceeded to keep all variables in level form.

This thesis conducted a Pedroni cointegration test to examine the long-run relationships in the model. The credit rating term again proved to be problematic due to its low variance; it was omitted in the cointegration analysis. The weighted statistics for the panel-PP and panel-

ADF were found to be statistically significant at the 5% level and the group-PP and group-ADF statistics were found to be significant at the 10% level. Hence, we rejected the null hypothesis of no cointegration and concluded that there is cointegration in the model.

There are important implications that can be drawn from the findings of this thesis. The fact that this thesis found evidence of cointegration suggests that the benefits of diversifying a portfolio of European government bonds may not be as pronounced. Since it was found that bond yields move together over time, investing in one government bond over another will not bring higher (or lower) returns in the long run. In other words, since bond yields and prices move together over the long-run, buying only one type of European sovereign bond would theoretically give the same long-run returns as buying a basket of bonds.

Additionally, the cointegration of bond markets may complicate the task of monetary policymakers at the ECB. If, as this thesis has found, bonds move together over time then it may become more difficult to develop a well-targeted monetary policy. If bonds across Europe move together, identifying the source of an economic shock will become more challenging because government bond yield are all moving in the same direction. Essentially, integrated European bond markets complicate the task of developing a tailored monetary policy for individual countries in the Eurozone, particularly in the presence of asymmetric economic shocks.

Appendix

Appendix A
Stacked Regressions

Table 1.

Dependent Variable: Y_?
Method: Pooled Least Squares

Sample (adjusted): 1998M12 2013M12
Included observations: 181 after adjustments
Cross-sections included: 12
Total pool (unbalanced) observations: 2105
White diagonal standard errors & covariance (d.f. corrected)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	11.58473	0.630724	18.36737	0.0000
BAS_?	3.531391	0.758860	4.653547	0.0000
CR_?	-0.088214	0.006497	-13.57803	0.0000
INF_?	-0.061845	0.020976	-2.948400	0.0032
IR	0.494833	0.020286	24.39337	0.0000
VOL	0.012928	0.002007	6.441817	0.0000

R-squared	0.703475	Mean dependent var	4.519597
Adjusted R-squared	0.702768	S.D. dependent var	2.160071
S.E. of regression	1.177648	Akaike info criterion	3.167761
Sum squared resid	2911.007	Schwarz criterion	3.183872
Log likelihood	-3328.069	Hannan-Quinn criter.	3.173662
F-statistic	995.9312	Durbin-Watson stat	0.158862
Prob(F-statistic)	0.000000		

Table 2.

Dependent Variable: Y_?
Method: Pooled Least Squares

Sample (adjusted): 1995M01 2013M12
Included observations: 228 after adjustments
Cross-sections included: 12
Total pool (unbalanced) observations: 2324
White diagonal standard errors & covariance (d.f. corrected)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	11.24078	0.617174	18.21332	0.0000
BAS_?	3.549377	0.750844	4.727185	0.0000
CR_?	-0.075105	0.006263	-11.99087	0.0000
INF_?	0.070474	0.019539	3.606824	0.0003
VOL	0.004552	0.002447	1.860100	0.0630

R-squared	0.563647	Mean dependent var	4.691348
Adjusted R-squared	0.562894	S.D. dependent var	2.167393
S.E. of regression	1.432950	Akaike info criterion	3.559496
Sum squared resid	4761.706	Schwarz criterion	3.571869
Log likelihood	-4131.135	Hannan-Quinn criter.	3.564005
F-statistic	748.8763	Durbin-Watson stat	0.097148
Prob(F-statistic)	0.000000		

Table 3.

Dependent Variable: Y_?
Method: Pooled Least Squares

Sample (adjusted): 1995M01 2013M12
Included observations: 228 after adjustments
Cross-sections included: 12
Total pool (unbalanced) observations: 2324
White diagonal standard errors & covariance (d.f. corrected)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	11.23640	0.610542	18.40397	0.0000
BAS_?	3.551589	0.752105	4.722201	0.0000
CR_?	-0.075130	0.006207	-12.10389	0.0000
INF_?	0.070574	0.019580	3.604438	0.0003
VOL	0.004631	0.002448	1.891823	0.0586
D2	1.897226	0.264771	7.165524	0.0000
D3	0.531325	0.193537	2.745349	0.0061
D4	-0.262839	1.268114	-0.207268	0.8358

R-squared	0.565543	Mean dependent var	4.691348
Adjusted R-squared	0.564229	S.D. dependent var	2.167393
S.E. of regression	1.430760	Akaike info criterion	3.557724
Sum squared resid	4741.021	Schwarz criterion	3.577522
Log likelihood	-4126.076	Hannan-Quinn criter.	3.564938
F-statistic	430.6838	Durbin-Watson stat	0.106193
Prob(F-statistic)	0.000000		

Appendix B

Fixed Effects Model

Dependent Variable: Y_?
Method: Pooled EGLS (Cross-section weights)

Sample: 1995M01 2013M12
Included observations: 228
Cross-sections included: 12
Total pool (unbalanced) observations: 2352
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	9.896022	0.303616	32.59388	0.0000
BAS_?	4.260200	0.209771	20.30877	0.0000
CR_?	-0.064554	0.003300	-19.56024	0.0000
INF_?(-1)	0.127467	0.019673	6.479411	0.0000
VOL	0.013210	0.002358	5.602207	0.0000
Fixed Effects (Cross)				
AT--C	-0.142442			
BE--C	-0.535225			
DE--C	0.100441			
EL--C	0.019258			
ES--C	-0.054498			
FI--C	0.049877			
FR--C	0.343855			
IR--C	0.089615			
IT--C	-0.513379			
NL--C	-0.254204			
PT--C	-0.133703			
UK--C	0.722574			

Effects Specification

Cross-section fixed (dummy variables)

Weighted Statistics

R-squared	0.490029	Mean dependent var	5.408621
Adjusted R-squared	0.486754	S.D. dependent var	2.247226
S.E. of regression	1.346329	Sum squared resid	4234.235
F-statistic	149.6434	Durbin-Watson stat	0.086386
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.571640	Mean dependent var	4.707997
Sum squared resid	4760.463	Durbin-Watson stat	0.128378

Dependent Variable: Y_?
Method: Pooled EGLS (Cross-section weights)
Date: 04/04/16 Time: 23:38
Sample: 1995M01 2013M12
Included observations: 228
Cross-sections included: 12
Total pool (unbalanced) observations: 2352
Linear estimation after one-step weighting matrix

Dependent Variable: Y_?
Method: Pooled EGLS (Cross-section weights)

Sample: 1995M01 2013M12
Included observations: 228
Cross-sections included: 12
Total pool (unbalanced) observations: 2352
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	9.965650	0.305707	32.59869	0.0000
BAS_?	4.260839	0.210603	20.23163	0.0000
CR_?	-0.065386	0.003322	-19.68253	0.0000
INF_?(-1)	0.128170	0.019625	6.531136	0.0000
VOL	0.013230	0.002346	5.639444	0.0000
D1	3.835224	0.797988	4.806116	0.0000
D2	1.588313	0.630108	2.520699	0.0118
D3	0.536166	0.445404	1.203776	0.2288
D4	-0.942239	0.309913	-3.040330	0.0024
Fixed Effects (Cross)				
AT--C	-0.125400			
BE--C	-0.528972			
DE--C	0.090460			
EL--C	-0.007238			
ES--C	-0.047645			
FI--C	0.055428			
FR--C	0.333738			
IR--C	0.098900			
IT--C	-0.509608			
NL--C	-0.237258			
PT--C	-0.131867			
UK--C	0.711976			

Effects Specification

Cross-section fixed (dummy variables)

Weighted Statistics

R-squared	0.493175	Mean dependent var	5.406159
Adjusted R-squared	0.489046	S.D. dependent var	2.221593
S.E. of regression	1.338173	Sum squared resid	4175.930
F-statistic	119.4314	Durbin-Watson stat	0.110654
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.577388	Mean dependent var	4.707997
Sum squared resid	4696.592	Durbin-Watson stat	0.148884

Appendix C
Autoregressive Models

Dependent Variable: Y_?
Method: Pooled EGLS (Cross-section weights)

Sample (adjusted): 1995M03 2013M12
Included observations: 226 after adjustments
Cross-sections included: 12
Total pool (unbalanced) observations: 2336
Iterate coefficients after one-step weighting matrix
White diagonal standard errors & covariance (d.f. corrected)
Convergence achieved after 17 total coef iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.031052	0.809565	6.214517	0.0000
BAS_?	1.412087	0.474799	2.974070	0.0030
CR_?	-0.014595	0.008464	-1.724381	0.0848
INF_?(-1)	0.078768	0.013063	6.029716	0.0000
VOL(-1)	-0.002915	0.000831	-3.507562	0.0005
D2	-0.098386	0.018457	-5.330681	0.0000
D3	0.048683	0.066701	0.729864	0.4655
D4	-0.015568	0.038760	-0.401669	0.6880
AR(1)	0.982097	0.003930	249.8810	0.0000
Fixed Effects (Cross)				
AT--C	-0.520560			
BE--C	-0.592393			
DE--C	-0.910703			
EL--C	2.641856			
ES--C	0.054468			
FI--C	-0.880526			
FR--C	-0.700177			
IR--C	0.223173			
IT--C	0.221998			
NL--C	-0.493136			
PT--C	1.731607			
UK--C	-0.302627			

Effects Specification

Cross-section fixed (dummy variables)

Weighted Statistics

R-squared	0.978014	Mean dependent var	7.464162
Adjusted R-squared	0.977834	S.D. dependent var	3.049385
S.E. of regression	0.354939	Sum squared resid	291.7731
F-statistic	5422.332	Durbin-Watson stat	1.616344
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.970575	Mean dependent var	4.692600
Sum squared resid	323.0329	Durbin-Watson stat	1.718586

Dependent Variable: Y_?
Method: Pooled EGLS (Cross-section weights)

Sample (adjusted): 1995M04 2013M12
Included observations: 225 after adjustments
Cross-sections included: 12
Total pool (unbalanced) observations: 2324
Iterate coefficients after one-step weighting matrix
White diagonal standard errors & covariance (d.f. corrected)
Convergence achieved after 18 total coef iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.005262	0.770790	6.493681	0.0000
BAS_?	1.369854	0.543804	2.519023	0.0118
CR_?	-0.011613	0.008187	-1.418522	0.1562
INF_?(-1)	0.058627	0.013177	4.449293	0.0000
VOL(-1)	-0.002444	0.000785	-3.115090	0.0019
D2	-0.106088	0.017233	-6.156168	0.0000
D3	0.052433	0.052901	0.991142	0.3217
D4	-0.018416	0.030735	-0.599197	0.5491
AR(1)	1.182614	0.033148	35.67697	0.0000
AR(2)	-0.202396	0.032517	-6.224345	0.0000
Fixed Effects (Cross)				
AT--C	-0.638708			
BE--C	-0.568844			
DE--C	-0.782054			
EL--C	2.582060			
ES--C	0.104122			
FI--C	-0.744621			
FR--C	-0.582813			
IR--C	0.233009			
IT--C	0.140727			
NL--C	-0.644500			
PT--C	1.370831			
UK--C	-0.143643			

Effects Specification

Cross-section fixed (dummy variables)

Weighted Statistics

R-squared	0.978648	Mean dependent var	7.489753
Adjusted R-squared	0.978463	S.D. dependent var	3.070806
S.E. of regression	0.349180	Sum squared resid	280.7975
F-statistic	5277.877	Durbin-Watson stat	1.971083
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.970921	Mean dependent var	4.683484
Sum squared resid	317.2693	Durbin-Watson stat	2.068006

Appendix D
Seemingly Unrelated Regressions (SUR)

Dependent Variable: Y_?
Method: Pooled EGLS (Cross-section SUR)

Sample (adjusted): 1999M12 2013M12
Included observations: 169 after adjustments
Cross-sections included: 12
Total pool (balanced) observations: 2028
Linear estimation after one-step weighting matrix
White diagonal standard errors & covariance (d.f. corrected)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	12.95169	0.328127	39.47153	0.0000
BAS_?	2.621385	0.292797	8.952897	0.0000
CR_?	-0.105078	0.003356	-31.31493	0.0000
INF_?(-1)	-0.002830	0.002877	-0.983760	0.3254
IR	0.501620	0.022383	22.41109	0.0000
VOL(-1)	0.015594	0.002491	6.260983	0.0000
D4	-0.693137	0.317332	-2.184268	0.0291
Fixed Effects (Cross)				
AT--C	0.305269			
BE--C	-0.494447			
DE--C	-0.008670			
EL--C	-0.639331			
ES--C	0.178871			
FI--C	0.203513			
FR--C	0.259409			
IR--C	0.350546			
IT--C	-0.652254			
NL--C	0.190631			
PT--C	-0.215855			
UK--C	0.522319			

Effects Specification

Cross-section fixed (dummy variables)

Weighted Statistics

R-squared	0.813460	Mean dependent var	1.477550
Adjusted R-squared	0.811882	S.D. dependent var	3.699507
S.E. of regression	0.970248	Sum squared resid	1892.175
F-statistic	515.5981	Durbin-Watson stat	0.454350
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.725621	Mean dependent var	4.521251
Sum squared resid	2731.326	Durbin-Watson stat	0.143398

Dependent Variable: Y_?
Method: Pooled EGLS (Cross-section SUR)

Sample (adjusted): 2000M01 2013M12
Included observations: 168 after adjustments
Cross-sections included: 12
Total pool (balanced) observations: 2016
Iterate coefficients after one-step weighting matrix
White diagonal standard errors & covariance (d.f. corrected)
Convergence achieved after 19 total coef iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.507204	0.785708	7.009225	0.0000
BAS_?	1.300813	0.373588	3.481942	0.0005
CR_?	-0.016486	0.007453	-2.211937	0.0271
INF_?(-1)	0.015973	0.005106	3.128123	0.0018
IR	0.134200	0.058687	2.286716	0.0223
VOL(-1)	-0.004609	0.002257	-2.041540	0.0413
D4	0.007235	0.121050	0.059772	0.9523
AR(1)	0.967509	0.011169	86.62216	0.0000
Fixed Effects (Cross)				
AT--C	-0.621448			
BE--C	-0.578192			
DE--C	-0.960957			
EL--C	2.836931			
ES--C	0.148930			
FI--C	-0.751983			
FR--C	-0.618732			
IR--C	0.349128			
IT--C	0.113870			
NL--C	-0.729372			
PT--C	1.083221			
UK--C	-0.271397			

Effects Specification

Cross-section fixed (dummy variables)

Weighted Statistics

R-squared	0.964632	Mean dependent var	5.677369
Adjusted R-squared	0.964313	S.D. dependent var	7.372506
S.E. of regression	0.911410	Sum squared resid	1658.844
F-statistic	3025.932	Durbin-Watson stat	1.843818
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.969704	Mean dependent var	4.515726
Sum squared resid	301.2340	Durbin-Watson stat	1.705886

Appendix E

Unit Root Tests

Levin-Lin-Chu Unit Root Test: BAS

Pool unit root test: Summary
Series: BAS_AT, BAS_BE, BAS_DE, BAS_EL, BAS_ES, BAS_FI, BAS_FR, BAS_IR, BAS_IT, BAS_NL, BAS_PT, BAS_UK

Sample: 1994M06 2013M12
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 12
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-1.96538	0.0247	12	2297
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-6.43414	0.0000	12	2297
ADF - Fisher Chi-square	118.583	0.0000	12	2297
PP - Fisher Chi-square	241.740	0.0000	12	2339

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Levin-Lin-Chu Unit Root Test: CR

Pool unit root test: Summary
Series: CR_AT, CR_BE, CR_DE, CR_EL, CR_ES, CR_FI, CR_FR, CR_IR, CR_IT, CR_NL, CR_PT, CR_UK

Sample: 1994M06 2013M12
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 5
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	2.40671	0.9920	7	1571
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	2.89816	0.9981	7	1571
ADF - Fisher Chi-square	11.3794	0.6560	7	1571
PP - Fisher Chi-square	13.0354	0.5237	7	1579

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Levin-Lin-Chu Unit Root Test: CR First Difference

Pool unit root test: Summary
Series: CR_AT, CR_BE, CR_DE, CR_EL, CR_ES, CR_FI, CR_FR, CR_IR, CR_IT, CR_NL, CR_PT, CR_UK

Sample: 1994M06 2013M12
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 4
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-13.9170	0.0000	4	886
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-16.5977	0.0000	4	886
ADF - Fisher Chi-square	212.873	0.0000	4	886
PP - Fisher Chi-square	431.533	0.0000	4	894

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Levin-Lin-Chu Unit Root Test: INF

Pool unit root test: Summary
Series: INF_AT, INF_BE, INF_DE, INF_EL, INF_ES, INF_FI, INF_FR, INF_IR, INF_IT, INF_NL, INF_PT, INF_UK

Sample: 1994M06 2013M12
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 12
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	0.64575	0.7408	12	2739
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-5.50803	0.0000	12	2739
ADF - Fisher Chi-square	77.4758	0.0000	12	2739
PP - Fisher Chi-square	72.2242	0.0000	12	2808

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

ADF Unit Root Test: IR

Null Hypothesis: IR has a unit root
Exogenous: Constant
Lag Length: 3 (Automatic - based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.138918	0.2298
Test critical values:	1% level	-3.467418	
	5% level	-2.877729	
	10% level	-2.575480	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(IR)
Method: Least Squares

Sample (adjusted): 1999M04 2013M12
Included observations: 177 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
IR(-1)	-0.021774	0.010180	-2.138918	0.0339
D(IR(-1))	0.176879	0.071959	2.458071	0.0150
D(IR(-2))	0.186640	0.072244	2.583470	0.0106
D(IR(-3))	0.286960	0.068681	4.178151	0.0000
C	0.029804	0.019283	1.545646	0.1240

R-squared	0.233195	Mean dependent var	-0.011299
Adjusted R-squared	0.215363	S.D. dependent var	0.172340
S.E. of regression	0.152659	Akaike info criterion	-0.893385
Sum squared resid	4.008395	Schwarz criterion	-0.803663
Log likelihood	84.06454	Hannan-Quinn criter.	-0.856997
F-statistic	13.07687	Durbin-Watson stat	1.947702
Prob(F-statistic)	0.000000		

Null Hypothesis: IR has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 3 (Automatic - based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.244300	0.0793
Test critical values:	1% level	-4.010740	
	5% level	-3.435413	
	10% level	-3.141734	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(IR)
Method: Least Squares

Sample (adjusted): 1999M04 2013M12
Included observations: 177 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
IR(-1)	-0.042627	0.013139	-3.244300	0.0014
D(IR(-1))	0.171770	0.070957	2.420767	0.0165
D(IR(-2))	0.190484	0.071225	2.674410	0.0082
D(IR(-3))	0.307465	0.068208	4.507766	0.0000
C	0.165573	0.058407	2.834792	0.0051
@TREND("1994M06")	-0.000714	0.000291	-2.458303	0.0150

R-squared	0.259370	Mean dependent var	-0.011299
Adjusted R-squared	0.237714	S.D. dependent var	0.172340
S.E. of regression	0.150468	Akaike info criterion	-0.916816
Sum squared resid	3.871571	Schwarz criterion	-0.809150
Log likelihood	87.13819	Hannan-Quinn criter.	-0.873151
F-statistic	11.97689	Durbin-Watson stat	1.965397
Prob(F-statistic)	0.000000		

Null Hypothesis: D(IR) has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.255440	0.0007
Test critical values:	1% level	-3.467418	
	5% level	-2.877729	
	10% level	-2.575480	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(IR,2)
Method: Least Squares

Sample (adjusted): 1999M04 2013M12
Included observations: 177 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(IR(-1))	-0.387950	0.091166	-4.255440	0.0000
D(IR(-1),2)	-0.439934	0.088339	-4.980076	0.0000
D(IR(-2),2)	-0.267817	0.068795	-3.892948	0.0001
C	-0.003249	0.011652	-0.278815	0.7807

R-squared	0.432412	Mean dependent var	0.000000
Adjusted R-squared	0.422569	S.D. dependent var	0.202961
S.E. of regression	0.154228	Akaike info criterion	-0.878433
Sum squared resid	4.115013	Schwarz criterion	-0.806656
Log likelihood	81.74132	Hannan-Quinn criter.	-0.849323
F-statistic	43.93285	Durbin-Watson stat	1.931760
Prob(F-statistic)	0.000000		

KPSS Unit Root Test: IR

Null Hypothesis: IR is stationary
Exogenous: Constant
Bandwidth: 10 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.800966
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Residual variance (no correction)	1.321476
HAC corrected variance (Bartlett kernel)	12.95246

KPSS Test Equation
Dependent Variable: IR
Method: Least Squares

Sample (adjusted): 1998M12 2013M12
Included observations: 181 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.498619	0.085683	17.49032	0.0000

R-squared	0.000000	Mean dependent var	1.498619
Adjusted R-squared	0.000000	S.D. dependent var	1.152743
S.E. of regression	1.152743	Akaike info criterion	3.127676
Sum squared resid	239.1872	Schwarz criterion	3.145347
Log likelihood	-282.0547	Hannan-Quinn criter.	3.134840
Durbin-Watson stat	0.024301		

Null Hypothesis: IR is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 10 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.102845
Asymptotic critical values*:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Residual variance (no correction)	0.772942
HAC corrected variance (Bartlett kernel)	7.157833

KPSS Test Equation
Dependent Variable: IR
Method: Least Squares

Sample (adjusted): 1998M12 2013M12
Included observations: 181 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.539806	0.192657	18.37360	0.0000
@TREND("1994M06")	-0.014175	0.001258	-11.27080	0.0000

R-squared	0.415092	Mean dependent var	1.498619
Adjusted R-squared	0.411824	S.D. dependent var	1.152743
S.E. of regression	0.884069	Akaike info criterion	2.602425
Sum squared resid	139.9025	Schwarz criterion	2.637768
Log likelihood	-233.5195	Hannan-Quinn criter.	2.616754
F-statistic	127.0310	Durbin-Watson stat	0.041248
Prob(F-statistic)	0.000000		

Null Hypothesis: D(IR) is stationary
Exogenous: Constant
Bandwidth: 8 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.051991
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Residual variance (no correction)	0.032058
HAC corrected variance (Bartlett kernel)	0.085051

KPSS Test Equation
Dependent Variable: D(IR)
Method: Least Squares

Sample (adjusted): 1999M01 2013M12
Included observations: 180 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.015278	0.013383	-1.141607	0.2551

R-squared	0.000000	Mean dependent var	-0.015278
Adjusted R-squared	0.000000	S.D. dependent var	0.179548
S.E. of regression	0.179548	Akaike info criterion	-0.591212
Sum squared resid	5.770486	Schwarz criterion	-0.573474
Log likelihood	54.20911	Hannan-Quinn criter.	-0.584020
Durbin-Watson stat	1.353872		

ADF Unit Root Test: VOL

Null Hypothesis: VOL has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=14)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.320716	0.0005
Test critical values:	1% level	-3.459101	
	5% level	-2.874086	
	10% level	-2.573533	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(VOL)
Method: Least Squares

Sample (adjusted): 1995M02 2013M12
Included observations: 227 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
VOL(-1)	-0.154493	0.035756	-4.320716	0.0000
C	3.724111	0.930199	4.003565	0.0001

R-squared	0.076615	Mean dependent var	-0.013304
Adjusted R-squared	0.072511	S.D. dependent var	5.352261
S.E. of regression	5.154561	Akaike info criterion	6.126413
Sum squared resid	5978.138	Schwarz criterion	6.156588
Log likelihood	-693.3478	Hannan-Quinn criter.	6.138589
F-statistic	18.66859	Durbin-Watson stat	1.963198
Prob(F-statistic)	0.000023		

Zivot-Andrews Unit Root Test with Structural Breaks: VOL

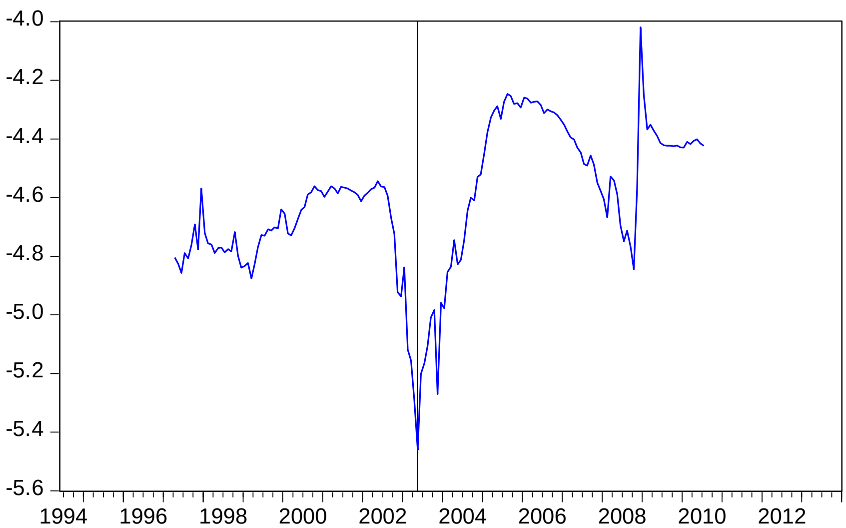
Zivot-Andrews Unit Root Test

Sample: 1994M06 2013M12
Included observations: 235
Null Hypothesis: VOL has a unit root with a structural
break in both the intercept and trend
Chosen lag length: 0 (maximum lags: 4)
Chosen break point: 2003M05

	t-Statistic	Prob. *
Zivot-Andrews test statistic	-5.460803	0.010291
1% critical value:	-5.57	
5% critical value:	-5.08	
10% critical value:	-4.82	

* Probability values are calculated from a standard t-distribution
and do not take into account the breakpoint selection process

Zivot-Andrew Breakpoints



Unit Root Test on Residuals of SUR Model

Group unit root test: Summary
Series: RESIDAT, RESIDBE, RESIDDE, RESIDEL, RESIDES, RESIDFI,
RESIDFR, RESIDIR, RESIDIT, RESIDNL, RESIDPT, RESIDUK

Sample: 1994M06 2013M12
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 3
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-34.0178	0.0000	12	1999
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-32.6007	0.0000	12	1999
ADF - Fisher Chi-square	775.006	0.0000	12	1999
PP - Fisher Chi-square	906.416	0.0000	12	2004

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.

Unit Root Test on Residuals of Stacked Regression

Group unit root test: Summary
Series: RESIDAT, RESIDBE, RESIDDE, RESIDEL, RESIDES, RESIDFI,
RESIDFR, RESIDIR, RESIDIT, RESIDNL, RESIDPT, RESIDUK
Date: 04/07/16 Time: 11:27
Sample: 1994M06 2013M12
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 6
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-0.92064	0.1786	12	2327
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-2.43195	0.0075	12	2327
ADF - Fisher Chi-square	42.1225	0.0125	12	2327
PP - Fisher Chi-square	45.9402	0.0045	12	2336

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.

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