Three Essays on the European Sovereign Debt Crisis with a Special Focus on Greece

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THREE ESSAYS ON THE EUROPEAN SOVEREIGN DEBT CRISIS WITH A SPECIAL FOCUS ON GREECE

by

FLORA LEVENTI

A dissertation submitted to the Graduate Faculty in Economics in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

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This manuscript has been read and accepted by the Graduate Faculty in Economics in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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THE CITY UNIVERSITY OF NEW YORK
ABSTRACT

Three Essays On The European Sovereign Debt Crisis With A Special Focus On Greece

by

Flora Leventi

Advisor: Professor Merih Uctum

This dissertation consists of three chapters where I examine several aspects of the European sovereign debt crisis. The first chapter focuses on systemic risk. Following the financial crisis of 2007-08, both in academic as well as policy circles, much of the research has focused toward the systemic importance of financial institutions. Parallel to that research, but to somewhat lesser extent, there have been improvements in our understanding of how risk is transmitted from the financial system to the real economy. This chapter investigates a related yet distinct manifestation of systemic risk, namely systemic sovereign risk. Using data on sovereign credit default swap spreads from 11 euro member countries the study seeks to examine how the sovereign risk of one member country can affect others, as well as the overall impact in the system. The proposed work is based on the approach of Adrian and Brunnermeier (2010), used to assess systemic risk contributions among financial institutions. Focusing on sovereigns rather than financial institutions, this work will expand a small but growing body of literature examining the recent European sovereign debt crisis.

In the second chapter I present a brief overview of the stylized facts for the Greek economy starting from the period after the end of the military dictatorship and the transition to democracy up until early 2016.

In the third chapter I revisit the issue of fiscal sustainability in Greece in a retrospective framework, meaning that our interest lies in evaluating the sustainability of past fiscal policies and whether
these can lead to a sustainable fiscal path. My empirical analysis uses annual data from 1970 to 2015 from a single source (AMECO). The econometric methodology is divided into two parts. In the first part, I focus on the sustainability of government debt using unit root tests that allow for structural breaks. In the second part, I test for cointegration between government revenues and expenditures with two procedures, namely the Bounds test of Pesaran and Shin and Johansen’s test. The results from both the unit root tests and the cointegration tests indicate Greek fiscal policy is unsustainable. In order to account for structural breaks, I employ the methodology of Bai (1997) and Bai and Perron (1998) and incorporate the breaks when testing for cointegration between government revenues and expenditures. The methodology employs the Dynamic OLS framework of Stock and Watson (1993). Even when I account for structural breaks, I find no evidence of strong form sustainability between the two series. However, my results do not reject the weak form sustainability of Quintos (1995). I argue that evidence of weak form sustainability for Greece can be interpreted as a higher risk of unsustainability, which can be used to explain Greece’s current fiscal distress.
Acknowledgments

This work is dedicated in memory of my father. His passion for knowledge and excellence helped me build and accomplish my own dreams, even though I was not fortunate enough to have him by my side through my studies. Thank you for instilling in me the beauty of the “road less travelled”.

My profound appreciation and gratitude goes to my mother, without whose support and countless sacrifices, I would not have been able to complete or even begin this work. I am also indebted to my uncle, who contributed the most to the completion of my studies.

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I am very grateful to the members of my committee for their patience and support, especially given that I was away from New York during the most critical stages of my dissertation. Also to Professor Herron for sharing his thesis LaTeX template along with very helpful comments.

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Chapter 1

Conditional risk in the euro-zone: Using CDS data of European sovereigns to quantify interconnectivity

1.1 Introduction

The last ten years have undoubtedly been very turbulent for financial markets worldwide. The financial crisis of 2007-2009 wiped out several global financial institutions and led academics and policy makers to re-consider the importance of financial linkages and the role of contagion. Without even having recovered from the credit crisis, financial markets were hit yet again with another crisis - the European sovereign debt crisis. While perhaps not having as far-reaching implications as the financial crisis of 2007-2009, the European sovereign debt crisis has certainly caused significant stress within the Euro area and led many observers into even questioning the effectiveness and purpose of the European Monetary Union and its future.
CHAPTER 1. CONDITIONAL RISK IN THE EURO-ZONE

1.2 Statement of the Problem

There has been a lot of emphasis on studying the co-movements in the credit risk of financial institutions, in other words estimating how the credit risk of one institution affects that of other institutions. Several econometric methodologies and data have been employed to address this question. Most papers, for example, use the CDS spreads of financial institutions, Moody’s KMV model for expected default frequencies, corporate bond spreads, distance to default measures, and Value at Risk (VaR) analysis. An important complication in studying the co-movements of risk measures is that these co-movements will most likely differ depending on the state of the economy and the general market sentiment. In other words, as has been well documented in the literature, co-movements of the risk-measures exhibit a non-linear pattern, and in particular they tend to be more acute in times of distress (i.e. when the risk is higher). This in turn implies the need to use non-linear estimation techniques, such as extreme value theory, regime switching estimation, and quantile regressions.

Compared to the studies focusing on systemic risk in the financial system and the co-movements of risk measures for financial institutions, systemic sovereign risk has received relatively less attention, at least until recently. The European sovereign debt crisis however has lead researchers (mostly at the policy level) to address the issue of sovereign risk and how it can be transmitted between countries.

The increased internationalization of financial markets has led to financial institutions being dependent on economic developments that take place far beyond their origin country. Partly, this is the result of having subsidiaries or holding companies abroad. Moreover, financial innovation in the form of complex financial instruments (such as various derivative products) amplified the interconnectedness among financial institutions, and consequently their interdependence. Our level of understanding of the mechanisms through which risk is transferred between financial firms and the financial system has greatly improved by recent research in that area. A related area that can
benefit by more theoretical as well as empirical work is the spreading of risk from the financial system into the real economy.

Along the same lines, systemic sovereign risk is a promising area for future research. How financial distress experienced in one country can spread to another is a question that is not sufficiently explored. One way in which countries can affect one another is through their interlinked financial institutions, given the common exposures of the latter. Another way, which might have a more direct connection to the real economies of the countries, is through sovereign debt. This is in a sense a special case since it requires that the countries under investigation are part of a system in which they share a common currency, follow the same monetary policy, and have some general formulations regarding fiscal policy that has implications for national debt and deficit levels.

This work seeks to broaden our understanding of systemic sovereign risk by quantifying risk contributions between countries, and between countries and the entire system. The purpose is to develop a systemic risk measure that can identify the systemic importance of certain countries, by how much they are increasing the risk of other countries and the risk of the entire system. Moreover, the goal is to construct a measure that can be used not only to predict systemic sovereign risk contributions but also to forecast them. These last elements can prove to be useful at the policy level. They could be used by regulators and policy makers both at the country as well system level as a tool to guide austerity measures. Additionally, investors and other market participants might benefit from such information.

1.3 Background of the Study

Theoretical and empirical work on systemic risk and concepts related to it has exploded following the financial crisis of 2007-2008. A review of that literature would be a formidable endeavor but it is beyond the purposes of this paper. Instead, this section reviews some of the recent empirical work that is more closely related to this paper, namely systemic risk within the sovereign CDS
4

CHAPTER 1. CONDITIONAL RISK IN THE EURO-ZONE

markets. Before reviewing the literature however, I briefly discuss the characteristics and nature of credit default swaps.

1.3.1 The characteristics of credit default swaps

Without going into great lengths, here I offer an overview of the main characteristics of credit default swaps as financial products, as well as the market and its participants. A credit default swap is one of the most popular types of credit derivative products. It provides insurance against the credit risk of a reference entity which can be company, a sovereign, an index, or a basket of assets. In the case of a single-name CDS the reference entity is either a company or a sovereign, whereas as in a multi-name CDS the reference entity is an index or a basket of assets. Just like in all financial products there are two parties involved in this type of contract: the buyer of protection/insurance and the seller of protection/insurance. The payoff depends on whether or not the reference entity (the company or the sovereign in the case of the single-name CDS) defaults on its obligations, or more specifically if there is a so-called “credit event”. Buying protection gives the right to sell bonds that have been issued by the reference entity for their face value in the case of a credit event. The seller of protection has the obligation to buy the bonds for their face value in the case of a credit event. The buyer of protection pays a periodic fee to the seller (typically every quarter, half year, or year) until maturity or until a credit event occurs. This periodic fee depends on the total face value of the underlying bonds that can be sold; in other words, the notional value. When expressed in annual terms, the premium paid as a percentage of the notional amount is known as the credit default swap’s spread. CDS’s are quoted in basis points, where 1 basis point is equal to 0.01%. Thus, if the CDS spread for Greece is 1,000 basis points or 10% per year, then in order to insure $10 million of debt against default, an investor would have to pay $1,000,000 or 10% of the notional amount of $10 million per year.

1The most widely used multi-name credit derivative is the collateralized debt obligation or CDO
2Recall that the face or par value of a coupon bearing bond is the principal amount that a bondholder receives when the bond matures, given that there is no default
There are several instances that qualify as credit events and thus protection is triggered. According to the International Swaps and Derivatives Association (ISDA)\(^3\) these are: bankruptcy, failure to pay (either the principal or a coupon), obligation acceleration or obligation default, repudiation or moratorium (in the case of sovereign reference entities), and restructuring. If any of these credit events occur, there are two forms of settlement: physical or cash. In physical settlement the protection buyer delivers the defaulted underlying bond and the protection seller pays the face value of the bond\(^4\). In cash settlement, the protection seller pays (in cash) the difference between the face value and the recovery value of the underlying bond. The recovery value is determined at the time when the credit event occurs and depends on the type of credit event\(^5\).

Credit default swaps first appeared during the early nineties and a number of authors attribute their introduction to JP Morgan\(^6\). Since then, the market for credit default swaps has grown significantly even though their use (or misuse) has been heavily criticized by many, especially in relation to the financial crisis of 2007-08\(^7\). In Fig. 1.1 we see the evolution of all over-the-counter derivatives products in terms of notional amount outstanding and gross market values respectively, while Fig. 1.2 shows the evolution of these two measures only for credit derivatives, breaking them down according to the reference entity (i.e. single-name vs. multi-name).

### 1.3.2 The joint dynamics between bank and sovereign CDS spreads

One line of the recent empirical literature examines the relationship between the sovereign and bank CDS markets, with an emphasis on whether and how bank bailout programs have affected

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\(^3\)Credit default swaps are traded over-the-counter (OTC), and as such, are for the most part unregulated. However, the ISDA provides legal and technical guidelines for the trading of OTC derivatives. Moreover, the ISDA has created the ISDA Master Agreement, which is a standardized contract used for transactions of OTC derivatives products. For more information see [http://www2.isda.org/](http://www2.isda.org/).

\(^4\)In most cases, the buyer has the right to deliver any bond that has defaulted and was referenced in the contract, provided that they are of the same seniority. This implies that the buyer of protection essentially buys the so-called cheapest-to-deliver option.

\(^5\)The recovery value is the market value of the bond right after default. This value is set by an auction procedure.

\(^6\)See for example Lanchester (2009), Tett (2006), and Philips (2008) among others.

\(^7\)Stulz (2009) provides a nice overview of the use of credit default swaps and their use before and during the financial crisis.
sovereign CDS spreads. Alter and Schüler (2012) for instance investigate differences in the relationship between sovereign and bank CDS spreads before and after government interventions. They use daily data from June 2007 to May 2010 on a number of euro-zone countries (both core and periphery), and their respective domestic banks. They find that prior to the bailout programs the direction of contagion is from banks to sovereigns, whereas changes in sovereign CDS spreads have only a weak impact both on bank CDS spreads and the sovereign CDS market overall. The previous finding is supported in all countries in their sample with the exception of Italy and Portugal. This implies that there might be important differences between core and periphery countries. They also find a reversal of the relationship after the bailout programs; the effect of changes in banks’ CDS spreads on sovereigns becomes insignificant in the long run and sovereign CDS spreads are the major driver of bank CDS spreads. Finally, the authors find that even though the effects of a sovereign shock on banks is homogeneous at the domestic level, it is country depended when looking across countries and can be grouped into core versus periphery countries. This once again implies that there might be important gains in examining the dynamics of sovereign credit interdependencies across countries.

Acharya, Drechsler and Schnabl (2014) also find support for a two-way feedback effect between the financial sector and euro-zone sovereigns for the period of 2007 to 2011. The authors show that a higher level of stress in the financial sector is associated with greater bank bailouts, increases in sovereign credit risk, and higher debt-to-GDP ratios. Moreover, using bank and CDS data they show that in the period after the implementation of bailout programs, changes in bank CDS spreads are largely explained by changes in sovereign CDS spreads. This result is strong even after controlling for aggregate and bank-specific determinants of CDS spreads. Thus, their main conclusion is that bank bailouts lead to higher sovereign credit risk, which in turn leads to a weakening of the financial sector since it reduces the value of government guarantees and bond holdings.
Ejsing and Lemke (2011) examine the same relationship during the period of January 2008 to June 2009. They find that the introduction of bailout programs led to a decline in bank CDS spreads at the expense of a rise in sovereign CDS spreads. Moreover, the authors find that while the bailout programs decreased the sensitivity of bank CDSs to future shocks, they increased the sensitivity of sovereign CDSs.

Finally, Dieckmann and Plank (2012) highlight the private-to-public risk transfer in countries that implemented bailout programs. Their work focuses on the period from January 2007 to April 2010, using data on eighteen European economies. They show that the state of the financial system, both at a country as well as a global level, are important factors for the behavior of CDS spreads, and the size of this impact depends on how important a country’s financial system is. Moreover, they show that Economic and Monetary Union member countries are more important to the health of the financial system, and because of this the private-to-public risk transfer tends to be larger. Finally, it is worth mentioning that the authors similarly to Alter and Schüler (2012), stress the importance of examining the public-to-public risk transfer, which reinforces the motivation behind the present paper.

1.3.3 The relationship between sovereign CDS and bonds spreads

Some other authors have focused on the relationship between the sovereign CDS and their respective sovereign bonds. Fontana and Scheicher (2010) for example focus on 10 euro area economies for the period from January 2006 to June 2010, using weekly observations on CDS spreads and bond yields. They find that common factors strongly affected the recent repricing of sovereign risk, and argue that some of these factors signal changes in investor appetite for risk. Moreover, the authors find that for the majority of the countries in their sample, CDS spreads are greater than bond spreads which might be attributed to “flight to liquidity” effects and limits to arbitrage. Finally, they find that price discovery in the sovereign CDS and bond markets is heterogenous across countries.
Arce, Mayordomo and Peña (2013) use daily CDS spreads and sovereign bond yields for eleven EMU countries from January 2004 to January 2012 in trying to explain differences in pricing between the two markets by looking at several risk factors and sources of market frictions. For example, they find that counterparty risk and funding costs have a negative effect on the CDS-bond basis, while higher liquidity in the bond market relative to the CDS market has a positive effect on the basis. Finally, the authors show that the price-discovery process is state-dependent and use risk factors and market friction proxies to examine this state dependency. They show for example that the level of counterparty risk lessens the ability of the CDS market to lead the price discovery process, whereas ECB’s debt purchases negatively affect the bond market in leading the price discovery process.

Delis and Mylonidis (2011) focus on four Southern European countries (Spain, Italy, Portugal and Greece) from July 2004 to May 2010, and use 10-year bond and CDS spreads. They conduct a series of rolling Granger-causality tests and find that CDS spreads Granger cause bond spreads almost uniformly. However, at times of increased financial and economic distress, the authors detect feedback causality that they appoint to higher levels of risk aversion.

O’Kane (2012) also finds that CDS spreads Granger cause bond spreads for the case of Spain and Greece, but for Italy and France the direction is reversed, while for Portugal and Ireland he finds evidence of two-way causality. The author uses the 5-year maturity in both the CDS and bond markets for the period from January 2008 to September 2011.

Delatte, Gex and López-Villavicencio (2012) use daily 5-year maturity data on CDS and bond spreads on ten euro-zone member countries (five core and five periphery countries) from January 2008 to July 2010. They use a panel smooth transition regression to study the adjustment process to the equilibrium relationship between CDS and bond prices and find that it is not linear. More specifically, they show that the bond market leads the price discovery process only in the core countries and during tranquil periods. As the level of stress increases however, the CDS market

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8The CDS-bond basis is defined as the difference between the CDS and bond spreads.
leads the discovery process. For countries in the periphery the CDS market dominates both in low and high stress periods.

Calice, Chen and Williams (2013) use a time varying vector autoregression model to study the price discovery process in the sovereign CDS and bond markets paying particular attention to the effect of liquidity differences in the two markets. The authors find evidence of considerable variation in the patterns of the transmission effect (between the CDS and bond markets) between maturities and across countries. Liquidity in the sovereign CDS market appears to have a strong time-varying effect on sovereign bond spreads in several countries, including Greece, Portugal and Ireland. The authors also comment on the importance of studying spillover effects between countries rather than the relationship between the CDS and bond markets in individual countries, providing further support for the present proposal.

### 1.3.4 Sovereign CDS spreads and economic fundamentals

A third strand of literature looks at the relationship between sovereign CDS spreads and economic fundamentals. Aizenman, Hutchison and Jinjarak (2013) use dynamic panel regressions to study the effect of debt-to-tax and deficit-to-tax ratios, as well as other macroeconomic fundamentals, on the pricing of sovereign risk as proxied by CDS spreads. The authors run their analyses on fifty countries with an emphasis on the so called SWEAP (South-West Euro-zone Periphery) countries. Not surprisingly, they find that fiscal and macroeconomic variables are important determinants of sovereign risk. Their interesting finding is that the CDSs of periphery countries are priced much higher compared to countries out of the euro-zone that have similar fundamentals. One possible explanation that the authors offer is that these differences might reflect the market’s negative expectations about future fundamentals in the SWEAP countries.

Ang and Longstaff (2013) study CDS spreads for the U.S. Treasury, a number of U.S. states and several euro-zone countries. They decompose spreads into a systemic and a sovereign specific

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9The SWEAP countries are Spain, Portugal, Italy, Ireland and Greece.
component. They find that systemic risk represents a much larger fraction of total credit risk in the case of European sovereigns as compared to U.S. states. Moreover, they find evidence of a strong correlation between the U.S.’s and euro-zone’s systemic sovereign credit risks, and show that this systemic component is affected by global financial market variables rather than macroeconomic fundamentals.

Caceres, Guzzo and Segoviano (2010) consider two main factors that can explain large movements in sovereign CDS spreads, namely changes in global risk aversion and country-specific risks. They find that global risk aversion and a country’s fiscal fundamentals are both important determinants but at different phases. At the beginning of the financial crisis global risk aversion appears to have played a more important role, while during the more recent sovereign debt crisis, country-specific changes in fundamentals are the main driven behind the increased volatility in sovereign CDS spreads. Moreover, during the early phase, countries that were largely hit by the financial crisis seem to be the source of risk, while during the later sovereign debt crisis countries at the euro-zone’s periphery are the main source of risk.

Finally, Arghyrou and Kontonikas (2012) also find support for a change in factors explaining sovereign CDS pricing. For the period after August 2007 prices are mostly driven by changes in macro fundamentals and international risk factors. Regarding the European sovereign debt crisis in particular, the authors find that initially the main source of contagion was the Greek debt crisis, while after February 2010 sources of contagion include Greece, Ireland, Spain, and Portugal. Finally, the authors find that the rapid worsening of the Greek debt crisis during the period from November 2009 to February 2010 was largely due to adverse market expectations regarding the country’s fiscal fundamentals.

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10The authors distinguish between country specific risks that can affect CDS spreads directly due to a deterioration of a country’s fiscal fundamentals, or indirectly through spillovers from other sovereigns.
1.3.5 Contagion and spillover effects among sovereigns

Most of the recent literature falls within the aforementioned lines. However, a growing fourth body of empirical research and the one that is most related to this paper, investigates the contagion and spillovers effects among sovereigns. The intensification of the European sovereign debt crisis is the main motivation for the authors of the following papers.

Beirne and Fratzscher (2013) detect the presence of contagion during the crisis by distinguishing three types of contagion: fundamentals contagion due to increased sensitivity of financial markets to existing fundamentals, regional contagion arising from an increase in sovereign risk spillovers across countries, and herding contagion due to a simultaneous but transitory overreaction of financial markets. The authors examine the period from 2004 to 2010 for a total of 31 advanced and emerging economies, using CDS spreads, sovereign bond yields, and sovereign credit ratings as measures of sovereign credit risk. During the crisis period, the authors find evidence of fundamentals contagion as financial markets’ sensitivity to country specific economic fundamentals increased compared to the pre-crisis period. Moreover, countries in the periphery of the euro-zone experienced this increase more strongly. Regional contagion appears to have been a less important factor in explaining the rise of sovereign risk. Similarly, herding contagion although present, was short lived and not as strong as the transmission from the fundamentals channel.

Caporin et al. (2013) use a definition of contagion that is based on a change in the propagation mechanisms for the transmission of shocks. They study eight countries (France, Germany, Italy, U.K., Greece, Ireland, Portugal, and Spain) from November 2008 to September 2011 using three econometric methodologies: nonlinear regressions, quantile regressions, and Bayesian quantile regression with heteroskedasticity. Their results indicate that the co-movements of CDS spreads that were observed during the sovereign debt crisis are not the result of a change in the intensity or size of the shock. In other words, the interdependence of spreads and consequently the relationship between different countries is the same during normal and stress times, but this does not mean that

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11 Data on sovereign yields and credit ratings start at 1999.
transmission effects are not present.

Kalbaska and Gątkowski (2012) use the same set of countries (plus the U.S.) as Caporin et al. (2013) but for the period of 2005 to 2010. The authors conduct an exponentially-weighted moving average correlation analysis in four different periods and find that the estimated correlations increased after August 2007. This result is also supported using Granger causality tests. Moreover, impulse response analysis showed that the CDSs of Spain and Ireland have the largest impact on European CDS spreads, whereas the U.K. has the lowest. Finally, focusing on the periods before and after the first bailout package to Greece (May 2010), they perform an adjusted correlation analysis and find that core countries (Germany, France, and the U.K.) have a larger capacity in triggering contagion compared to periphery countries. Portugal is found to be the most susceptible country to shocks, while the U.K. the least.

Bai, Julliard and Yuan (2012) look at eleven euro-zone countries for the period from January 2006 to May 2012. The authors approach contagion by studying correlations in country fundamentals, stemming from local and aggregate credit shocks, as well as liquidity shocks. They set up a stylized rational expectations equilibrium model to illustrate the feedback and spillover effects between credit and liquidity risks. They show that even though liquidity affected sovereign spreads after the credit crisis of 2008, it played a minor role after the late 2009. Additionally, using a VAR model with structural breaks, they find no evidence of a feedback effect from liquidity shocks to fundamental credit shocks both at the domestic and aggregate levels. The authors identify however significant spillover effects stemming from the fundamental credit component. In particular, credit shocks in Belgium, Greece, Ireland, and the Netherlands appear to have significant effects on the aggregated credit shocks in other European countries. In addition, the CDS spreads of Ireland, Italy, and Portugal react positively and significantly to foreign credit shocks. Finally, as the sovereign debt crisis intensified, the observed variation in sovereign bond yields is largely attributed to the fundamental credit risk channel. Thus, the authors conclude that contagion during the European sovereign debt crisis is mainly through the fundamental credit risk channel rather than the
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liquidity one.

In Lucas, Schwaab and Zhang (2014)\textsuperscript{12}, particular attention is given to skewness and heavy-tails, typically observed with high-frequency financial data. The authors estimate joint and conditional probabilities of default using CDS data for ten euro-zone economies for the period from January 2008 to February 2013. Their empirical framework is based on a dynamic skewed t-distribution\textsuperscript{13} allowing for dynamic volatilities and correlations, which takes into account the observed increase in uncertainty and risk dependence during distress. Their analysis yields three main results: Firstly, risk dependence is strongly time-varying (both correlations and volatility increase substantially during stress periods). Secondly, sovereign credit events appear to have significant spillover effects and lead to an overall increase in conditional risk. Lastly, key ECB announcements had a major impact on joint and conditional risk perceptions, as proxied by CDS prices.

Focusing on the case of Greece, Brutti and Sauré (2013) estimate the transmission of shocks originating from Greece to other European countries. Their sample includes twelve countries for the period from January 2008 to March 2011. The authors use financial news shocks that are relevant to Greece’s debt problems, and through a VAR model of CDS spreads identify structural shocks for the remaining eleven countries. In addition, they use cross-country financial exposures on sovereign debt holdings to assess the transmission of these structural shocks in those countries. Their results indicate that cross-country bank exposures to sovereign debt are an important determinant in the transmission of shocks. On the other hand, the authors do not find significant evidence for the transmission of shocks through bank-to-bank lending.

The preceding section briefly reviewed a selection of papers relevant to this paper. Nevertheless, there are far more papers that share a common background with this paper, than there is space available here. A more extensive review of the literature on sovereign CDS spreads can be found\textsuperscript{12}A previous version of this paper appeared as a Tinbergen Institute Discussion Paper under the title “Conditional Probabilities and Contagion Measures for Euro Area Sovereign Default Risk”, 2012. \textsuperscript{13}In particular, they use a Dynamic Generalized Hyperbolic Skewed $t$ Distribution, and consider four parametrizations for time-varying volatility and correlation.
1.4 Conditional risk in the euro-zone

In this section, I undertake the analysis of my proposed model, using the models of Adrian and Brunnermeir (2010), Chan-Lau, Espinosa and Solé (2009) and IMF (2009) as a benchmark, and then providing some slight modifications.

1.4.1 Introduction and background

To remind the reader, my goal is to construct a statistical measure of sovereign systemic risk. Central in the analysis is the concept of value-at-risk (VaR). Instead however of using asset returns we use credit default swap (CDS) spreads and thus the VaR in this case is the threshold value above which the sovereign CDS spreads do not rise above, for a chosen level of confidence. In other words, the VaR for a confidence level \( q \) is defined by:

\[
Pr(X^i_t > VaR^i_q) = q
\]  

(1.1)

where \( X^i_t \) is the value of CDS spread of country \( i \). Note here that in the typical VaR definition for asset returns the above inequality is reversed since in that case we are interested in specifying the threshold value at which the asset returns will not fall below. With CDS spreads however it is the higher values that indicate a worse scenario and not vice versa, hence our definition of the VaR has the inequality reversed. This VaR definition relies on historical CDS values and in our setting, signifies the unconditional VaR. One of the key insights of Adrian and Brunnermeir (2010) was to recognize that looking at the VaR of an institution in isolation might overlook the effect that other institutions can have, thus failing to account for the interconnectivity among financial firms and consequently the level of systemic risk. Instead of using the unconditional VaR the authors
propose a new measure which they call conditional VaR or CoVaR. This is defined as:

\[ Pr(X^i_t > CoVaR^i_j | X^j_t = VaR^j_q) = q \]  

(1.2)

This definition gives the VaR of bank (or country in our model) \( i \), conditional on the event that another bank/country \( j \) has reached a stressful state (i.e. has reached its own VaR level). A large positive number for \( CoVaR^i_j \) would mean that country \( j \) contributes a lot to the risk of country \( i \), or the risk spillover is large. One would therefore expect that when a systemically important country is under stress, the VaR of another country will tend to be higher as well. It is also important to know exactly how much higher the conditional VaR will be compared to the unconditional. This is given in Adrian and Brunnermeir (2010) by \( \Delta CoVaR \):

\[ \Delta CoVaR^i_j = CoVaR^i_j - VaR^i_q \]  

(1.3)

Another way to think of \( \Delta CoVaR^i_j \) is in terms of the externality imposed by country \( j \) on country \( i \). Once again, one would expect this measure to be positive with higher values indicating a higher spillover.

To estimate \( CoVaR \) I follow Adrian and Brunnermeir (2010), Chan-Lau, Espinosa and Solé (2009) and IMF (2009) and use quantile regressions. Quantile regression is of course not the only method to estimate this model. The \( CoVaR \) measure can be estimated from models with time-varying second moments or from models using measures of extreme events. For example, Girardi and Ergün (2013) use a multivariate GARCH model to obtain \( CoVaR \) estimates for a large number of financial institutions, while Zhou (2010) uses a multivariate Extreme Value Theory (EVT) framework to estimate the \( CoVaR \) of financial institutions. One of the main advantages of using the quantile regression framework as opposed to a stochastic volatility or a GARCH model, is that one does not need to make any specific distributional assumptions about \( \epsilon \). On the other hand,
EVT’s major short coming emanates from its exclusive focus on tail realizations, thus ignoring the information content of the main portion of the data.

The quantile regression model that I follow is described by the following equation:

\[ X_i^t = \alpha_{q,i} + \sum_{m=1}^{K} \beta_{q,m}^i R_{m,t} + \gamma_{q,i} X_{j,t} + \epsilon_{i,t} \]  

(1.4)

where \( X_i \) is the first difference of the CDS of country \( i \), \( q \) is the quantile I wish to estimate, and \( R \) is a vector of \( m \) common risk factors.

Before moving on to express the \( CoVaR \) metric, it is worth discussing this model a bit further. First, I should note that Adrian and Brunnermeir (2010) focus on the case where \( i = \) system, i.e. all financial institutions (commercial and investment banks, and insurance and real estate companies). In this way, the authors aim to study the systemic impact of individual financial institutions on the entire financial system, and they term this “Contribution \( \Delta CoVaR \)”\(^\text{14}\). Clearly, there are several conditioning possibilities, and therefore direction matters. Here I examine the case of “Network \( \Delta CoVaR^{|ij} \)”, i.e. the \( VaR \) of country \( i \) conditional on country \( j \) being at its \( VaR \) level. This can be viewed as the most general case. One last possibility is to examine the vulnerability or the exposure that a specific country or financial institution has given the entire system being in distress. Adrian and Brunnermeir (2010) call this “Exposure \( \Delta CoVaR \)”, which measures the extent to which an individual institution (or country) is affected by systemic events. Both Chan-Lau, Espinosa and Solé (2009) and IMF (2009) focus on the case that I examine here in the baseline model, namely the change in the \( VaR \) of \( i \) conditional on \( j \) being in distress (i.e. at its own \( VaR \) level). Regardless of how the conditioning event is defined, it is important to note that I am not making any causal statements here and neither any of the other papers that I have cited. Rather, what I am after are associations or correlations between the metrics of \( i \) and \( j \). For example, when

\(^{14}\)I examine this case as an extension in subsection 1.5.2
estimating the quantile regressions, in one equation we would have the following causal link:

\[ X^i_t \leftarrow R_{m,t}, X_{t,j} \quad (1.5) \]

while in another we would have the opposite:

\[ X^j_t \leftarrow R_{m,t}, X_{t,i} \quad (1.6) \]

From equation (1.4) one could argue that, if the CDS spread of country \( i \) and \( j \) are co-determined then this would possibly lead to reverse causality issues, given that both spreads are at time \( t \). In other words if \( i \)'s spread is an explanatory variable for \( j \)'s spread and vice versa, then this essentially make them endogenous. Therefore, to make any causal statements we would need an instrument.

I have made a strategic choice to focus on associations rather than causation. This is because I feel that the association is of interest on its own, and for many economic questions it is in fact the relevant aspect. Another reason is that finding a good instrument in this particular setting maybe quite challenging, and the consequences of an invalid instrument would bring us back to the original problem arising from endogeneity. Finally, bootstrap techniques could be employed to estimate the covariance matrices, which will be valid even if \( \epsilon^{ij}_t \) and \( \epsilon^{ji}_t \) are not independent of \( X^j_t \) and \( X^i_t \) respectively.

Going back to equation (1.4) the \( CoVaR^{ij} \) is simply the fitted values of the previous quantile
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Quantile regression procedures ensure that the error term, \( \epsilon_i^{ij,q,t} \) evaluated at quantile \( q \) is 0 on average. In fact, the quantile regression in equation 1.4 consists of optimizing the following function:

\[
\min_{\alpha_q, \beta_{q,m}, \gamma_q} \sum_t \left\{ q \left| X_i^{ij,q,t} - \alpha_q - \sum_{m=1}^{K} \beta_{q,m} R_{m,t} + \gamma_q V aR_{q,t}^j \right| \right\} \left\{ (1-q) \left| X_i^{ij,q,t} - \alpha_q - \sum_{m=1}^{K} \beta_{q,m} R_{m,t} + \gamma_q V aR_{q,t}^j \right| \right\}
\]

if \( \left( X_i^{ij,q,t} - \alpha_q - \sum_{m=1}^{K} \beta_{q,m} R_{m,t} + \gamma_q V aR_{q,t}^j \right) \geq 0 \)

and

if \( \left( X_i^{ij,q,t} - \alpha_q - \sum_{m=1}^{K} \beta_{q,m} R_{m,t} + \gamma_q V aR_{q,t}^j \right) < 0 \)

The quantile regression estimators are obtained as the solution to this linear programming problem, for which several algorithms exist (EViews uses a modified version of the simplex algorithm; in Matlab the minimization was done both using “CVX”; a Matlab-based modeling system for convex optimization, as well as standard linear programming techniques using the simplex algorithm. My results were identical for all practical purposes). The estimated quantile regression coefficient can be shown to be asymptotically normally distributed under mild regularity conditions (Koenker (2005)). Moreover, there are several alternatives for estimating the covariance matrices depending on the model assumptions. Koenker (2005) shows that the covariance matrices estimated using bootstrap techniques are valid even if the residuals and explanatory variables are not independent. There are also several other direct methods for independent but not identical distribution settings.

\[
CoVaR_{q,t}^{ij} = \alpha_q^{ij} + \sum_{m=1}^{K} \beta_{q,m}^{ij} R_{m,t} + \gamma_q^{ij} V aR_{q,t}^j
\]

where \( V aR_{q,t}^j \) is the unconditional VaR of country \( j \) based on the empirical sample. Then the \( \Delta CoVaR_{q,t}^{ij} \) is calculated as:

\[
\Delta CoVaR_{q,t}^{ij} = CoVaR_{q,t}^{ij} - V aR_{q,t}^i
\]
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The CoRisk thus express the additional VaR of country $i$ if country $j$ is in distress, as a percentage increase compared to country $i$’s unconditional VaR. The values of the risk factors in the previous formula are those when country $j$ hit that high stress value, i.e. country $j$’s VaR. If this VaR happens to fall in between two values, I take a linear interpolation of the following form:

$$rVaR_{q,low} + (1 - r)VaR_{q,high} = VaR_{q}$$

(1.11)

1.4.2 Data description and sources

Daily data on sovereign credit default spreads were collected for eleven euro-zone economies: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, and Spain. The CDS data refer to 5-year senior contracts and all are denominated in US dollars. I follow the literature and choose the USD denominated contracts as they are the ones that are most liquid and actively traded. For all CDS data I have the mid-price, ask-price, and bid-price. In the analysis, following convention, the mid-price quotes were used. All CDS data were downloaded from the S&P Capital IQ platform, which collects CDS quotes from outside vendors. I performed cross deletion to take care of missing observations. This results in a sample with 1476 observations per series, ranging from April, 02 2008 to June, 03 2014. Table 3.1 presents some basic descriptive statistics of the series. As evident in Fig. 1.3, Greek CDS spreads hit record levels, far above than those of other Southern euro-zone economies. I therefore run 110 regressions for every chosen quantile. Following the literature, I choose the 95th and 99th quantiles. I use the first differences of the CDS data since the level series all contain a unit root (see Fig. 1.4).

I include a set of six common risk factors that have been shown to affect sovereign CDS spreads in the literature. The return on the Eurostoxx 50 index is used to account for the effect of the European stock market. The slope of the yield curve, defined as the difference of the spread between the 10 year and the 3 month US Treasuries, is used as a proxy for the business cycle. The spread between the 1 year Euribor rate and the 1 year US Treasury, is used as a measure of
default risk in the interbank market. I also include the spread between the 3 month EONIA swap rate and the 3 month US Treasury to proxy the severity of liquidity squeeze. The VIX index is used as a measure of the general risk appetite. Finally, I control for currency fluctuation using the appreciation/depreciation of the euro spot rate against the US dollar. The EuroStoxx50 index is obtained from the S&P Capital IQ platform. The VIX index was obtained from the Chicago Board of Options Exchange. The spot exchange rate was obtained from Bloomberg. The 3-month EONIA swap rate and the 1-year Euribor rate were obtained from the European Money Markets Institute. Finally, rates on the US Treasuries were obtained from the Federal Reserve’s website.

1.4.3 Results: Baseline model

Table 1.2 presents my results from the baseline model. All estimated coefficients (the $\beta$’s and the $\gamma$’s are significant at conventional levels. Each entry in the table reports the additional of CoVaR over VaR at the 95th percentile (i.e. $\Delta CoVaR$) for the country listed in the row, when the VaR of country listed in the column has hit its own 95th percentile. For example, when France comes under stress (i.e. when its VaR reaches the 95th percentile), Italy’s VaR at the 95th percentile increases by four basis points or 67% compared to its unconditional VaR. An important observation here is that these effects don’t need to be symmetric, and in fact are not. Moreover, as one can see in Fig. 1.5 the conditional risk as measured by CoVaR is higher than the standalone VaR. The most vulnerable country in my sample is Greece, followed by Portugal. That is Greece registers the highest (on average) increase in the conditional risk measure

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16 An example to illustrate how I get the numbers in the tables: After running the quantile regressions, I compute the estimated values (i.e. the $CoVaR^{ij}_{q,t}$). Recall at this point that the values of the common risk factors are those when country $i$ is at its empirical $q$. This ensures that these values are discrete. To get $\Delta CoVaR^{ij}_{q,t}$ or the absolute increase (in basis points), I subtract the $VaR^i_q$ based on the empirical sample (for any given $j$ and $q$ this will be a constant number), from $CoVaR^{ij}_{q,t}$. Finally, to get the % increase in $\Delta CoVaR^{ij}_{q,t}$ I divide $\Delta CoVaR^{ij}_{q,t}$ by $VaR^i_q$. For example, the $VaR^{95}_{95}$ is 7.5. The $CoVaR^{Austria}_{95,95}$ was estimated to be 11.76. Thus $\Delta CoVaR^{Austria}_{95,95}$ is approximately 4 bps and the % $\Delta CoVaR^{ij}_{95,95}$ is approximately 58%
as the “Vulnerability” index indicates, which is simply the column average for each country when
the corresponding row country is in the same level of distress (the 95th percentile in this case).
In particular, the change in the Greek CDS spread increases on average by 154% or 339 basis
points, when another country reaches its own 95% VaR. Portugal has the second highest excess
of CoVaR over VaR with 22 basis points (or 71%). The most systemically important country is the
Netherlands, having a systemic importance index of 95%. This means that when the Netherlands is
at its own distress state (the 95% value) the CoRisk metric of other countries increases on average
by 95% or 60 basis points. Greece on the other hand is found to have an average systemic impact
of just four basis points. The numbers in the “Systemic Importance” (S.I.) column is simply the
row average for each country.

1.4.4 Results: Model with lagged risk factors

I also consider a model where the set of common risk factors are introduced with a lag. The
main model specification of Adrian and Brunnermeir (2010), the common risk factors are in fact in-
troduced with a lag. This follows from a standard factor model for asset returns, which the authors
present in an appendix. While in my setting the variable of interest is not an asset return as in their
work, I chose to examine the case of lagged common risk factors as an additional robustness test. I
should note that in Chan-Lau, Espinosa and Solé (2009) and IMF (2009), where the main variable
used to define VaR is CDS spreads, the common risk factors enter the model contemporaneously.
In the lagged specification scenario I run the following quantile regression:

\[
X_{i,t} = \alpha_i^{ij} + \sum_{m=1}^K \beta_{q,m}^{ij} R_{m,t-1} + \gamma_i^{ij} X_{j,t} + \epsilon_i^{ij}
\]  

(1.12)

and the conditional risk metric is consequently defined as:

\[
CoRisk_{ij}^t = 100 \times \left( \frac{\alpha_i^{ij} + \sum_{m=1}^K \beta_{q,m}^{ij} R_{m,t-1} + \gamma_i^{ij} VaR_{q,t}^i}{VaR_{q,t}^i} - 1 \right),
\]  

(1.13)
Table 1.3 presents the results from this specification. As one can see my previous conclusions do not change. Greece is again the most vulnerable country; the increase in CoVaR is 348 basis points or 158%, followed by Portugal with an increase of 70 basis points (or 21%). As in the previous model we see that the difference between the first most vulnerable country (Greece) and the second (Portugal) is substantial. The Netherlands once again is the most systemic country; when the Netherlands reach their 95% VaR the average increase in other countries 95% is 60 basis points (the same increase as in the previous model).

1.4.5 Higher stress regime

Tables 1.4 and 1.5 present my results based on a more extreme scenario. In both cases I perform the analysis at the 99th percentile, which compared to my previous models, represent a higher stress state. It is true that the further we go into the tail, we run the risk of producing less reliable estimates given the rare occurrence of extreme points\(^{17}\). However, there is an extensive body of literature that address precisely these issues. For example, Koenker and Bassett (1978) and Bassett and Koenker (1978) provide details on small sample and asymptotic properties of quantile regression, while Chernozhukov and Umantsev (2001) and Chernozhukov and Du (2006) focus specifically on VaR applications of quantile regressions near extremes. In addition, VaR analysis by definition focuses on extreme events, and with respect to the models used in this paper, Adrian and Brunnermeir (2010) run their analysis both at the 5% and at the 1%, while Chan-Lau, Espinosa and Solé (2009) focus only at the 1%. Table 1.4 shows the equivalent of our baseline model, and Table 1.5 shows the model with one lag. One would expect that at higher levels of stress, as represented here by the higher percentile, the conditional risk values would increase. That is as Spain, for example, reaches its 99% VaR the conditional effect it has on other countries’ 99% VaR will be higher, compared to my earlier estimates for the 95% VaR. However, both models indicate that at least in some cases not only the effect is not higher but it actually changes sign, and

\(^{17}\)Recall that my sample size (1476 observations per series) while not small, is still not extensively large
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becomes negative. This implies then that when a country reaches its own 99% VaR the conditional effect on other countries is a drop in their corresponding 99% VaR. This finding isn’t the case for all countries but rather is focused mostly on Greece and in some instances on some other Southern eurozone countries.

More specifically, from Table 1.4 we see that Greece is still the most vulnerable country; it suffers the highest increase in our conditional risk metric when other countries reach their 99% VaR (an increase of 581 basis points). Greece is followed by Portugal once again with an average increase of 45 basis points. In this model the most systemic country appears to be France; when France hits its 99% VaR the average increase in other countries is 176 basis points, followed by Austria (153 basis points). The interesting finding is with respect to the least systemic countries. Greece and Ireland have a negative effect on other countries’ VaR once they hit their 99% VaR. Greece in particular has a negative effect on each country with the exception of Spain. Ireland on the other hand has the expected effect (i.e. positive) on every country but Greece. Ireland’s negative effect on Greece is so big that it makes the average negative as well. Together with Ireland, Portugal also has a negative effect on Greece of 185 basis points, making Portugal the least systemic country with an average of negative 9 basis points.

Table 1.5 presents the results from the model with one lag. Once again Greece is the most vulnerable country followed by Portugal, with an average increase of 491 and 50 basis points in their 99% VaR when another country from the group hits a distress state. The most systemic country is France followed by Austria, as in the previous model. An important difference from the previous model is that the impact of Greece here is positive (with the exception of Ireland) albeit very small; the average increase in other countries’ 99% VaR when Greece is in distress is just 4 basis points or 17%. Moreover, just as before Ireland and Portugal seem to have a negative effect on Greece of -32 and -212 basis points respectively. I also still observe that due to the large negative effect Portugal has on Greece, the average systemic impact of Portugal comes out to be negative, making it the only country having a negative impact. The most interesting perhaps fact in
these results, not evidenced in the previous model, is that the Netherlands show a negative impact on Greece of -149 basis points. That is when the Netherlands reach their own distress state this is associated with a reduction in our conditional systemic risk metric for Greece. The percentage change is not large (-10%) but what makes this particular case interesting compared to the other cases is the fact that before all the negative cases were associated with economies in the eurozone’s periphery, in particular Ireland, Portugal, and Greece.

1.4.6 Conclusions

Based on all previous results I can draw three main conclusions. The first one, which is based on the baseline models (with and without a lag) when \( q = 0.95 \), is that the unconditional \( \text{VaR} \) is always lower than the conditional \( \text{VaR} \) or \( \text{CoVaR} \), leading to a positive difference of the conditional risk metric. In other words, the \( \text{VaR} \) of a country increases conditional on the event that another country has reached it’s own \( \text{VaR} \) level. I also observe that countries in the periphery of the eurozone do not appear to have a very large impact on the conditional risk of core economies, as indicated by the smaller conditional risk metrics (i.e. their systemic importance). Moreover, countries in the periphery seem to be more vulnerable compared to core counties. Based solely on this finding, one might argue that bailing out countries in the periphery of the eurozone was not justified since they do not seem to pose a substantial systemic threat to the core eurozone economies. Of course this would be a rather naive or myopic argument since it does not take into account the socio-political implications of a sovereign default within the eurozone. In fact it only highlights that in this particular definition/formulation of conditional risk, these smaller countries might not be big contributors.

The second conclusion is that, at least for some countries, there appears to be a reversal of their effect on the conditional risk. At higher percentiles (\( q = 0.95 \) vs. \( q = 0.99 \)) the effect instead of being larger as one would expect, becomes not only smaller but negative. As we’ve seen however, this applies to a certain group of countries in the periphery, most notably Greece.
A possible explanation for this is that as Greece’s risk reaches even higher levels it becomes the epicenter of the concern. Thus what other countries experience might appear to be less alarming. In this case Greece’s credit risk becomes so high that it dwarfs that of other countries’. If this is true, then demand for protection against a Greek default would rise substantially while protection against other sovereign defaults would go down. In other words, after a certain threshold for Greece, investors might increase their holdings of Greek CDS while reduce their holdings of other sovereign CDSs, explaining the negative conditional risk metric. The same would be true for the cases of Ireland and Portugal.

The third conclusion is that there is a rather clear divide between periphery and core countries. Countries in the periphery are more vulnerable compared to core countries in all models. Moreover, countries in the periphery also appear to be the least systemic ones compared to countries at the core.

1.4.7 Comparison of results with similar studies

In this section I briefly review the results of some studies similar to this one, either in the main empirical question (qualitatively) or in their methodology (quantitatively). To the best of my knowledge the study by Wong and Fong (2011) is the only one using the CoVaR setup using country data\(^\text{18}\). More specifically, the authors examine the interlinkages between 11 Asia-Pacific economies\(^\text{19}\), using country level CDS data. Using the same approach as the one here, Wong and Fong (2011) find that for most of the countries considered the conditional risk (i.e. the CoVaR) is significantly higher compared to the unconditional risk (i.e. the VaR). More specifically, they find that the VaR of an economy at its 99th percentile increases on average by nine basis points or 45%, when another economy reaches the same level of distress (i.e. reaches its own 99th percentile). The highest $\Delta CoVaR$ (27 basis points) is attributed to Indonesia, making it the most vulnerable

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\(^{18}\)Other studies in which the CoVaR methodology has been employed use financial institution data. 

\(^{19}\)These are: Australia, China, Hong Kong, Indonesia, Japan, Korea, Malaysia, New Zealand, Philippines, Singapore, and Thailand
country in their sample, while Australia and New Zealand have the smallest $\Delta CoVaR$ (3 basis points). Finally, China and Korea appear to lead potentially the biggest impact (i.e. being the most “systemic” countries) with an average of 13 basis points, while Singapore appears to lead to the smallest impact (6 basis points).

In subsection 1.3.5 I reviewed some of the main papers that focus on the European sovereign debt crisis in relation to contagion and spillover effects. Here I remind the reader of the main results as they relate to spillover effects and also present two more relevant studies. Beirne and Fratzscher (2013) do not find evidence of spillovers from countries in the periphery of the euro-zone (i.e. Greece, Ireland, Italy, Portugal, and Spain) to other core countries. In fact, they find some evidence supporting a decrease in regional spillovers during the crisis period. Caporin et al. (2013) show that correlations of CDS changes does not dependent on the size and sign of CDS movements. Moreover, they show that cross-country correlations actually declined as the sovereign crisis intensified. The results of Kalbaska and Gątkowski (2012) show that cross-country correlations increase after August 2007. They also find evidence of a larger impact of core countries (Germany, France, and the U.K.) compared to periphery countries in triggering contagion. Bai, Julliard and Yuan (2012) spillover effects are largely driven by aggregate credit shocks. In particular, the authors find that credit shocks in Belgium, Greece, Ireland, and the Netherlands can have a significant impact on the aggregated credit shocks in other European countries. The work of Lucas, Schwaab and Zhang (2014) shows that there are significant spillover effects which can lead to an overall increase in conditional risk, stemming from a sovereign credit event. In Brutti and Sauré (2013) it is shown that cross-country bank exposures is a major determinant in the transmission of shocks. Heinz and Sun (2014) use a panel GLS error correction model focusing on the period from January 2007 to December 2012 and find that during the European sovereign debt crisis, CDS spread changes in Italy and Spain had the biggest impact on other eurozone country spreads. During the global financial crisis however, Ireland was found to have the highest impact on other euro area economies. Finally, Hurlin, Popescu and Turcu (2013) construct a systemic risk measure
for sovereign risk (SsRisk) which is based on Marginal Expected Shortfall (MES), as proposed by Brownlees and Engle (2010). The authors estimate MES using a Dynamic Conditional Correlation (DCC) model. They use daily government bond yields of eurozone countries together with quarterly sovereign debt data, on the period 2000-2011. The authors find that countries whose public finances have worsened (and thus their sovereign yields are higher), also exhibit higher rankings in their marginal contribution to systemic risk.

1.5 Extensions

1.5.1 Quantile examination

Another way to examine risk codependence based on the quantile regression model I have described is by looking at how the estimated coefficients for the country variables (i.e. \( \hat{\gamma}_{ij} | q \)) change for different levels of risk. That is solving the quantile regression stated earlier for different quantiles. Chan-Lau, Espinosa and Solé (2009) refers to this coefficient as the risk dependence coefficient, which as a function of \( q \) shows how the risk of country \( j \) affects country \( i \). As the quantile \( q \) increases, implying a more stressful regime, we would expect this coefficient to increase as well. Thus at higher levels of risk, risk codependence is expected to be higher or the higher the risk of country \( j \) is the greater the impact will be on country \( i \). Fig. 1.10 shows the average estimated coefficient \( \hat{\gamma}_{ij} | q \) for eurozone countries in the vertical axis as a function of the default risk of another member, sorted by quantiles on the horizontal axis. For example the top right graph for Austria (“source”) shows for a given level of default risk the corresponding default risk codependence arising from Austria as measured by the average value of the coefficient \( \gamma_{ij} | q \) estimated while setting the default risk of countries in the rest of the eurozone as the dependent variable. All coefficients are significant at the 5 percent level. Given that higher quantiles correspond to higher stress levels,

\(^{20}\)This is the average across \( i = 1, \ldots, 11 \) with \( j \neq i \). Thus in each of these graphs, country “\( j \)” or the “source” country is fixed, while country “\( i \)” or the “recipient” country changes.
the upward sloping pattern we see in Fig. 1.10 suggests that codependence rises as default risk rises.

### 1.5.2 Different conditioning events

So far, the analysis has focused on the conditioning event being that another country is in distress, thus focusing on country pairs. However, we can also examine the impact of individual countries on the system as a whole, which in my case is the set of countries in the sample. Furthermore, we can examine the impact that high risk countries have on low risk countries, and vice versa. In other words, look closer at the relationship between core and periphery countries.

In order to examine the impact of individual sovereigns on the system of countries in our sample we need a measure that represents sovereign credit risk in the eurozone. Since there are no Eurobonds and consequently no CDS contracts for the system of countries, I take a weighted average of the CDS spreads of the countries in my sample. I consider two different approaches for the weights; in the first one, weights are determined using GDP and in the second one using public debt. I used all the years in the sample for which annual data are available for both GDP and public debt and I obtained the data from Eurostat. Table 1.8 presents the data and the corresponding weights for the most recent year (2014) along with the averages for entire period (2008-2014) for each country. The system variables are computed as follows:

\[
\bar{X}^{GDP} = \frac{1}{11} \sum_{i=1}^{11} w_i^{GDP} CDS_i
\]

\[
\bar{X}^{Debt} = \frac{1}{11} \sum_{i=1}^{11} w_i^{Debt} CDS_i
\]

\[
\bar{X}^{Simple} = \frac{1}{11} \sum_{i=1}^{11} w_i^{Simple} CDS_i
\]

I estimate the quantile regressions this time using the constructed system variable as the de-
DEPENDENT variable and compute the corresponding CoRisk measures. The corresponding quantile regressions are as follows:

\[
\tilde{X}^{GDP} = \alpha_q \tilde{X}^{GDP|j} + \sum_{m=1}^{K} \beta_{q,m} \tilde{X}^{GDP|j} R_{m,t} + \gamma_q \tilde{X}^{GDP|j} X_{t}^j + \epsilon_t \tilde{X}^{GDP|j}
\] (1.17)

\[
\tilde{X}^{Debt} = \alpha_q \tilde{X}^{Debt|j} + \sum_{m=1}^{K} \beta_{q,m} \tilde{X}^{Debt|j} R_{m,t} + \gamma_q \tilde{X}^{Debt|j} X_{t}^j + \epsilon_t \tilde{X}^{Debt|j}
\] (1.18)

\[
\tilde{X}^{Simple} = \alpha_q \tilde{X}^{Simple|j} + \sum_{m=1}^{K} \beta_{q,m} \tilde{X}^{Simple|j} R_{m,t} + \gamma_q \tilde{X}^{Simple|j} X_{t}^j + \epsilon_t \tilde{X}^{Simple|j}
\] (1.19)

Table 1.9 presents my results for the GDP based and Debt weight system variables. For comparison purposes I also include the results from a model using a simple average to construct the system dependent variable (i.e. a simple average of the changes in CDS spreads of the member countries).

As we can see in Table 1.9 the Netherlands appear to have the largest impact on the system regardless of the way the system variables is created. For example, when the Netherlands are at their VaR level, there is an increase in VaR of the system of 124% using GDP weights and 138% increase using Debt weights. The second largest contributor is Portugal with a 100% increase and 112% using GDP weights and Debt weights respectively. We also observe that both Greece and Ireland are associated with the smallest increase. Thus despite their fiscal wows Greece and Ireland seem to have a minor impact on the overall system, whereas Portugal’s one appears to be rather large despite the fact the weight of Portugal both based on GDP and Debt is very small (1.84 and 2.28 respectively from Table 1.8. These results are fairly consistent with the ones presented in Table 1.2 (the baseline model), where the Netherlands have the highest systemic index of 95% and Portugal has a systemic index of 91%. The same is true for Greece and Ireland; in the baseline model their systemic index is 30%, which is the lowest.

The last aspect of this analysis based on the conditioning event (i.e. which country is taken to be in distress) is to examine core countries against periphery countries and vice versa. I follow both
the relevant literature as well as the industry and the press, and include Austria, Belgium, Finland, France, Germany, and the Netherlands in my set of core countries. Greece, Ireland, Italy, Portugal, and Spain form the group of periphery countries. Note that this classification is very different than grouping countries based on debt or GDP. The core and periphery variables are based on the average CDS spread changes of the countries in the respective groups. In order to compute the systemic risk metrics (CoRisk) we need to specify the risk factor values for the group on which the conditioning is based. I considered to ways to compute the values for the common risk factors in this setting. The first one takes the average of the risk factor values of the countries of each group. The second one is based on the created variables we have for the core and the periphery countries. That is I first calculate the VaR of the two new series. Then the risk factor values are the ones on which the VaR was registered. Once again if the VaR falls between two days I take a linear interpolation as described earlier. Table 1.10 presents the results from the quantile regressions evaluated at \( q = 0.95 \). As we can see the core group of countries appears to have a larger impact on the periphery countries compared to the other way round, in both models. There is a significant difference especially for the impact of the countries in the periphery depending on the way in which risk factor values were computed. I believe that the second way (as depicted by Core2 and Periphery2) is more appropriate because the values are based on the actual new series. Thus, we see that even though core countries have a larger systemic impact on countries in the periphery, the impact of all periphery countries is not negligible (87%).

1.5.3 Different time periods

In this section I perform the analysis on different time periods of the European sovereign debt crisis. The breakdown of the different periods takes into account European Central Bank’s policy interventions and announcements, credit events, the introduction of the European Financial Stability Facility and later on the Securities Markets Programme, among others. Having broken down the sample period into sub-periods I repeat the analysis and construct the new conditional
risk metrics to examine if and how they differ in the different sub-periods.

Deciding which days to use as start and end points of the different subsamples is by no means an easy task. There is plethora of potentially important events and announcements from different sources that apply to different countries or in some cases to a group of countries. Moreover, these announcements and/or events originate from different sources (e.g. politicians, the ECB, the press etc.) and their effect and importance will most likely differ. Finally, some announcements have a positive or “calming” effect on the markets (e.g. announcements of bailout packages and similar deal agreements), while others have a negative or “stressing” effect on the markets (e.g. debt and other budget statistics/revisions that do not meet pre-agreed benchmarks).

Keeping these considerations in mind, I have chosen to break the sample into fairly equal subsamples. The first subsample runs from April 2008 to April 2010. The second subsample from May 2010 to June 2012, and the third subsample from August 2012 to June 2014. The choice to breakdown the sample in this particular way was motivated by considering the main policy responses. The first period does not include any major policy actions regarding sovereign concerns. In fact, it is toward the end of that period that Greece’s sovereign woes became fully and widely disclosed. Thus, even though this period involves so-called credit events, it does not involve policy actions. The second period starts with the EU and IMF announcing a €110 billion bailout package on May 2, 2010. The rest of this period is characterized by a number of sovereign credit events and a widening of CDS spreads (including those of Ireland and Portugal, and several other for Greece), as well as numerous policy actions. Finally, the third period shows a gradual and steady decline in spreads. It is not that this third period does not include adverse credit announcements or policy actions, as the sovereign debt crisis continues well beyond the end of my sample. However, I believe that the impact that these events had on CDS spreads (and the market

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21 The exception to this is the case of Iceland, who is the very first sovereign victim. However, because Iceland is not in my sample nor is part of the euro, I do not focus on its case.

22 “Fully and widely” are not minor points here, as there is a wide held belief that officials both at the IMF and the EU were aware of Greece’s reporting practices and inaccurate statistics.
in general) have a less “shocking” component compared to those in the second period. Moreover, as evidenced in the lowering of the spreads, there is a noticeable change in the pattern of the series, which could be attributable to a lagging effect of some of the policy actions.

Before moving into the results for this part it should be noted that my purpose here is not to examine and evaluate in detail the effect of policy and other announcements. Rather it should be viewed as an extension of my baseline model and whether the previous results hold when looking in different time periods. A closer examination of the impact of policy announcements, bailout packages, and other related credit events or in potential ways that could be used to analyze them, goes beyond the purposes of this paper.

Instead of focusing on the country by country analysis I chose to run the analysis using the system variable that we created in the previous section using GDP weights. Table 1.11 presents my results from the three time periods, together with the results from the full sample for comparison purposes. As one can see, there are significant differences between periods for all countries studied. Moreover, the differences are even more striking if we compare the average of the three periods with the results from the full sample. For example, the average for the three periods for Germany is 39% whereas in the full sample it is 82%. In other cases, such as Greece, the average of the three periods is higher compared to the full sample (44% and 29% respectively).

These results do not point specifically into a general conclusion as in each period the countries with the highest and lowest conditional metrics change. Moreover, they are different compared to the full sample case. Perhaps one important observation is that Greece does not have the lowest conditional risk metric in any of the sample periods. In fact during the third period the increase in the VaR of the system conditional in Greece being at its 95th VaR level is 81%, which is considerably larger compared to the full sample case of 29%.

Perhaps the only safe conclusion to be made given these results is that the time frame of the analysis has a significant impact on the results. This should be expected in some sense since the entire period is characterized by major changes in policy. A closer examination of the impact of
policy changes and actions would be a promising route for future research. For example, in this paper I chose to break the sample into three periods; before, during, and after major policy actions. One could also look at the period before and after policy changes. Finally, it is important to keep in mind that the setup of this methodology already focuses on extreme events, even in the full sample case. Recall that the quantile regressions are conditional on country (or group of countries) \( j \) being in distress. Moreover, the values of the risk factors used to compute the conditional risk metrics are those when the VaR of country (or group of counties) \( j \) is observed. One might therefore argue that key negative events are already embedded in this setup, without breaking the sample into different periods. Of course looking at different periods, will lead to different VaR levels and risk factor values at these VaR levels, which is why the choice of break dates should not just be based on some key event but should rather reflect a regime change.
Figure 1.1: All over-the-counter derivatives; Source: https://www.bis.org
Figure 1.2: Credit derivatives; Source: https://www.bis.org
Figure 1.3: Sovereign CDS spread levels with Greece (top) and without Greece (bottom)
Figure 1.4: First differences of sovereign CDS spreads with Greece (top) and without Greece (bottom)
Figure 1.5: Average CoVaR vs VaR of CDS spread changes with Greece (top) and without Greece (bottom)
Figure 1.6: Systemic Importance - Absolute Increase
Figure 1.7: Systemic Importance - Percent Increase
Figure 1.8: Vulnerability - Absolute Increase
Figure 1.9: Vulnerability - Percent Increase
Figure 1.10: Risk codependence as a function of quantile
Table 1.1: Descriptive statistics of the series

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<th>Austria</th>
<th>Belgium</th>
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<th>Italy</th>
<th>Netherlands</th>
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<td>0.0088</td>
<td>0.0219</td>
<td>0.0089</td>
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<td>Max</td>
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<td>5,672.66</td>
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<td>Min</td>
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<td>-29.7</td>
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<td>Std. Dev.</td>
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<td>6.05</td>
<td>1.72</td>
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<td>598.92</td>
<td>15.27</td>
<td>10.71</td>
<td>2.67</td>
<td>22.57</td>
<td>10.81</td>
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</tbody>
</table>

\(^a\) Statistics are based on the CDS series in first differences.
### Table 1.2: CoRisk metric for changes in sovereign CDS spreads baseline model evaluated at $q = 0.95$, Apr 2008 - Jun 2014

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<th>S.I.$^b$</th>
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$^a$ Each cell gives the estimated increase in the VaR of the economy listed in the column conditional on the economy in the row being at its own VaR level.

$^b$ Systemic Importance is the row average showing the additional risk experienced by other countries when the economy listed in the row is at its VaR level.

$^c$ Vulnerability is column average, which shows the increase in risk suffered by the economy listed in the column when the other economies are under stress.

$^d$ VaR is the 95th percentile of the change in CDS spreads.
Table 1.3: CoRisk metric for changes in sovereign CDS spreads model with one lag, evaluated at $q = 0.95$, Apr 2008 - Jun 2014

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| Vulnerability | 4 | 6 | 1 | 3 | 2 | 348 | 19 | 10 | 3 | 21 | 8 |

\( ^a \) Each cell gives the estimated increase in the VaR of the economy listed in the column conditional on the economy in the row being at its own VaR level.

\( ^b \) Systemic Importance is the row average showing the additional risk experienced by other countries when the economy listed in the row is at its VaR level.

\( ^c \) Vulnerability is column average, which shows the increase in risk suffered by the economy listed in the column when the other economies are under stress.

\( ^d \) VaR is the 95th percentile of the change in CDS spreads.
Table 1.4: CoRisk metric for changes in sovereign CDS spreads baseline model evaluated at $q = 0.99$, Apr 2008 - Jun 2014

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$^a$ Each cell gives the estimated increase in the VaR of the economy listed in the column conditional on the economy in the row being at its own VaR level.

$^b$ Systemic Importance is the row average showing the additional risk experienced by other countries when the economy listed in the row is at its VaR level.

$^c$ Vulnerability is column average, which shows the increase in risk suffered by the economy listed in the column when the other economies are under stress.

$^d$ VaR is the 99th percentile of the change in CDS spreads.
Table 1.5: CoRisk metric for changes in sovereign CDS spreads, model with one lag evaluated at $q = 0.99$, Apr 2008 - Jun 2014

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* Each cell gives the estimated increase in the VaR of the economy listed in the column conditional on the economy in the row being at its own VaR level.

* Systemic Importance is the row average showing the additional risk experienced by other countries when the economy listed in the row is at its VaR level.

* Vulnerability is column average, which shows the increase in risk suffered by the economy listed in the column when the other economies are under stress.

* VaR is the 99th percentile of the change in CDS spreads.
Table 1.6: Systemic Importance

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*a Systemic Importance shows the additional average risk experienced by other countries when the economy listed is at its VaR level.*
### Table 1.7: Vulnerability

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<td>5.9</td>
<td>1.2</td>
<td>12.3</td>
<td>5</td>
</tr>
<tr>
<td>0.92</td>
<td>2.4</td>
<td>3</td>
<td>0.9</td>
<td>1.9</td>
<td>1.2</td>
<td>145.4</td>
<td>8.9</td>
<td>6.7</td>
<td>1.5</td>
<td>14.7</td>
<td>5.4</td>
</tr>
<tr>
<td>0.93</td>
<td>2.8</td>
<td>3.8</td>
<td>1</td>
<td>2.3</td>
<td>1.5</td>
<td>212.4</td>
<td>11.2</td>
<td>7.5</td>
<td>1.8</td>
<td>16.9</td>
<td>6.1</td>
</tr>
<tr>
<td>0.94</td>
<td>3.7</td>
<td>4.4</td>
<td>1.1</td>
<td>2.6</td>
<td>1.6</td>
<td>262.5</td>
<td>13.5</td>
<td>8.2</td>
<td>2.2</td>
<td>19.2</td>
<td>7</td>
</tr>
<tr>
<td>0.95</td>
<td>4.4</td>
<td>5.2</td>
<td>1.4</td>
<td>3.1</td>
<td>1.8</td>
<td>339.5</td>
<td>16.5</td>
<td>9.7</td>
<td>2.6</td>
<td>21.7</td>
<td>8.1</td>
</tr>
<tr>
<td>0.96</td>
<td>4.1</td>
<td>5.9</td>
<td>1.1</td>
<td>3.7</td>
<td>1.7</td>
<td>300.3</td>
<td>17.3</td>
<td>11.4</td>
<td>2.2</td>
<td>25.8</td>
<td>9.7</td>
</tr>
<tr>
<td>0.97</td>
<td>4.3</td>
<td>6.1</td>
<td>1.4</td>
<td>3.5</td>
<td>1.8</td>
<td>519</td>
<td>18.4</td>
<td>13.0</td>
<td>2.7</td>
<td>28.2</td>
<td>13.2</td>
</tr>
<tr>
<td>0.98</td>
<td>5.2</td>
<td>6.8</td>
<td>2</td>
<td>2.9</td>
<td>1.9</td>
<td>429</td>
<td>21.4</td>
<td>13.1</td>
<td>4.2</td>
<td>36.7</td>
<td>17.8</td>
</tr>
<tr>
<td>0.99</td>
<td>7.5</td>
<td>7.2</td>
<td>2.9</td>
<td>2.9</td>
<td>2.3</td>
<td>581</td>
<td>26.7</td>
<td>13.8</td>
<td>6</td>
<td>45.2</td>
<td>19.4</td>
</tr>
</tbody>
</table>

\[a\] Vulnerability shows the average increase in risk suffered by the economy listed when the other economies are under stress.
Table 1.8: GDP, public debt and corresponding country weights

<table>
<thead>
<tr>
<th>Country</th>
<th>Austria</th>
<th>Belgium</th>
<th>Finland</th>
<th>France</th>
<th>Germany</th>
<th>Greece</th>
<th>Ireland</th>
<th>Italy</th>
<th>Netherlands</th>
<th>Portugal</th>
<th>Spain</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP 2014</td>
<td>329</td>
<td>402</td>
<td>204</td>
<td>2,142</td>
<td>2,904</td>
<td>179</td>
<td>185</td>
<td>1,616</td>
<td>655</td>
<td>173</td>
<td>1,058</td>
</tr>
<tr>
<td>GDP 2008-14</td>
<td>307</td>
<td>377</td>
<td>195</td>
<td>2,048</td>
<td>2,679</td>
<td>210</td>
<td>175</td>
<td>1,613</td>
<td>638</td>
<td>174</td>
<td>1,073</td>
</tr>
<tr>
<td>Debt 2014</td>
<td>278</td>
<td>428</td>
<td>121</td>
<td>2,038</td>
<td>2,170</td>
<td>317</td>
<td>203</td>
<td>2,135</td>
<td>451</td>
<td>225</td>
<td>1,034</td>
</tr>
<tr>
<td>Debt 2008-14</td>
<td>246</td>
<td>381</td>
<td>95</td>
<td>1,734</td>
<td>2,020</td>
<td>324</td>
<td>164</td>
<td>1,913</td>
<td>397</td>
<td>186</td>
<td>756</td>
</tr>
<tr>
<td>GDP weights ’14</td>
<td>3.34</td>
<td>4.08</td>
<td>2.07</td>
<td>21.75</td>
<td>29.48</td>
<td>1.82</td>
<td>1.88</td>
<td>16.41</td>
<td>6.65</td>
<td>1.76</td>
<td>10.75</td>
</tr>
<tr>
<td>GDP weights avg</td>
<td>3.23</td>
<td>3.97</td>
<td>2.05</td>
<td>21.58</td>
<td>28.21</td>
<td>2.22</td>
<td>1.84</td>
<td>17.01</td>
<td>6.73</td>
<td>1.84</td>
<td>11.32</td>
</tr>
<tr>
<td>Debt weights ’14</td>
<td>2.96</td>
<td>4.56</td>
<td>1.29</td>
<td>21.68</td>
<td>23.08</td>
<td>3.37</td>
<td>2.16</td>
<td>22.71</td>
<td>4.80</td>
<td>2.40</td>
<td>11.00</td>
</tr>
<tr>
<td>Debt weights avg</td>
<td>3.06</td>
<td>4.75</td>
<td>1.16</td>
<td>21.49</td>
<td>25.17</td>
<td>3.64</td>
<td>1.98</td>
<td>23.89</td>
<td>4.95</td>
<td>2.28</td>
<td>9.19</td>
</tr>
</tbody>
</table>

\(^a\) GDP and Debt values are in billions of euros  
\(^b\) The 2008-14 values for GDP and Debt are the annual averages of GDP and Debt for those years  
\(^c\) The GDP weight for 2014 is the GDP in 2014 for each country divided by the total GDP in 2014 of the 11 countries. The GDP weight average is the average GDP weight for each country in 2008-2014  
\(^d\) The Debt weight for 2014 is the Debt in 2014 for each country divided by the total Debt in 2014 of the 11 countries. The Debt weight average is the average Debt weight for each country in 2008-2014  
\(^e\) The Debt values for 2008-10 are not available for Greece, thus all Debt related values for Greece use years 2010-14
Table 1.9: CoRisk metric for changes in sovereign CDS spreads, evaluated at $q = 0.95$, Apr 2008 - Jun 2014

<table>
<thead>
<tr>
<th></th>
<th>System _ GDP $^b$</th>
<th>System _ Debt $^c$</th>
<th>System _ simple $^d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>41</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>Belgium</td>
<td>90</td>
<td>106</td>
<td>174</td>
</tr>
<tr>
<td>Finland</td>
<td>54</td>
<td>52</td>
<td>72</td>
</tr>
<tr>
<td>France</td>
<td>73</td>
<td>93</td>
<td>137</td>
</tr>
<tr>
<td>Germany</td>
<td>82</td>
<td>100</td>
<td>147</td>
</tr>
<tr>
<td>Greece</td>
<td>29</td>
<td>22</td>
<td>18</td>
</tr>
<tr>
<td>Ireland</td>
<td>36</td>
<td>30</td>
<td>54</td>
</tr>
<tr>
<td>Italy</td>
<td>111</td>
<td>107</td>
<td>137</td>
</tr>
<tr>
<td>Netherlands</td>
<td>124</td>
<td>138</td>
<td>183</td>
</tr>
<tr>
<td>Portugal</td>
<td>100</td>
<td>112</td>
<td>146</td>
</tr>
<tr>
<td>Spain</td>
<td>97</td>
<td>99</td>
<td>147</td>
</tr>
</tbody>
</table>

**Absolute Increase (basis points)**

<table>
<thead>
<tr>
<th></th>
<th>System _ GDP $^b$</th>
<th>System _ Debt $^c$</th>
<th>System _ simple $^d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>0.43</td>
<td>0.57</td>
<td>14.53</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.95</td>
<td>1.5</td>
<td>45.8</td>
</tr>
<tr>
<td>Finland</td>
<td>0.57</td>
<td>0.73</td>
<td>19.02</td>
</tr>
<tr>
<td>France</td>
<td>0.77</td>
<td>1.32</td>
<td>36.04</td>
</tr>
<tr>
<td>Germany</td>
<td>0.86</td>
<td>1.41</td>
<td>38.65</td>
</tr>
<tr>
<td>Greece</td>
<td>0.31</td>
<td>0.32</td>
<td>4.79</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.38</td>
<td>0.42</td>
<td>14.23</td>
</tr>
<tr>
<td>Italy</td>
<td>1.17</td>
<td>1.51</td>
<td>36.08</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1.3</td>
<td>1.96</td>
<td>48.09</td>
</tr>
<tr>
<td>Portugal</td>
<td>1.05</td>
<td>1.59</td>
<td>38.45</td>
</tr>
<tr>
<td>Spain</td>
<td>1.02</td>
<td>1.41</td>
<td>38.52</td>
</tr>
</tbody>
</table>

$^a$ Each cell gives the estimated increase in the VaR of the system conditional on the economy in the row being at its own VaR level.

$^b$ System _ GDP is the system variable using GDP weights

$^c$ System _ Debt is the system variable using Debt weights

$^d$ System _ simple is the unweighted average for the system variable
Table 1.10: CoRisk metric for changes in sovereign CDS spreads: core and periphery model evaluated at \( q = 0.95 \), Apr 2008 - Jun 20

<table>
<thead>
<tr>
<th>Percentage Increase (%)</th>
<th>Absolute Increase (basis points)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Core1</td>
</tr>
<tr>
<td>Core1</td>
<td>142</td>
</tr>
<tr>
<td>Periphery1</td>
<td>48</td>
</tr>
<tr>
<td>Core2</td>
<td></td>
</tr>
<tr>
<td>Periphery2</td>
<td>87</td>
</tr>
</tbody>
</table>

\(^{a}\) Each cell gives the estimated increase in the VaR of the group listed in the column conditional on the group in the row being at its own VaR level.

\(^{b}\) Core1 and Periphery1 use the risk factor values based on the average of the risk factor values of the countries of each group.

\(^{c}\) Core2 and Periphery2 use the risk factor values based on the created variables for the core and the periphery countries.
Table 1.11: CoRisk metric for changes in sovereign CDS spreads, evaluated at $q = 0.95$, subsamples

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage Increase (%)</th>
<th>Absolute Increase (basis points)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Period 1</td>
<td>Period 2</td>
</tr>
<tr>
<td>Austria</td>
<td>42</td>
<td>70</td>
</tr>
<tr>
<td>Belgium</td>
<td>5</td>
<td>51</td>
</tr>
<tr>
<td>Finland</td>
<td>65</td>
<td>24</td>
</tr>
<tr>
<td>France</td>
<td>36</td>
<td>147</td>
</tr>
<tr>
<td>Germany</td>
<td>65</td>
<td>44</td>
</tr>
<tr>
<td>Greece</td>
<td>30</td>
<td>22</td>
</tr>
<tr>
<td>Ireland</td>
<td>30</td>
<td>3</td>
</tr>
<tr>
<td>Italy</td>
<td>20</td>
<td>88</td>
</tr>
<tr>
<td>Netherlands</td>
<td>47</td>
<td>131</td>
</tr>
<tr>
<td>Portugal</td>
<td>53</td>
<td>48</td>
</tr>
<tr>
<td>Spain</td>
<td>24</td>
<td>1</td>
</tr>
</tbody>
</table>

*a* Each cell gives the estimated increase in the VaR of the system conditional on the economy in the row being at its own VaR level. The system variable uses GDP weights.

*b* Period 1: April 01, 2008 - April 31, 2010

*c* Period 2: May 01, 2010 - July 30, 2012

*d* Period 3: August 01, 2012 - June 03, 2014
Chapter 2

The Greek sovereign debt crisis: A brief historical account

2.1 Introduction

In trying to understand the deeper causes and roots of the undergoing Greek debt crisis, it is important to choose the right starting point. In other words, one needs to go back far enough in time in order to fully reveal the entire picture - simply starting at the onset of the crisis (about 6 years ago) would be insufficient. Of course, going back as far as the beginning of the Greek modern state (around the 1830s) seems like a stretch. Rather, a more reasonable starting point would be roughly two decades after the end of WWII \(^1\).

After the end of the civil war in 1949 and up until the early 1970s, Greece’s macroeconomic performance was characterized by strong growth and low inflation. During the 1970’s however, the situation was reversed with growth slowing down and inflation rising. During the 1980s and up until the early 1990s the Greek economy was in a rather bad state. Beginning in the mid-1990s Greece’s economic performance started showing clear signs of improvement. In the years from

\(^1\)The occupation of the Axis Powers ended in October 1944, with the liberation of Athens. Greece regained power of the Dodecanese two years later, with the 1947 Peace Treaty of Italy.
2001 to 2008 growth rates increased, inflation was contained, and unemployment fell. After 2008 and with the international financial crisis intensifying, the economy started slowing down, and by late 2009 the economy entered into a recession, which has yet to come out.

In the next sections, I take a closer look at Greece’s macroeconomic performance in three different time periods, namely the period after WWII and before Greece’s euro area participation, the period after joining the euro and up until the mid-2000s, and finally the period from 2008 up until early 2016.

2.2 The Greek economy after WWII and up until the early 1990s

Greece experienced an economic expansion after WWII, which in a sense is only natural after a war time period. With the funds from the Marshall plan, Greece moved from being mainly an agricultural country to an industrial one. As we can see in Fig. 2.1 the unemployment rate, was however, high compared to today’s standards for most of the advanced economies 2, especially during the mid-1980s and mid-1990s. Moreover, while during the military dictatorship (1967-1974) inflation was relatively modest, prices surged during the period from 1973 to the mid-1990s, with inflation rising an average of about 17.7% 3 (see Fig. 2.2).

The steep rise in inflation in 1973 was not only due to the first oil shock of 1973/74, and the subsequent rise in the prices of commodities and raw materials. Another important reason was the collapse of the Bretton Woods system a couple of year earlier. Greece was part of the Bretton Woods system from 1953 until its collapse in August 1971, with the drachma pegged to the US dollar (which was pegged to gold). The final main reason for the acceleration of inflation after 1973 is slightly more complicated. As was mentioned earlier, the period after the end of the civil war in

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2 Here I do not refer to Greece’s current unemployment rate as today’s standard.
3 This figure is based on the simple average change of the CPI inflation rate from 1973 to 1995.
1949 was characterized by strong growth and monetary stability. Up until the onset of the military junta in 1969, the political regime despite its repressive nature followed relatively prudent fiscal and monetary policies. Investment both public (especially in large infrastructure projects) and private increased considerably, while government consumption spending declined. The Currency Committee\(^4\), which was established in 1946, was responsible for the conduct of monetary, credit, and foreign exchange policy, and while the banking system was heavily controlled, the Committee directed reserves and savings into high return sectors. Moreover, because labor unions were under firm government control, labor cost increases were contained. This together with increases in productivity helped keep inflation at low levels and created a favorable business environment, which was also fostered by low business taxes and property rights legislation. Unfortunately, the expansionary policies during the dictatorship, the great expansion of domestic demand, the high reliance on foreign aid, and the high trade deficits, led to an overheating of the economy. By 1969 the Greek economy was operating near full capacity. This together with sticky wage and price adjustment due to administrative controls is the third reason why inflationary pressures started in the early 1970s.

Most of Greece’s governments after the military dictatorship tried to battle stagflation by following expansionary fiscal policies, and in particular by leveraging deficit spending, while monetary policy was to a large extent accommodative. It is important to realize that the first governments after the dictatorship faced significant social pressures for a redistribution of income and wealth (mostly through wage policy) and for a more liberal political system. Moreover, the public wanted an active role of the state both as a producer as well as an employer, with the ultimate goal of improving living standards to levels comparable to those of Western European countries. The election of 1981 brought the socialist party Panhellenic Socialist Movement (PASOK) and Andreas Papandreou into power who satisfied these demands, even to the point of excess, as did the

\(^4\)The Currency Committee was part of a series of newly established government agencies. It reflected the need for a closer cooperation between the government and the Bank of Greece in order to cope with the economic challenges the country faced after the end of WWII and the civil war.
following governments up until the early 1990s. Consequently, Greece’s public debt ballooned (see Fig. 2.3 and Fig. 2.4).

Greece had parliamentary elections in 1993, which were won by PASOK and Andreas Papandreou. The new government did not follow the fiscal consolidation and structural reform plans of the departed government of New Democracy (ND). The steep rise in the debt ratio in Fig. 2.3 is mostly due to the increase in interest payments. Moreover, while the primary balance in 1992 was in surplus, after the elections in 1993 it turned into a deficit.
At some point in the mid-1980s it had become apparent that the fiscal policies pursued were not sustainable. This lead the government\footnote{PASOK at that time}, through the Bank of Greece, to two significant devaluations of the drachma, in 1983 and 1985.\footnote{In 1983 the drachma was devalued by 16\% against the US dollar and by 15\% against the ECU. In 1985 the} Moreover, in another attempt to control the fiscal situation, a
program of fiscal and monetary tightness, known as the 1986-1987 Stabilization Program, was adopted in 1985 only to be abandoned in late 1987. This together with the relaxation of wage controls and the political uncertainty during the years from 1987 to the early 1990s\(^8\) pushed the inflation rate back up and worsened the deficit. In the elections of 1990 the new government of ND initiated another medium-term adjustment program for the years 1991 to 1993 with the goal of bringing the deficit down and lowering inflation. However, the measures did not prove sufficient and there was also little progress concerning structural reforms, with large deviations from the original targets. The political cycle and the elections of 1993 contributed to the deterioration of fiscal figures. Moreover, the recession in the EU during the early 1990s had a large negative impact on the Greek economy.

With high unemployment, high inflation, and rising debt and deficit levels it was no surprise that Greece had to pay a much higher premium in international markets in order to borrow more, compared to other countries in the upcoming monetary union (see Fig. 2.5).

### 2.3 The Greek economy from the mid-1990s and up until the mid-2000s

Greece became the 10th member of what was then known as the European Economic Community (EEC) in 1981, almost 20 years after its initial application.\(^9\) This long delay was partly

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\(^8\)During this period a major political and financial scandal broke out, with George Koskotas, a then prominent Greek banker being at the center. The scandal ultimately brought down the PASOK government in 1989 and had major political consequences for both PASOK and ND, as well as for the general political scene and its relation to the press and the banking system.

\(^9\)Greece was in fact the first European country to sign an Association Agreement with the European Community, which at the time included Belgium, France, Italy, Luxembourg, the Netherlands, and West Germany, in July 1961. This agreement, which is known as the Athens Agreement, provided for the establishment of a customs union, the gradual development of common policies in the agricultural sector, free movement of labor and no transport barriers, fiscal policy harmonization, and common rules for competition and economic policy. It also included provisions for making resources available to Greece in order to facilitate its economic development.
due the suspension of accession efforts during the Colonels’ regime\textsuperscript{10}, but also because Greece’s economy was not entirely ready for an integration of this type.\textsuperscript{11} Full economic integration with Europe was one of the main priorities of Greek governments starting in the mid-1990s. Securing access to the European monetary union and adopting the common currency was Greece’s ultimate goal. As such, Greece worked in an effort to lower inflation and bring down the deficits in order to satisfy the obligations of the Maastricht Treaty\textsuperscript{12}, which was the road to the creation of the common currency. The Maastricht Treaty specified five obligations, the so-called Maastricht or euro-convergence criteria. These were: 1) Inflation no more than 1.5\% above the average of the three lowest inflation rates of the other member states, 2) The annual government deficit to GDP must be below 3\%, 3) The government debt to GDP ratio must not be above 60\%, 4) The nominal long-term interest rate must not exceed 2\% higher than the average of the three lowest inflation

\textsuperscript{10}The Athens Agreement was suspended and limited only to matters of day-to-day management until democracy and parliamentary structures were restored. The military dictatorship, more generally, was a period of diplomatic isolation with Greece even having to leave the Council of Europe in 1969.

\textsuperscript{11}There are other geopolitical reasons for this delay, which are inevitably related to economic performance, but their analysis goes beyond the scope of this paper.

\textsuperscript{12}The Maastricht Treaty was signed in 1992 by twelve European countries, namely, Belgium, Denmark, France, Germany, Greece, Italy, Ireland, Luxembourg, the Netherlands, Portugal, Spain, and the United Kingdom.
member states, and 5) Participation in the exchange rate mechanism (ERM II) for two consecutive years with no devaluation of the domestic currency during that period.

Beginning in the mid-1990s successive Greek governments adopted a tight fiscal policy stance. In 1994 the government (PASOK) announced a new convergence program for the years 1994 to 1999 in order to bring down the deficit, stabilize the debt to GDP ratio and lower inflation. Monetary policy during that period was also tightened and focused on an exchange rate target (the so-called “hard-drachma policy”). As we can see in Fig. 2.6 Greek inflation fell sharply during the 1990s, reaching comparable average euro-area levels. Furthermore, with the participation of the drachma into the European Exchange Rate Mechanism (ERM) in 1998 fiscal and monetary policies were redefined once more. The government adopted additional budgetary measures, including incomes policy and several structural reforms were introduced, such as privatizations in the banking industry, labor market reforms, and liberalizations in the energy and telecommunications sectors.

![Figure 2.6: Annual CPI Inflation](image)

As noted earlier, one of the requirements of the Maastricht Treaty was that deficits had to be
CHAPTER 2. THE GREEK SOVEREIGN DEBT CRISIS

under 3% of GDP. As we can see in Fig. 2.7, deficits improved throughout much of the 1990s. However, there has been much discussion concerning the deficit in 1999, which was the reference year used when Greece gained access to the European and Monetary Union of the European Union in 2000, and whether it was in fact below the 3% rule. The issue was raised by Eurostat, who refused to validate the data that had been provided by the National Statistical Service of Greece. The main reasons for the dispute were due to a change in the official EU calculation methodology concerning national and regional accounts (ESA79 to ESA95), as well as a temporary change by the Greek government in the way military expenses were recorded. An internal financial audit conducted by the Greek government (New Democracy) in 2004 showed that indeed the deficit numbers were below the 3% rule when using the old ESA79 methodology that was in place at the time Greece and all other euro-zone members applied for entry. Under the ESA95 methodology however, the deficit would have been slightly above the 3% limit, with Greece not being the only country exceeding the 3% rule.

As mentioned earlier, Greece had met the Maastricht criteria, and thus qualified to join the euro in 2000; one year after the original introduction of the common currency. However, it took another year for Greece to actually be admitted (January 2001). As we have seen earlier, Greece’s national currency, the drachma, was subject to high rates of inflation. The adoption of the new currency provided stability and confidence since it was backed by the European Central Bank. Consequently, Greece was able to borrow at much lower rates in financial markets. As a result, yields on Greek government bonds converged to the yields of other sovereigns that were part of the euro-zone. Did financial markets all of a sudden dismiss their concerns regarding the Greek economy and its rather unstable economic past? This is a question that has no easy answers and it

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14 The ESA methodology for reporting national and regional accounts is adjusted periodically to reflect changes that in the general economic environment. The adaptation in the way in which macroeconomic statistics are compiled and Eurostat’s methodology is similar to the one used by the United Nations Statistical Commission (System of National Accounts, or SNA). The current ESA methodology is the ESA 2010 which is in line with the 2008 SNA
15 Euro coins and notes replaced all national currencies (12 at that time) in January 2002.
is both relevant and of much interest. Looking at Fig. 2.8, we can see that after 2001 and up until the Great Recession of 2008-09, Greek and German sovereign yields were almost the same. This would imply that the sovereign credit risk of Greece and Germany were practically the same. Few people today would agree that this was true. At that time, however, financial markets seemed to think that the two countries had similar, if not identical, sovereign risk.

Greece certainly benefited from joining the common currency. Although recently another point of debate—heated perhaps—is whether the prosperity that followed by adopting the common currency was real or fictional, most people would agree that at least for a number of years the benefits exceeded the costs. And in fact, any negative consequences that might have come as a result of giving up the drachma and monetary independence have to do more with Greece’s deep-rooted structural problems, inefficiencies, and the lack of political will to correct them, and less with the adoption of the euro per se. This is evidenced in Fig. 2.9. Greek quarterly GDP growth accelerated in the years after it joined the common currency union. More specifically, between 1996 and 2006, quarterly economic growth increased by an average of 3.9\% compared to the previous year\textsuperscript{16}. Du-

\textsuperscript{16}Annualized rate
ring the same period, the euro-zone as a whole grew at about 2.2%. Moreover, living standards improved significantly. Real GDP per capita increased from €15,000 in 1995 to €22,000 in 2006\textsuperscript{17} or by 47% (see Fig. 2.10).

Unfortunately, however, some other numbers also increased. Only these ones were not for the best. I am of course referring to government finances, which worsened. All of the efforts that Greece has made to improve its finances and bring down the deficits in order to join the euro, seemed to phase-out and eventually deteriorate as we can see in Fig. 2.11, especially after 2002. While Fig. 2.11 gives us an aggregate picture of the problem, it is useful to examine the government’s budget in more detail. In Fig. 2.12 we see the evolution of the main aggregates of the general government. We can see that the general government’s total expenditures (i.e. including interest) have been above total revenues for the entire period shown. Moreover, in 2000 primary expenditures surpassed revenues and have been higher than revenues up until recently. It is also worth noticing the upward trend of both primary and total expenditures after the late 1990s, while

\textsuperscript{17}Per capita figures in 2010 Euros
revenues remained relatively flat. Fig. 2.13 and Fig. 2.14 present the main revenue sources for the general government (as a % of GDP and in billions of euros respectively). The main interesting feature of the revenue figures is the low contribution to the overall revenue from taxes on income.
and property, compared to the taxes on production and from social contributions. Also, note how closely taxes series follow total revenues. In fact, from 1995 to 2008 the overall contribution of taxes to the revenues of the general government averaged 52.5%. In Fig. 2.15 and Fig.2.16 we
Figure 2.13: Revenue of General Government as % of GDP

Figure 2.14: Revenue of General Government (in bil. €)
see the breakdown of expenditures of the general government (as a % of GDP and in billions of euros respectively). We can see the upward trend in social benefits and their large share in primary expenditures. Moreover, compensation of employees as a share of GDP remained relatively flat in the period shown, together with intermediate consumption (i.e. goods and services). The large spike in 2013 of capital transfers is due to the amounts that were transferred to financial institutions, more specifically the four large systemic banks (National Bank of Greece, Alpha Bank, Piraeus Bank, and Eurobank Egrasias). These capital transfers were carried out by the Hellenic Financial Stability Fund (HFSF), a Greek special purpose vehicle that was established in July 2010 as a state-owned private legal entity. The HFSF is funded by the European Financial Stability Fund (EFSF) with the purpose of maintaining the stability of the Greek banking system. The capital transfers during the year of 2013 were divided between banks’ recapitalizations, share capital increases, and resolution cases following the merger of ten Greek banks into the four systemic banks mentioned above.

Finally, Fig. 2.17 shows the primary and overall balance of the general government, while Table 2.1 and Table 2.2 present the data in detail.
CHAPTER 2. THE GREEK SOVEREIGN DEBT CRISIS

Figure 2.15: Expenditure of General Government as % of GDP

Figure 2.16: Expenditure of General Government (in bil. €)
Figure 2.17: Primary balance and overall balance of General Government as % of GDP
### Table 2.1: Main aggregates of general government, 1995-2004 (as percentage of GDP)

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Revenue</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxes on production and imports, receivable</td>
<td>12.3</td>
<td>12.6</td>
<td>12.7</td>
<td>12.4</td>
<td>13.0</td>
<td>13.1</td>
<td>12.7</td>
<td>12.8</td>
<td>12.1</td>
<td>11.6</td>
</tr>
<tr>
<td>Taxes on income and property, receivable</td>
<td>6.6</td>
<td>6.4</td>
<td>7.1</td>
<td>8.5</td>
<td>8.9</td>
<td>9.8</td>
<td>8.6</td>
<td>8.9</td>
<td>8.1</td>
<td>8.1</td>
</tr>
<tr>
<td>Social contributions</td>
<td>10.4</td>
<td>10.4</td>
<td>10.6</td>
<td>10.8</td>
<td>11.0</td>
<td>11.6</td>
<td>11.7</td>
<td>12.6</td>
<td>12.5</td>
<td>12.1</td>
</tr>
<tr>
<td>Other current revenue</td>
<td>5.4</td>
<td>5.3</td>
<td>5.4</td>
<td>5.0</td>
<td>5.1</td>
<td>5.1</td>
<td>5.9</td>
<td>4.7</td>
<td>4.7</td>
<td>5.5</td>
</tr>
<tr>
<td>Capital transfers, receivable</td>
<td>1.6</td>
<td>2.3</td>
<td>1.8</td>
<td>2.2</td>
<td>2.3</td>
<td>2.9</td>
<td>1.6</td>
<td>0.8</td>
<td>1.4</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Total expenditure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td>Primary expenditure</td>
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<td>34.8</td>
<td>35.4</td>
<td>37.5</td>
<td>38.6</td>
<td>39.6</td>
<td>39.7</td>
<td>40.2</td>
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<td>Compensation of employees</td>
<td>10.2</td>
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<td>10.3</td>
<td>10.2</td>
<td>10.3</td>
<td>10.5</td>
<td>10.4</td>
<td>10.9</td>
<td>10.6</td>
<td>11.3</td>
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<td>Social benefits</td>
<td>13.0</td>
<td>13.0</td>
<td>13.0</td>
<td>13.3</td>
<td>13.8</td>
<td>14.5</td>
<td>14.9</td>
<td>14.9</td>
<td>15.5</td>
<td>15.1</td>
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<tr>
<td>Goods &amp; services</td>
<td>5.3</td>
<td>5.5</td>
<td>5.0</td>
<td>5.2</td>
<td>5.5</td>
<td>5.3</td>
<td>6.0</td>
<td>5.7</td>
<td>5.9</td>
<td>6.4</td>
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<td>Subsidies, payable</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.1</td>
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<tr>
<td>Other current transfers, payable</td>
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<td>1.8</td>
<td>1.4</td>
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<td>1.6</td>
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<td>2.0</td>
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<td>Capital transfers, payable</td>
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<td>4.6</td>
<td>5.6</td>
<td>7.0</td>
<td>7.3</td>
<td>7.6</td>
<td>6.9</td>
<td>7.2</td>
<td>8.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Interest payments</td>
<td>10.7</td>
<td>10.3</td>
<td>8.3</td>
<td>7.7</td>
<td>7.6</td>
<td>6.9</td>
<td>6.3</td>
<td>5.6</td>
<td>4.9</td>
<td>4.8</td>
</tr>
<tr>
<td><strong>Primary balance (excluding interest)</strong></td>
<td>1.0</td>
<td>2.1</td>
<td>2.3</td>
<td>1.4</td>
<td>1.8</td>
<td>2.8</td>
<td>0.8</td>
<td>-0.5</td>
<td>-2.9</td>
<td>-4.0</td>
</tr>
<tr>
<td><strong>Overall balance</strong></td>
<td>-9.7</td>
<td>-8.2</td>
<td>-6.1</td>
<td>-6.3</td>
<td>-5.8</td>
<td>-4.1</td>
<td>-5.5</td>
<td>-6.0</td>
<td>-7.8</td>
<td>-8.8</td>
</tr>
</tbody>
</table>

*Source: The Greek Economy, ELSTAT, various issues and OECD Economic Outlook, various issues*
Table 2.2: Main aggregates of general government, 2005-2014 (as percentage of GDP) cont.

<table>
<thead>
<tr>
<th>Year</th>
<th>Revenue</th>
<th>Total expenditure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>39.4</td>
</tr>
<tr>
<td>Taxes on production and imports, receivable</td>
<td>11.9</td>
<td>12.2</td>
</tr>
<tr>
<td>Taxes on income and property, receivable</td>
<td>9.0</td>
<td>8.3</td>
</tr>
<tr>
<td>Social contributions</td>
<td>12.3</td>
<td>11.9</td>
</tr>
<tr>
<td>Other current revenue</td>
<td>4.4</td>
<td>4.3</td>
</tr>
<tr>
<td>Capital transfers, receivable</td>
<td>1.9</td>
<td>2.4</td>
</tr>
<tr>
<td>Primary expenditure</td>
<td>40.9</td>
<td>40.7</td>
</tr>
<tr>
<td>Compensation of employees</td>
<td>11.4</td>
<td>11.0</td>
</tr>
<tr>
<td>Social benefits</td>
<td>16.0</td>
<td>16.5</td>
</tr>
<tr>
<td>Goods &amp; services</td>
<td>5.9</td>
<td>6.3</td>
</tr>
<tr>
<td>Subsidies, payable</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Other current transfers, payable</td>
<td>2.1</td>
<td>1.7</td>
</tr>
<tr>
<td>Capital transfers, payable</td>
<td>5.4</td>
<td>5.2</td>
</tr>
<tr>
<td>Interest payments</td>
<td>4.7</td>
<td>4.4</td>
</tr>
<tr>
<td>Primary balance (excluding interest)</td>
<td>-1.5</td>
<td>-1.5</td>
</tr>
<tr>
<td>Overall balance</td>
<td>-6.2</td>
<td>-5.9</td>
</tr>
</tbody>
</table>

*Source: The Greek Economy, ELSTAT, various issues and OECD Economic Outlook, various issues*
Before proceeding to the next section there are a few final points that are worth summarizing. First, for the period from 1994 to 1999 it is important to note that the composition of fiscal consolidation was not ideal. While, as we have seen, deficits did decline, the consolidation was based mostly on tax increases and falling interest payments, while at the same time primary expenditures increased. Moreover, a major issue was that Greece entered the European Monetary Union with a serious drawback: its debt to GDP ratio, although it had been stabilized, it was over 100% of GDP. Second, the period from 2000 to 2004 was the first phase of euro participation, which inevitably led to more lose monetary policy, including lower interest rates (as we have seen), the easing or elimination of credit restrictions, and a drop in the reserve requirement. During this phase fiscal policy instead of counterbalancing the fixed monetary stance, was progressively relaxed as well, with tax reductions behind the revenue shortfalls and primary expenditure increased behind the total expenditure overruns\(^{18}\). As a result, the primary surplus turned into a deficit in 2002, marking the start of a significant deterioration both for the primary as well as the overall balance. These adverse effects were not offset by the positive developments in economic activity, such as lower inflation, low interest rates and higher GDP growth fueled by higher investment and consumption growth. Thus, during the 2000-2004 period the debt to GDP ratio remained relatively flat. The final outcome of this period was that Greece became subjected to the Excessive Deficit Procedure (EDP)\(^{19}\) in May 2005, shortly after the Greek elections that were won by ND. Finally, given that the EDP was initiated fiscal policy was in a sense predetermined. The government of ND had to cut down the deficit at 3% of GDP by the end of 2006. Unfortunately, however the measures that the government took to curb expenditures were not enough, and even though the deficit appeared to be below the 3% limit by end of 2006, later revisions proved otherwise. In fact, the fiscal measures deteriorated even further in 2007. But based on the figures reported initially, the EDP was terminated, which raises some questions regarding the European Union’s and Eurostat’s degree of

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\(^{18}\)The expenditure overruns were also partly due to the Olympic Games of 2004, which were held in Athens

\(^{19}\)EDP is the European Union’s detailed outline for the correction of excessive deficit (over 3% of GDP) or debt levels (over 60% of GDP)
2.4 The Greek economy during the late 2000s and up until early 2016

During the period leading to the financial crisis of 2008-09, Greek debt levels were relatively high in line with the high deficit levels that were mentioned before. In addition, GDP growth started to show the first signs of a slow-down. The overall heightened anxiety in financial markets during that period also attracted investors’ attention to Greece, especially after the elections of 2009 which brought PASOK into power. The newly elect President George Papandreou revealed that the actual deficit was over two times higher than the one that had been reported by the previous government of New Democracy (ND) (12.6% vs. 6% of GDP). There were three main reasons for the revision: 1) the GDP growth rate was also revised downward during that year, 2) the adjustment for social security funds, and 3) the addition of data figures from a number of public sector enterprises into the general government budget. This had a direct impact on Greek sovereign yields as we can see in Fig. 2.18, which returned to pre-euro-zone entry levels. Clearly, Greek and German debt were no longer considered to bear the same credit risk.

The period after the revelation of the revised deficit numbers (2009) and up until today is characterized by constant efforts, negotiations, conflicts and tension between the European Commission, the International Monetary Fund, the European Central Bank, and the several Greek governments that have come into power. The first period of negotiations led to Greece’s first bailout package in May 2010. The Greek government promised to impose severe austerity measures (pension cuts, reduction of the public sector and reductions in public sector wages, higher taxes etc.) in exchange for a €110 billion ($145 billion) loan. Unfortunately, these contractionary measures had a negative effect on the Greek economy making the situation even worse. Greece received its

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20PASOK came to power on October 6, 2009.
second bailout package of €240 billion in March 2012, which also did not prove enough to lift the economy out of the recession. The recession, one the worst in Europe since the Great Depression, has cut the size of the Greek economy by roughly 25% (see Fig. 2.19). Unemployment reached an all time high since 1993 at over 25%, far higher than almost all other member states\textsuperscript{21} and unfortunately with no credible signs of dropping to normal levels (see Fig. 2.20).

At the same time, the country’s overall debt load has deteriorated. This of course comes at no surprise. Even though the two bailouts reduced the debt service burden, the drop was only temporary and the key debt-to-GDP ratio continued to increase as GDP collapsed. Evidently this makes the situation even worse as it becomes harder for pay off (see Fig. 2.21). With the Greek economy declining approximately 25%, the unemployment level surging, steep pension and public sector wage cuts, higher taxes in almost every single aspect of economic activity, and general social and political unrest, while not achieving debt sustainability, it is reasonable to expect some

\textsuperscript{21}The only member country that comes close is Spain with an unemployment rate of 22.3% in 2015. For comparison purposes, the average unemployment rate in the 2009-2015 period was 20.5% in Greece, 22.4% in Spain, and 13.5% in Portugal.
doubts regarding the effectiveness of the policies that the Troika (i.e. the European Commission, the European Central Bank, and the International Monetary Fund) followed in the Greek case.

Throughout this period the Greeks have been asked to exercise their right to vote several times, which as one would expect led to increased uncertainty and did little to calm financial markets. In
January 2015, Greeks for the first time since the end of the military dictatorship and the end of the civil war, gave power to a left-leaning party “SYRIZA” (Coalition of Radical Left), which formed a coalition with the right party of “Independent Greeks” (“ANEL”). The new government was led by Prime Minister Alexis Tsipras, with the hopes that Greece would be able to re-negotiate and end the austerity measures that the new government believed led to the worst of its recession. Unfortunately for Greeks, these negotiations were not as successful as the new government had envisioned and the new deal with creditors that eventually materialized was hardly better than the old deal. Instead, it led to a number of complications with severe negative effects for the Greek economy, that are discussed next.

A first example was a slow motion run on Greek banks (see Fig. 2.22). And being a part of the Eurosystem, this implied that Greek banks became increasingly reliant on funding from the European Central Bank (see Fig. 2.23). The sharp rise in total liabilities during 2012 and 2015, and the fall in 2014 largely reflect changes in the use of the emergency liquidity facility (ELA). The ELA is a special type of loan facility that is provided by a national central bank (the Bank of

\footnote{The SYRIZA/ANEL government came into power on January 26, 2016.}
CHAPTER 2. THE GREEK SOVEREIGN DEBT CRISIS

Greece in this case) of the Eurosystem to solvent financial institutions that face temporary liquidity constraints. The European Central Bank’s (ECB) Governing Council sets the limit and imposes any restrictions that may have an adverse effect on ECB’s policy. Liquidity through ELA is rather costly, with rates much higher than regular ECB financing (typically 1.55% vs 0.05% in the case of Greece23), but financial institutions that do not have adequate collateral for regular ECB financing turn to this emergency facility, with the national central bank essentially acting as the “lender of last resort”.

Another negative impact occurred during the summer of 2015 when the situation became even worse for Greek banks and consequently for the rest of the economy and Greek citizens. The European Central Bank (ECB) ceased funding abruptly after Greek leadership called for a referendum on whether the country should accept the bailout terms of its international creditors. Much has been said regarding this referendum, from whether or not it violated the Greek constitution to whether

23The 1.55% is the rate that banks face for cash they receive from the ELA. There is an even more costly form of ELA funding, when it is backed by issues guaranteed by the Greek state. In this case, banks pay an additional 1.15% on the nominal value of the bonds they post as collateral that are then subject to significant haircuts. Thus, the most expensive portion of ELA funding can go beyond 3.5%.
the question being asked was in fact valid.\textsuperscript{24} Moreover, following the end of the funding from the ECB, the Greek government had to impose capital controls and a bank holiday, causing serious social and political unrest right in the middle of the summer–Greece’s strongest season for its most profitable sector–tourism. The capital controls, which are expected to be lifted by mid-2016, also caused serious disruptions in imports and retail sales.

The Greeks voted “No” to the bailout terms with 61.31%, but with a voter turnout of slightly more than 60%. Some percentage of those who voted “No” were in favor of the country leaving the euro altogether. The majority of the “No” supporters however believed that the left-leaning government would truly be able to re-negotiate with the creditors in better terms. Unfortunately, this did not happen. And after several weeks of strenuous negotiations, a rather hostile climate, and unprecedented uncertainty, a new package was drafted with even harsher terms. Since then the Greek economy has been trying to absorb these new measures and come to terms with the fact that political rhetoric, especially pre-election, hardly agrees with economic reality.

\textsuperscript{24} Greece’s creditors argued that the referendum had in fact no value since the proposal and its terms were no longer on the table when Greeks actually voted.
To further illustrate the adverse effects of the re-negotiations and the new deal of the SYRIZA-ANEL government it is helpful to look at some of the key macroeconomic indicators. Generally, the first three quarters of 2015 were characterized by a strong deterioration of the economic climate in Greece (see Fig. 2.24).

Moreover, during the first half of 2015 GDP growth slowed down, while in the third quarter of 2015 the Greek economy returned to recessionary conditions, after the brief and anemic period of growth it had experienced in 2014. Table 2.3 summarizes the main macroeconomic developments during the past two years, and Table 2.4 those of the general government. The most important factor behind the negative effect on GDP growth during the third and fourth quarters of 2015 is the adverse development in domestic demand from 0.8% in the second quarter of 2015 to -2% in the third quarter. The bank holiday and the imposition of the capital controls are largely responsible for the drop in domestic demand, as well as the sharp decline in fixed capital formation (from 2.9% in 2015Q3 to -11.4% in 2015Q3) and private consumption (from 0.7% in 2015Q3 to -0.3% in 2015Q3). In addition, the upward trend in exports was reversed considerably, while imports de-

25% rate of change vis-a-vis the same quarter of the previous year.
CHAPTER 2. **THE GREEK SOVEREIGN DEBT CRISIS**

...teriorated further, both due to the disruption in the domestic banking system. Overall, the positive contribution to the rate of change of the GDP from the decline in imports was significantly higher than the corresponding negative contribution from the drop in exports. The overall contribution of the external sector to the rate of change of the GDP was strongly positive (3.3%), which played a crucial role in reducing the intensity of the recession. The final point that deserves attention is the change in inventories, which played a crucial role in the negative rate of change of the real GDP in the 2015Q3. Once again the capital controls and the bank holiday were to blame. Since the smooth flow of imports was heavily disrupted, the demand for imported goods and raw materials had to be covered by the amount of stocks. Therefore, the contribution of the change in stocks to the rate of change of the real GDP in the third quarter of 2015 was considerably negative. Fig. 2.25 shows the contribution to the real GDP growth rate of its main components, and summarizes the previous discussion.

Figure 2.25: Contributions to the rate of change of the real GDP - Domestic and net external demand
During the final quarter of 2015 as evidenced in Fig. 2.24, Fig. 2.25, and Table 2.3 there were some gradual signs of recovery. However, it is rather unlikely that the economy will return to positive real GDP growth rates during 2016. On the positive side, it appears that the uncertainty regarding the country’s economic performance as well as its place within Europe has subsided considerably. At the same time, and despite the relative stability, the domestic economic climate remains rather fragile given the necessary structural adjustments that need to be implemented gradually and in several pillars of economic activity, with the reform of pension system and social security funds being the most critical. Finally, the recent geopolitical developments and the refugee crisis, and their addressing pose a significant challenge for Greece.

In this chapter I tried to give a brief overview of the main developments in the Greek economy after WWII in an attempt to find the root-causes of Greece’s ongoing sovereign debt crisis. Politics and more specifically the fiscal policies that were followed during this period by all ruling parties (albeit to varying extends) together with the accommodative monetary policies have played a dramatic role in the magnitude of the problem. Table 2.5 lists the election year, the incoming party(ies) and the Prime Minister, while Fig. 2.26 presents the general government’s deficit (as a % of GDP) against election years. A graph which could serve as a rather good example of the political business cycle. With the exception of 1996 and perhaps marginally 2000, all the other election years are accompanied by a deterioration of the deficit.
Table 2.3: Main macroeconomic indicators

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</thead>
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<td>Private Consumption</td>
<td>1.1</td>
<td>0.1</td>
<td>0.7</td>
<td>0.9</td>
<td>0.7</td>
<td>1.7</td>
<td>-0.3</td>
<td>-0.9</td>
</tr>
<tr>
<td>Public Consumption</td>
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<td>1.9</td>
<td>-3.5</td>
<td>-8.1</td>
<td>0.4</td>
<td>-1.5</td>
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<td>2.8</td>
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<td>Gross fixed capital formation</td>
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<td>2.9</td>
<td>3.7</td>
<td>9.9</td>
<td>0.1</td>
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<td>Domestic demand(^b)</td>
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<td>-0.4</td>
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<td>-0.8</td>
<td>1.6</td>
<td>0.8</td>
<td>-2</td>
<td>0.6</td>
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<td>Exports of goods and services</td>
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<td>9.2</td>
<td>10.5</td>
<td>3.3</td>
<td>1.5</td>
<td>-10.3</td>
<td>-8.8</td>
</tr>
<tr>
<td>Exports of goods</td>
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<td>-0.6</td>
<td>2.3</td>
<td>11.2</td>
<td>5.8</td>
<td>2.1</td>
<td>1.7</td>
<td>3.3</td>
</tr>
<tr>
<td>Exports of services</td>
<td>10.9</td>
<td>11.5</td>
<td>16.6</td>
<td>10.2</td>
<td>1.1</td>
<td>0.4</td>
<td>-23.5</td>
<td>-20.9</td>
</tr>
<tr>
<td>Imports of goods and services</td>
<td>-0.2</td>
<td>9.7</td>
<td>6</td>
<td>16.2</td>
<td>9.3</td>
<td>-3.3</td>
<td>-19.8</td>
<td>-12.5</td>
</tr>
<tr>
<td>Imports of goods</td>
<td>-0.8</td>
<td>10.5</td>
<td>6.8</td>
<td>17.7</td>
<td>8.6</td>
<td>-4</td>
<td>-16.4</td>
<td>-10.4</td>
</tr>
<tr>
<td>Imports of services</td>
<td>2.7</td>
<td>6.3</td>
<td>2.2</td>
<td>9.5</td>
<td>12.1</td>
<td>-0.5</td>
<td>-33.5</td>
<td>-21.6</td>
</tr>
<tr>
<td>Balance of goods and services</td>
<td>-45.5</td>
<td>83.2</td>
<td>-28.2</td>
<td>129.8</td>
<td>107.9</td>
<td>-43.5</td>
<td>-173.4</td>
<td>-48.6</td>
</tr>
<tr>
<td>GDP</td>
<td>0.4</td>
<td>0.2</td>
<td>1.3</td>
<td>0.9</td>
<td>0.3</td>
<td>0.9</td>
<td>-1.7</td>
<td>-0.8</td>
</tr>
</tbody>
</table>

\(^a\) Rates of change compared to the corresponding quarter of the previous year (seasonally adjusted data at constant prices)

\(^b\) Domestic demand is the sum of private consumption, public consumption, and gross fixed capital formation

\(^c\) Source: National Accounts, ELSTAT (February 2016), own calculations
Figure 2.26: Elections and General government deficit (% of GDP)
## Table 2.4: Main aggregates of general government, 2015 (as percentage of GDP)

<table>
<thead>
<tr>
<th></th>
<th>2015Q1</th>
<th>2015Q2</th>
<th>2015Q3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Revenue</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxes on production and imports, receivable</td>
<td>13.6</td>
<td>13.5</td>
<td>14.1</td>
</tr>
<tr>
<td>Taxes on income and property, receivable</td>
<td>8.0</td>
<td>11.9</td>
<td>9.4</td>
</tr>
<tr>
<td>Social contributions</td>
<td>14.1</td>
<td>12.6</td>
<td>13.8</td>
</tr>
<tr>
<td>Other current revenue</td>
<td>1.3</td>
<td>1.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Capital transfers, receivable</td>
<td>4.9</td>
<td>4.6</td>
<td>5.1</td>
</tr>
<tr>
<td><strong>Total expenditure</strong></td>
<td>51.8</td>
<td>47.8</td>
<td>44.0</td>
</tr>
<tr>
<td>Primary expenditure</td>
<td>47.6</td>
<td>43.9</td>
<td>40.6</td>
</tr>
<tr>
<td>Compensation of employees</td>
<td>12.9</td>
<td>11.9</td>
<td>11.3</td>
</tr>
<tr>
<td>Social benefits</td>
<td>23.5</td>
<td>21.7</td>
<td>20.8</td>
</tr>
<tr>
<td>Goods &amp; services</td>
<td>3.6</td>
<td>3.8</td>
<td>3.7</td>
</tr>
<tr>
<td>Subsidies, payable</td>
<td>0.7</td>
<td>1.0</td>
<td>0.9</td>
</tr>
<tr>
<td>Other current transfers, payable</td>
<td>2.5</td>
<td>1.2</td>
<td>1.1</td>
</tr>
<tr>
<td>Capital transfers, payable</td>
<td>4.3</td>
<td>4.2</td>
<td>2.8</td>
</tr>
<tr>
<td>Interest payments</td>
<td>4.2</td>
<td>3.9</td>
<td>3.4</td>
</tr>
<tr>
<td><strong>Primary balance (excluding interest)</strong></td>
<td>-5.7</td>
<td>-0.1</td>
<td>2.1</td>
</tr>
<tr>
<td><strong>Overall balance</strong></td>
<td>-9.9</td>
<td>-4.0</td>
<td>-1.3</td>
</tr>
</tbody>
</table>

*Source: The Greek Economy, ELSTAT (April, 15 2016)*
Table 2.5: Elections and governing parties: 1974-2015

<table>
<thead>
<tr>
<th>Election Year</th>
<th>Incoming Government</th>
<th>Prime Minister</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974 (Nov)</td>
<td>ND</td>
<td>Konstantinos G. Karamanlis</td>
</tr>
<tr>
<td>1977 (Nov)</td>
<td>ND</td>
<td>Konstantinos G. Karamanlis</td>
</tr>
<tr>
<td>1981 (Oct)</td>
<td>PASOK</td>
<td>Andreas Papandreou</td>
</tr>
<tr>
<td>1985 (Jun)</td>
<td>PASOK</td>
<td>Andreas Papandreou</td>
</tr>
<tr>
<td>1989 (Jun)</td>
<td>ND in Coalition with KKE(^a) and EAR(^b)</td>
<td>Tzannis Tzannetakis</td>
</tr>
<tr>
<td>1989 (Nov)</td>
<td>National Unity(^c)</td>
<td>Xenophon Zolotas</td>
</tr>
<tr>
<td>1990 (Apr)</td>
<td>ND</td>
<td>Konstantinos Mitsotakis</td>
</tr>
<tr>
<td>1993 (Oct)</td>
<td>PASOK</td>
<td>Andreas Papandreou</td>
</tr>
<tr>
<td>1996 (Sep)</td>
<td>PASOK</td>
<td>Konstantinos Simitis</td>
</tr>
<tr>
<td>2000 (Mar)</td>
<td>PASOK</td>
<td>Konstantinos Simitis</td>
</tr>
<tr>
<td>2004 (Mar)</td>
<td>ND</td>
<td>Konstantinos A. Karamanlis</td>
</tr>
<tr>
<td>2007 (Sep)</td>
<td>ND</td>
<td>Konstantinos A. Karamanlis</td>
</tr>
<tr>
<td>2009 (Oct)</td>
<td>PASOK</td>
<td>George A. Papandreou</td>
</tr>
<tr>
<td>2012 (Jun)</td>
<td>ND in Coalition with PASOK and DIMAR(^d)</td>
<td>Antonis Samaras</td>
</tr>
<tr>
<td>2015 (Jan)</td>
<td>SYRIZA in Coalition with ANEL and OP(^e)</td>
<td>Alexis Tsipras(^f)</td>
</tr>
<tr>
<td>2015 (Sep)</td>
<td>SYRIZA in Coalition with ANEL and OP</td>
<td>Alexis Tsipras</td>
</tr>
</tbody>
</table>

\(^a\) Communist Party of Greece (KKE) and Greek Left (EAR). This coalition was also known as Synaspismos, or Alliance of the Left and Progress.
\(^b\) Supported by ND, PASOK, and the Coalition of the Left and Progress (KKE and EAR)
\(^c\) In November 11, 2011 George A. Papandreou stepped down to allow the creation of a national unity government in response to the debt crisis. The new coalition government of PASOK, ND, and Popular Orthodox Rally (LAOS) was led by Lucas Papademos and lasted from November 2011 to May 2012 when it failed. In May 2012 Panagiotis Pikrammenos was assigned head of caretaker government in order to lead the country to the polls in June, 20 2012.
\(^d\) Democratic Left (DIMAR)
\(^e\) Ecologists Greens (OP)
\(^f\) From August 27, 2015 to September 21, 2015 Vassiliki Thanou was assigned head of caretaker government in order to lead the country to the elections of September 21, 2015 after Tsipras resigned due to disagreements within SYRIZA concerning the bailout program.
Chapter 3


3.1 Introduction

Ever since the Greek government debt crisis started in late 2009, the question of whether the country’s debt is sustainable has been in the center of media and public attention, and has been a subject of debate among economists and policy makers both within as well as outside the country. Greece’s debt sustainability was once again in the forefront in relation to a Eurogroup\(^1\) meeting on May, 24 2016. The meeting and its outcome were of particular importance to Greece, as the decision on whether the country would receive the next tranche of financial support was one of the main topics in the agenda. Greece has been receiving financial support from euro-zone countries and the International Monetary Fund (IMF) since May 2010. The support is part of economic adjustment programs, which include several measures aimed in correcting fiscal imbalances and structural deficiencies. A discussion on Greece’s debt sustainability and the economy’s prospects would be incomplete without a review of the economic adjustment programs. Moreover, under-

\(^1\)The term Eurogroup refers to the informal meetings of the euro area finance ministers.
standing the key features of these programs is in fact a necessary step if one wishes to examine the sustainability of the debt. I briefly discuss next the main elements of the three economic adjustment programs that Greece has adopted and the economic developments that have taken place during the corresponding period.\(^2\)

The first economic adjustment program was agreed on May 2, 2010 between the Greek government, euro area members and the IMF. Under the agreement Greece would receive a total €80 billion during a three year period, from May 2010 through June 2013. The interest rate was set initially at 4.5% and the repayment period to 7 years. The amount would come in the form of bilateral loans provided by the other euro area states, which was termed the “Greek Loan Facility” (GLF). In addition, the IMF agreed to provide an extra €30 billion in the form of a Stand-By arrangement (SBA).\(^3\) The loans would be disbursed in installments to the Greek government conditional on the latter putting forth a number of austerity measures and implementing widespread structural reforms. The structural reforms aimed in increasing competitiveness and making the Greek economy more open. For example, with respect to labor market the Greek government would need to take steps to decrease union power and liberalize regulated professions. Reforms in product markets included the breaking down of state monopolies and the privatization of state assets. Moreover, reducing bureaucracy and tax evasion through a thorough modernization of public sector administration was deemed necessary, as was the close monitoring on the reporting of official fiscal statistics. The fiscal reforms and austerity measures were broken down in two fronts: sizeable reductions in public sector spending by reducing public sector wages and lowering pensions, and increases in direct and indirect taxes by increasing tax rates and imposing new taxes on real estate and other sources of wealth. The size and type of the austerity measures were set in accordance to achieving certain target debt-to-GDP ratios in the coming years. Those target levels were determined so as to ensure Greek debt sustainability and for Greece to regain access to capital.

\(^2\)Greece is currently on its third economic adjustment program.

\(^3\)The Stand-By arrangement is one of the most widely used lending instruments of the IMF. More details can be found at [http://www.imf.org/external/np/exr/facts/sba.htm](http://www.imf.org/external/np/exr/facts/sba.htm).
markets. They were set according to IMF’s Debt Sustainability Analysis (DSA) that was based on a number of assumptions such as growth rates, revenues from taxes and privatizations, and public spending cuts to determine the appropriate primary surpluses that had to be achieved each year so as to attain the target debt-to-GDP levels. The compliance of the Greek authorities regarding the implementation of the austerity measures and the structural reforms, would be reviewed by officials assigned by the so-called “Troika” - comprising the European Commission, the European Central Bank, and the IMF.

Unfortunately, the first program was not as successful as was initially anticipated. Partly due to the overly ambitious objectives that were assumed, partly because the inevitable recession that followed was much deeper than initially thought, and partly due to the political instability, social unrest, and administrative problems, Greece did not make the progress that was needed and missed several important fiscal targets. This eventually led to the adoption of the second economic adjustment program, whose financing was approved on March 14, 2012. The new program would disburse the amount pending from the first program (approximately €34.5 billion) plus an additional €130 billion for the years 2012 to 2014. The financing of the second bailout package differed from that of the first in several important ways. It was agreed that instead of using bilateral loans, the European Financial Stability Fund (EFSF) would provide a new aid package totaling €100 billion with a repayment period of 15 years and an interest rate of 3.5%. The EFSF was established in May 2010 as a special purpose vehicle in order to address the overall European sovereign debt crisis and guarantee the stability of the financial system and the common currency. Moreover, a feature of the second program that was absent from the first was the participation of the private sector in financing the remaining €30 billion. More specifically, the private sector involvement (PSI) entailed a 53.5% reduction in the nominal face value of Greek sovereign bonds held by private investors, aimed to bring down Greece’s debt, making this the biggest debt restructuring in history. This new rescue package for Greece was comprised of several layers of conditionality that extended or reinforced those of the first program. These layers can be broadly summarized into
four main areas: 1) the detailed timeline of a set of “prior actions” that would need to be completed before disbursement of the first loan tranche; 2) the establishment of a special segregated account to prioritize debt payments; 3) the tighter surveillance of the fiscal austerity program and the implementation of structural reforms; and 4) the strict implementation of the agreed privatization plan. The set of “prior actions” included, among others: 1) additional fiscal measures to compensate for slippages in previous budgets (worth approximately €3.2 billion or 1.5% of GDP); 2) measures to enhance wage flexibility with the goal of further reducing labor costs and increase competitiveness; 3) actions aiming to downsize the public sector and improve government efficiency; 4) additional steps to fully liberalize a range of closed professions; and 5) the recapitalization of the domestic banking system after the Private Sector Involvement (PSI).

But things did not go as smoothly as planned yet again and the final review of the second program pointed to important financing gaps. By the end of 2014 and despite a brief period of economic improvement, the Greek economy slipped back into a recession which marked a new period of political uncertainty and social unrest and the derailment of the second bailout program. On January 2015, the newly elect government led by Prime Minister Alexis Tsipras entered a long and strenuous period of negotiations with the Troika. The outcome of these negotiations was the agreement on a third macroeconomic adjustment program for Greece, which was finalized in August of 2015, but with various revisions up until today. The third program is set to run until August 2018, with quarterly updates on its conditionality taking into account the progress achieved. Under the new agreement Greece will receive up to €86 billion, which will be used for debt servicing needs, bank recapitalization, budget financing and arrears clearance. The European Stability Mechanism (ESM) that has replaced the EFSF could, in principle, fully finance the program if needed. However, the amount that the ESM will end up providing will depend broadly on whether the IMF decides to participate in the third program and whether Greece will be able to access capital markets during the duration of the program. Once again, the program reform agenda is centered around four pillars: 1) restoring fiscal sustainability; 2) safeguarding financial stability;
3) enhancing growth, competitiveness and investment; and 4) modernizing the state and public administration.

It is worth going over some of the main points of the third program since it is currently into effect. Included in the set of prior actions is a set of 18 key deliverables, notably: 1) a package of fiscal austerity measures amounting to 3% of GDP to help reach a primary surplus target of 3.5% of GDP in 2018; 2) fiscal contingency mechanism in the spirit of a balanced budget, that will be activated if annual government accounts show deviations from the agreed primary surplus targets of the previous years, 3) the establishment of a new Privatization Fund to manage revenues from privatizations; 4) the finalization of the Non-Performing Loans (NPL) framework; and 5) the full independence of the General Secretariat of Public Revenues. The main fiscal austerity measures include a major social security pension reform, an overhaul of the pension income tax, an increase in the top VAT tax from 23% to 24% and tax increases on gas and related fuels as well as increases on cigarettes and tobacco products. As for the primary surplus targets, according to the program those are as follows: 0.5% of GDP in 2016, 1.75% of GDP in 2017 and 3.5% of GDP thereafter. These targets, as in the previous programs, are derived from the European Commission’s DSA, and again are based in a number of assumptions such as the GDP growth rate of the economy. The insistence on achieving primary surpluses is because those are essential for the sustainability of Greek public debt in the years to come.

3.2 Statement of the problem

I believe that it is hard to argue against the statement that Greece’s debt sustainability presents an interesting case. Ever since the adoption of the first economic adjustment program there have been numerous debt sustainability analyses and several projections regarding Greece’s future macroeconomic performance, not all of which seemed to reach the same conclusion regarding sustainability. Most notable is perhaps the recent disagreement between the European Commission
and the IMF, which led the latter not willing to commit (at least at the beginning) to participate in
the funding of the third economic adjustment program for Greece.

The European Commission (EC) and the IMF examine sustainability prospectively in the sense
that sustainability is assessed by considering what types of policies should be implemented today
in order to eliminate the need for further future adjustments in the primary surplus and ensure
that the level of the debt (or debt-to-GDP ratio) is stable. Typically, the prospective analysis is
implemented using an accounting rather than an econometric framework. Both the EC and the
IMF use sensitivity and scenario analysis as well as stress tests to examine the fiscal adjustment
under time horizons. Debt sustainability and deficit adjustment is thus examined after considering
the impact of exogenous shocks on key variables such as economic growth, interest rates, debt
restructuring or deficit reduction and financial market pressure.

Fiscal sustainability can also be assessed retrospectively by examining whether a continuation
of past policies into the future would ensure the sustainability of fiscal policy, or whether a mo-
dification would be required to achieve sustainability. The retrospective approach, which is the
one I follow in this paper, is implemented using an econometric framework by utilizing historical
data. While the prospective approach might be more relevant for policy makers, I feel that the
retrospective approach using time series econometric techniques can yield valuable insights and
should be examined more thoroughly. Moreover, given that in the case of Greece the prospective
approaches of the EC and the IMF have not always been in agreement with each other\(^4\), I believe
that the use of a retrospective framework might offer a more insightful analysis.

\(^4\)Often, subsequent updates to the DSA’s of both the IMF and the EC reached different conclusions from the ones
of earlier DSA versions with respect to what type of actions should be undertaken to ensure sustainability. Uncertainty
regarding future projections on growth, progress and implementation of austerity and structural measures, and the
reaction of market participants are among the main reasons for these differences.
3.2.1 Motivation

Besides wanting to investigate the issue of fiscal sustainability in Greece using a retrospective framework, my motivation for this paper is driven by two other main forces. The first one is more general in nature and focuses on debt sustainability as it relates to economic policy. More specifically, debt sustainability has important implications on a nation’s fiscal policy, such as tax and incomes policy, the pension system and public spending on healthcare and infrastructure, which in turn affect economic growth. These policies also influence the interaction between the public and private sectors and have intergenerational effects. To this end, my paper aims to revisit the issue of whether Greece’s public debt is sustainable amidst all the current hype surrounding it.

The second driving force is more practical in the sense that it relates to the methodology and the data I use. As I discuss in the literature review, previous studies on the sustainability of Greek public debt are either not recent enough and thus do not cover the ongoing fiscal crisis, or in the few instances in which they do, the evidence is contradictory. My data spans the period from 1970 to 2015, which for fiscal variables is rather long. Moreover, I use a single source in order to minimize data discrepancies and achieve consistency as much as possible. While the use of a single source cannot rule out the existence of inconsistencies, I believe that it is an improvement compared to using several different sources. In addition, previous studies on Greek debt sustainability, recent or not, do not reach the same conclusion. Finally, while my empirical methodology is not novel, it combines several econometric techniques not all of which are present together in previous studies.

3.2.2 Stylized facts

Before proceeding to examine the fiscal sustainability hypothesis, a visual inspection and depiction of the series is constructive. Fig. 3.1 and Fig. 3.2 show the evolution of government debt in billions of national currency and as a % of GDP respectively. It is clear that there is an upward

\footnote{The national currency of Greece was the Greek Drachma up until 2000, when it was replaced by the euro.}
CHAPTER 3. FISCAL SUSTAINABILITY IN GREECE

trend in both the debt level in absolute terms and in the debt-to-GDP ratio. We can divide the trajectory of the debt-to-GDP ratio into six main sub-periods. The first one starts from the beginning of my sample and ends around the late 1970s. The second period starts in the beginning of the 1980s and ends around 1993. The third one covers the years 1994-1999, while the fourth period contains the years from 2000 to 2004. The fifth period starts in 2005 and lasts until 2009, and the sixth and last period is from 2009 and up to present. I next briefly highlight the main macroeconomic and fiscal developments in these periods.

Figure 3.1: General government consolidated gross debt (EUR, billions)

Throughout the 1970s the debt-to-GDP ratio was relatively stable and at low levels, averaging around 18%. The main reasons for this is that during this period Greece maintained relatively low fiscal deficits and enjoyed high growth rates. In 1981, the beginning of the second sub-period, the debt-to GDP ratio rose to 25.5% from 21.5% in 1980. This increase was led by a sharp deterioration of the general government deficit in 1981. The deficit went from 2.7% of GDP in 1980 to 9.1% in 1981. The debt-to-GDP ratio continued to rise until 1993 when it reached 95% of GDP. The rise in the debt-to-GDP ratio during these years can be explained by four main factors. First, there was a substantial increase in government spending, especially during the early part of the 1980s, as
the new socialist government elected in 1981 marked the beginning of a period of rising social and welfare spending. Another reason is the low growth rates during this period, both in Greece as well as at a global level and substantially high rates of inflation, averaging around 19%. Moreover, the high interest rate environment that characterizes this period had a negative impact on debt interest payments, making this the third reason for the higher levels of the debt-to-GDP ratio. Finally, a closer look at Fig. 3.3 can help us explain the last reason. The years in which we observe the steep increases in the deficit numbers (1981, 1985, 1989, 1990, and 1993) are all elections years, where government spending increased, as evidenced also in Fig. 3.4.

The signing of the Maastricht Treaty in 1992 set out the rules for euro participation, which included among others debt and deficit targets of 60% and 3% of GDP respectively. The Maastricht Treaty came into force in 1993, which by no coincidence is a year after the beginning of the third sub-period of the path of the debt-to-GDP ratio. As we can see in Fig. 3.2 there was a first reduction in the debt-to-GDP ratio in 1994 and were maintained until 1999. More generally fiscal policy was tight during this sub-period. The general government deficit declined from 12% in 1993 to 3% in 1999. On the negative side, interest payments were still considerably high at 10.7% of GDP in
1995, but by 1999 they were down to 7.6% as can be seen in Fig. 3.5. The efforts of the government during this period for fiscal consolidation, in order to ensure participation to the common currency, were however not as disciplined and thorough as needed. More specifically, consolidation was mostly based on tax hikes and falling interest payments; thus the composition was not broad based. In addition, primary expenditures increased from 36% in 1994 to 39% in 1999. Nevertheless,
the debt-to-GDP ratio was stabilized, albeit at a rather high point (around 100% of GDP) when Greece entered the common currency union. The macroeconomic developments during the fourth period were generally favorable. Economic activity improved considerably and the average annual growth of real GDP was around 4.6%, while inflation declined significantly and was around 3% (annual rate). Monetary policy loosened considerably since Greece became a member of the euro-zone. Unfortunately, fiscal policy followed the same path with tax cuts and higher primary expenditures, resulting in revenue shortfalls and expenditure overruns. As a result, the primary surpluses that were previously achieved were initially eliminated and then turned into deficits starting in 2002. As far as the debt-to-GDP ratio, it remained relatively stable during this period, despite the high GDP growth rates and the low interest rates. Fiscal magnitudes significantly worsened in 2003 and especially in 2004. More precisely, in March 2004 Greece had parliamentary elections, shortly after which the Greek authorities notified Eurostat that the deficit in 2003 was higher than previously reported. From then on Greece had to follow the Excessive Deficit Procedure (EDP) of

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6 The inflation rate was still much higher than the average of other European countries.
7 The EDP is initiated when a member state exceeds the 3% and 60% of GDP for deficit and debt respectively. In this event the European Commission sets a number or recommendations, deadlines, and targets that the member state must follow in order to correct the deficit and/or debt levels.
the European Union, and was asked to take corrective measures and eliminate the excessive deficit by end 2005. The 2004 Olympic Games that were organized in Athens, further complicated the problem because of fiscal mishaps and revisions regarding public expenditures. The fiscal audit that took place, both internally from the Greek government as well as from Eurostat, led to several revisions of the fiscal figures which created uncertainty about the validity of Greece’s finances.

In the start of the fifth period in 2005 Greece was already subjected to the EDP and fiscal policy was essentially focused around the target of eliminating the excessive deficit by 2006. Authorities reportedly did bring the deficit down to under 3%. However, as we can see in Fig. 3.3 the true deficit number in 2006 is well above 3%. This is because after the initial reporting there were several revisions. Despite this, Greece came out of the EDP in 2007, based on the 2006 report. The fiscal measures that authorities took to correct the excessive deficit were not sufficient however, and fiscal conditions worsened once again in the last part of 2007. The macroeconomic and fiscal conditions worsened significantly in 2008. GDP growth entered negative territory while revenues and expenditures both departed from the targets needed to ensure consolidation. The deficit climbed from 6.7% in 2007 to 10.2% in 2008, while the debt-to-GDP ratio reached 109% of GDP in 2009. As the global financial crisis intensified, the spreads on the 10-year Greek government bonds were negatively affected making the situation even worse.

The final period starts with another parliamentary election in October 2009. As can be seen in Fig. 3.3 and Fig. 3.4, fiscal magnitudes did not improve, but rather they registered new records. More specifically, revenues fell from 40.6% of GDP in 2008 to 38.9% in 2009, while expenditures reached an all-time high, rising from 46% of GDP in 2008 to 49% in 2009. As a result, the deficit in 2009 climbed to a whopping 15.2% of GDP and the debt-to-GDP ratio reached almost 127% of GDP. To no surprise, Greece was subjected to the EDP once again in 2009 based on the fiscal outcomes of 2007 and 2008. It should be noted that the high deficits registered during these years were structural and not cyclical as the result of the global financial crisis. The corrective measures under the new EDP led to an improvement in the deficit figure as tax revenues increased and expen-
ditures were cut. But these measures were seen as insufficient from financial markets and rating agencies\(^8\) who downgraded Greek sovereign bonds. The increased pressure from financial markets that send spreads on Greek government bonds to record levels and the round of downgrades forced the Greek government to request official financial assistance by the European Union and the IMF. This brought the first bailout package in May 2010.

### 3.3 Background of the Study

For the purposes of the present paper I have deliberately chosen to focus on empirical papers that have examined fiscal sustainability in Greece, either as a sole case or as part of a group of countries. In my opinion, Greece being a highly indebted advanced economy renders itself as rather interesting case. Narrowing the literature review on studies that have previously examined fiscal sustainability in Greece, facilitates the comparison of the methodologies and the possible different time spans considered.

#### 3.3.1 Literature review

To the best of my knowledge, the first study that considered public debt sustainability in Greece (among other countries) was that of Corsetti and Roubini (1991). The authors examine the stationarity of discounted public debt for OECD countries using annual data from 1960 to 1989. In the case of Greece,\(^9\) the authors find evidence that the Greek public debt is unsustainable. More specifically, the authors consider four tests of fiscal solvency using the discounted public debt, the debt-to-GDP ratio and the overall and current balance of the general government.\(^10\) Three models are then considered to test for the stationarity of each of the series that vary depending on whether

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\(^8\)Fitch, S&P and Moody’s all downgraded Greece several times both in 2009 and 2010

\(^9\)The data for Greece were from 1970 to 1989.

\(^10\)The overall balance is the real inflation and seigniorage adjusted fiscal balance inclusive of interest payments. The current balance is the real inflation and seigniorage adjusted fiscal balance inclusive of interest payments but net of capital formation minus depreciation.
a positive drift or time trend are considered. The main drawback of their approach is that the tests do not account for structural breaks.\footnote{It should be pointed out that at the time in which the Corsetti and Roubini (1991) paper was written, econometric techniques for the study of unit roots in the presence of structural breaks were not fully developed.}

Finally, the sustainability requirement examined in Corsetti and Roubini (1991) is known as “strong form” sustainability and as Quintos (1995) argued, this type of sustainability is not necessary for the IBC to hold in the long run. I discuss the differences between “strong form” and “weak form” sustainability later in the paper.

Caporale (1995) using annual data for Greece (among other EU countries) from 1960 to 1991 also rejects the sustainability of the Greek government debt. The author adopts a method used to detect speculative bubbles in financial markets and modifies it to examine whether governments can engage in bubble finance. As in Corsetti and Roubini (1991), his approach does not account for the presence of structural breaks.

Makrydakis, Tzavalis and Balfoussias (1999) study the sustainability of Greek fiscal policy during the period from 1958 to 1995 using the market value of discounted central government debt. In particular, they employ the sequential Zivot and Andrews (1992) test for a unit root that accounts for the endogenous determination of a one time structural change in regime. The authors identify a break in the series in 1979 and conclude that the Greek government does not satisfy its IBC in the long term, rendering fiscal policy unsustainable. However, the disadvantage of this methodology is that it accounts for only a single, one time break. In the presence of multiple breaks, these results may not hold.

Contrary to the previous studies, Papadopoulos and Sidiropoulos (1999) using annual data from 1961 to 1994 for Greece and four other EU countries start by examining the stationarity of total public deficit, government revenues and government expenditures using standard unit root tests and conclude that all series are stationary in first differences. They then proceed to examine stationarity in the presence of a structural break using the Zivot and Andrews (1992) test and show
that Greek public deficit and revenues are stationary using Model A (the “mean” model). A break is identified in 1979 for total public debt and in 1986 for government revenues. The Johansen (1988) and Johansen and Juselius (1990) methodology is employed to test for cointegration between government revenues and expenditures. The authors find evidence that the two series are cointegrated, with cointegrating vector \((1, 0.39)\). Finally, using the Gregory and Hansen (1996a) test for cointegration in the presence of regime shifts they are able to show that the variables are cointegrated and thus do not drift apart in the presence of breaks.\(^{12}\) As with the Zivot and Andrews (1992) tests, the Gregory and Hansen (1996a) tests only allow a single breakpoint.

Argyrou (2004)\(^{13}\) was the first to study fiscal policy sustainability in the case of Greece, while addressing both non-linear fiscal adjustment and the possibility of multiple structural breaks. Using quarterly data from 1970Q1 to 2000Q4 on public debt, general government revenues and expenditures. His empirical analysis is done in four parts; linear without structural breaks, linear with structural breaks, non-linear without breaks and non-linear with breaks. His findings indicate that conclusions regarding sustainability change when one considers both breaks and non-linearities. In particular, the linear analysis without breaks is carried out by testing for cointegration between government revenues and expenditures in a Dynamic Ordinary Least Squares (DOLS) setting\(^{14}\) as well as by estimating an error correction model (ECM) relating the two variables. From this analysis the results obtained are mixed; the results using DOLS are against sustainability while the ECM test result is in favor. When non-linearities in the public debt adjustment are taken into account using a Logistic Smooth Threshold Error Correction Model (L-STECM), while again not incorporating structural breaks, the results indicate that there is no sustainability. For the linear analysis with structural breaks Argyrou (2004) tests for multiple structural breaks using the Chi-square test proposed by Quintos (1995) in which breaks are endogenously determined. He identifies two

---

\(^{12}\)Papadopoulos and Sidiropoulos (1999) examine all three models, namely, level shift, level shift with trend and regime shift.

\(^{13}\)In a similar paper, Argyrou and Luintel (2007) obtain broadly similar results.

\(^{14}\)In the case of residual autocorrelation, the author uses Dynamic Generalized Least Squares (DGLS).
breaks; one in the second quarter of 1980, and another one in the third quarter of 1990. A robustness check using Quintos (1995)’s LR+ test also identifies two breakpoints (in 1982Q4 and 1991Q3). Incorporating the two breaks in the sustainability analysis, the author now finds that the Greek public debt is sustainable. In the last part, the non-linear framework is augmented to account for the presence of breaks. The results are in favor of fiscal sustainability, a finding that highlights the importance of accounting for multiple breaks.

Afonso (2005) collects annual data on general government debt, revenues and expenditures from 1970 to 2003 for 15 EU countries including Greece. He conducts stationarity tests on general government debt, with and without accounting for structural breaks\(^\text{15}\) (using the Perron (1989) and Zivot and Andrews (1992) tests in the former case and Dickey and Fuller (1981) and Phillips and Perron (1988) in the latter). In the absence of breaks from the analysis his findings regarding the Greek case are mixed and depend on the choice of test used (ADF vs. PP) and whether a trend is considered.\(^\text{16}\) Accounting for breaks, both tests considered indicate that the null hypothesis of a unit root cannot be rejected and therefore the debt is unsustainable in the Greek case. In testing for cointegration the author uses the Engle and Granger (1987) and Johansen (1988) tests, where both indicate no cointegration. He reaches the same conclusion when using the Gregory and Hansen (1996\textit{a}) test for cointegration in the presence of breaks. Afonso (2005) mentions that unlike previous studies the data he uses come from a single source (the annual macro-economic database), something that explains the small sample (33 observations).

Another study that focuses on the sustainability of Greek fiscal policy is by Katrakilidis and Tabakis (2006). The authors use annual data from 1956 to 2000 on government spending and revenues (as percentages of GDP). Using the Ng and Perron (2001), Kwiatkowski et al. (1992) and Elliott, Rothenberg and Stock (1996) unit root and stationarity tests both series are found to be

\(^{15}\)Only single, one time breaks were considered.

\(^{16}\)In particular, if only a constant and no trend is included in the ADF and PP auxiliary regressions, then the ADF test that the null of unit root cannot be rejected, while the PP test allows the rejection of the null. If a constant and a trend are included, both tests do not reject the null of a unit root.
integrated for order one. Their cointegration methodology follows that of Martin (2000) allowing for multiple endogenous breaks. The authors find evidence of cointegration between the two series and conclude that the Greek public deficit is weakly sustainable in the sense of Quintos (1995). In addition, they identify three breaks (1979, 1986 and 1995).

More recently, Collignon (2012) examined the issue of fiscal sustainability in relation to the European Union’s fiscal policy rules that require a deficit of no more than 3% of GDP and a debt level no higher than 60% of GDP. He uses data from 1978 to 2009 for fourteen EU countries, including Greece. He estimates the fiscal reaction function that relates the deficit and debt ratios to changes in primary surplus, using the 3% and 60% rules as target reference values. The estimated speed of adjustment coefficients by which the Greek government responds to deviations from these targets suggest that Greek fiscal policy is sustainable.

Finally, Neaime (2015) uses data from 1977 to 2013 on a number of European Union countries to revisit deficit and debt sustainability. His methodology uses the traditional unit root tests (ADF and PP) on government revenues, expenditures, the budget balance and debt, as well as the ratios of these variables to GDP. For Greece, all tests do not reject the null hypothesis of a unit root. Next, the author uses the Johansen (1988) methodology to examine cointegration between the expenditures and revenues series and concludes that Greek fiscal policy is unsustainable.

Given the contrasting evidence that previous studies report regarding the sustainability of fiscal policy in Greece, I believe that further examining the issue is beneficial. Moreover, my sample extends beyond that of earlier studies, and even in the case where the additional observations are few, they are important as they are part of the ongoing fiscal crisis. Finally, the question regarding the consistency of data on public finances is a frequent one. By using a single source for our data, I hope to address this issue.
3.3.2 The concept of sustainability

Before proceeding to a formal discussion of the theoretical background of our study, it is worthwhile to briefly discuss the concept of sustainability at a more intuitive level. Following the literature, one way to examine the issue of debt sustainability is by examining whether governments satisfy their intertemporal budget constraint (IBC) in present value terms. This implies testing whether the time series properties of fiscal variables are consistent with the no-Ponzi game condition whereby creditors expect the current debt to be equal to the sum of expected future primary surpluses. If this is found to be the case, then debt and fiscal policy are considered sustainable.

To test for fiscal sustainability in this framework there are two main empirical methodologies. The first one test the stationarity of the government debt or deficit series. If the debt or deficit series are non-stationary, then this implies that it is growing without bound over time. Consequently, subsequent debt will also grow without bound, which implies that both debt and fiscal policy are unsustainable. In this case, the present value IBC is not satisfied and the no-Ponzi game condition is violated. On the other hand, a stationary debt (or deficit) implies that the series is reverting to a certain mean over time, and in this case, debt and fiscal policy are sustainable, since the deficit is kept under control.

The second one examines whether there is a long run equilibrium relationship between government revenues and expenses using cointegration tests. Evidence of a long run relationship between the two series suggests that the government is not spending without bound and is taking into account the amount of revenues that is generating. This implies that it will not have to resort to deficit financing to cover future expenditures. Debt in this case would be sustainable and would not grow without bound.

In the section that follows I discuss the theoretical background for examining debt sustainability, while in Section 3.4 I discuss the empirical tests based on the theoretical background, their
implications and the corresponding conditions for sustainability.

3.3.3 Theoretical background

The starting point for examining fiscal policy sustainability is the government budget constraint used to derive the present value of the budget. The first equation describing the relationship between government expenditures, government revenues, and the public debt is given below:

\[ B_t = (1 + r_t) B_{t-1} - S_t \]  

(3.1)

where \( B_t \) is the outstanding debt at the end of period \( t \), \( r_t \) is the (one-period) ex post interest rate, and \( S_t \) is the primary surplus defined as government revenues \( (R_t) \) minus government expenses \( (G_t) \) exclusive of interest payments on the debt \( (S_t \equiv R_t - G_t) \). There are several measures that can be used for government debt. In this paper, I restrict my attention to real debt and debt as a percentage of GDP. As Hakkio and Rush (1991) point out, the interpretation of the interest rate in equation (3.1) depends on what measure is used to define the fiscal variables. In my case, when real variables are used, \( r_t \) is the real interest rate. If the variables are expressed as percentages of GDP, then \( r_t \) is the real interest rate adjusted for the growth rate of real GDP.

The flow budget constraint in equation (3.1) describes the time path of the stock of debt given the time paths of \( r_t \) and \( S_t \). In other words, it describes the dynamics of debt accumulation or decumulation. To see this more clearly rewrite equation (3.1) as:

\[ \Delta B_t = -S_t + r_t B_{t-1} \]  

(3.2)

which states that the change in public debt is equal to the primary surplus inclusive of interest payments \( (r_t B_{t-1}) \). Assuming that the variables in equations (3.1) and (3.2) are all expressed in real terms we can make three important observations as outlined in Cuddington (1999). First, note
that if the primary surplus is equal to zero \((S_t = 0)\) then \(\Delta B_t = r_t B_{t-1}\), which states that the stock of real debt will grow at a rate equal to the real interest rate. If, on the other hand, the government runs a primary deficit \((S_t < 0)\) the stock of debt will grow at a rate exceeding the real interest rate since the deficit represents an addition to the stock of debt.\(^{17}\) Finally, if the government runs a primary surplus \((S_t > 0)\), the stock of debt will grow at a slower rate than the interest rate. In the special case where the primary surplus is greater than interest payments on existing debt \((S_t > r_t B_{t-1} \text{ with } S_t > 0)\), the real debt will actually shrink over time.

Solving equation (3.1) for \(B_{t-1}\) and iterating it forwards \(n\)-periods we get from the flow budget constraint version to the \(n\)-period intertemporal budget constraint (IBC). If we assume that the real interest rate is constant\(^{18}\) and positive over time we get:

\[
B_{t-1} = \sum_{s=0}^{n} \frac{1}{(1 + r)^{s+1}} (R_{t+s} - G_{t+s}) + \frac{B_{t+n}}{(1 + r)^{n+1}}
\]

where \(R\) is government revenues and \(G\) is government expenditures excluding interest payments. Letting \(n\) approach infinity we get:

\[
B_{t-1} = \sum_{s=0}^{\infty} \frac{1}{(1 + r)^{s+1}} (R_{t+s} - G_{t+s}) + \lim_{n \to \infty} \frac{B_{t+n}}{(1 + r)^{n+1}}
\]

Sustainability requires that the last term in equation (3.4) is zero:

\[
\lim_{n \to \infty} \frac{B_{t+n}}{(1 + r)^{n+1}} = 0
\]

Equation (3.5) is known as the no-Ponzi game condition. It states that the discounted value of the future stock of debt converges to zero as the time horizon approaches infinity. In other words, the

\(^{17}\)In the case where the deficit is constant, the growth rate of the debt will converge asymptotically toward the interest rate.

\(^{18}\)I assume a constant interest rate for simplicity and ease of exposition. Similar results can be obtained for time-varying interest rates.
no-Ponzi game condition implies that the government cannot continuously rely on the issuance of new debt in order to cover interest expenses on existing debt. The limit in equation (3.5) will converge to zero as \( n \) goes to infinity if the real stock of debt grows at a rate that is slower than the rate of interest \( r \). If equation (3.5) is satisfied, it follows that equation (3.4) becomes:

\[
B_{t-1} = \sum_{s=0}^{\infty} \frac{1}{(1 + r)^{s+1}} (R_{t+s} - G_{t+s})
\]

(3.6)

, which states that the current outstanding stock of real debt, \( B_{t-1} \), is equal to the present discounted value of current and future primary surpluses. Equations (3.5) and (3.6) are therefore equivalent in this context and the government’s intertemporal budget constraint is satisfied.

One can also express equation (3.1) with the variables expressed as ratios of GDP. Assume a constant real interest rate and that output grows at a constant rate of \( y \):

\[
Y_t = (1 + y)Y_{t-1}
\]

(3.7)

Then, dividing each term of equation (3.1) by GDP yields:

\[
\frac{B_t}{Y_t} = (1 + r) \frac{B_{t-1}}{Y_{t-1}} - \frac{S_t}{Y_t}
\]

(3.8)

Substituting equation (3.7) into equation (3.8) yields:

\[
\frac{B_t}{Y_t} = \frac{(1 + r)}{(1 + y)} \frac{B_{t-1}}{Y_{t-1}} - \frac{S_t}{Y_t}
\]

(3.9)

Rewriting, we obtain:

\[
b_t = \frac{(1 + r)}{(1 + y)} b_{t-1} - s_t
\]

(3.10)

where the lower-case letters are the ratios of the corresponding upper-case letters of equation (3.1)
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to GDP, and \( y \) is the growth rate of GDP between periods \( t-1 \) and \( t \).\(^{19}\) Solving equation (3.10) for \( b_{t-1} \) and iterating it forwards \( n \)-periods and taking the limit as \( n \) approaches infinity, we get from the flow budget constraint version to the intertemporal budget constraint (IBC) with the variables expressed as ratios of GDP:

\[
b_{t-1} = \sum_{s=0}^{\infty} \left( \frac{1 + y}{1 + r} \right)^{s+1} \left[ \rho_{t+s} - g_{t+s} \right] + \lim_{s \to \infty} b_{t+s} \left( \frac{1 + y}{1 + r} \right)^{s+1} \tag{3.11}
\]

where again lower-case letters are the ratios of the corresponding upper-case letters of equation (3.4). The corresponding no-Ponzi game condition is:

\[
\lim_{s \to \infty} b_{t+s} \left( \frac{1 + y}{1 + r} \right)^{s+1} = 0 \tag{3.12}
\]

and if satisfied, equation (3.11) reduces to:

\[
b_{t-1} = \sum_{s=0}^{\infty} \left( \frac{1 + y}{1 + r} \right)^{s+1} \left[ \rho_{t+s} - g_{t+s} \right] \tag{3.13}
\]

Equations (3.12) and (3.13) are identical to the earlier versions when using real variables. This goes back to the point of Hakkio and Rush (1991) mentioned earlier regarding the interpretation of the interest rate - when real variables are expressed as ratios to GDP the real interest rate is adjusted for the real growth rate of GDP. However, while equations (3.12) and (3.13) are equivalent to equations (3.5) and (3.6) respectively, the interpretation is slightly different. Equation (3.12) states that as \( n \) approaches infinity the discounted value of the future debt-to-GDP ratio converges to zero, and as before implies that the government cannot rely continuously on the issuance of new debt in order to finance interest payments on existing debt. Equation (3.13) states that the current outstanding debt-to-GDP ratio, \( b_{t-1} \), is equal to the present discounted value of current and future primary surpluses expressed as a ratio of GDP. If \( r > y \), the limit in equation (3.12) will converge

\(^{19}\)From equation (3.10) the change in the public debt is \( \Delta b_t \equiv b_t - b_{t-1} = \frac{r-y}{1+y} b_{t-1} - s_t \)}
to zero if the debt-to-GDP ratio grows at a rate that is slower that the real interest rate adjusted for the growth of real GDP.\textsuperscript{20}

Irrespective of whether one examines the IBC in real terms or as shares of GDP, as Chortareas, Kapetanios and Uctum (2008) and Uctum, Thurston and Uctum (2006) point out the IBC can be interpreted as restricting the future long run relationship between government revenues and expenditures. The restriction is twofold: first, the two series should not drift too far apart from each other, and second, the government should generate enough future net primary surpluses to pay back the outstanding stock of debt. Moreover, provided that the IBC is not violated, short run primary deficits that would lead to debt accumulation would be offset by future primary surpluses and the budget to be balanced in present value terms, and the debt process will be mean reverting. In the section that follows I discuss the econometric tests of the sustainability concept.

### 3.4 Methodology: Empirical tests on fiscal policy sustainability

#### 3.4.1 Fiscal policy sustainability using government debt series: Unit Root tests

To examine whether the no-Ponzi game condition and the IBC are satisfied I follow the standard practice in the literature and test the hypothesis that the debt series is non-stationary. As mentioned earlier, if the null hypothesis of non-stationarity is rejected then the data generating process of the debt series is mean reverting and fiscal policy is considered sustainable. If, however, the null hypothesis is not rejected then the fiscal stance followed is not sustainable and the government violates the present value constraint and the no-Ponzi game constraint. To empirically test whether equation (3.5) is satisfied (and consequently equation (3.6)) one of the standard practices in the

\textsuperscript{20}Note that as Uctum and Wickens (2000) point out equations (3.5) and (3.12) do not require that the real stock of debt or the debt-to-GDP ratio goes to zero. In the first case, the requirement is that the real stock of debt grows at a rate slower that the real interest rate. In the second case, the debt-to-GDP ratio grows at a rate slower than the growth-adjusted real rate.
literature is to check whether government debt follows a stationary process, using standard unit root tests, such as those of Dickey and Fuller (1979) or Perron (1989).

However, a common problem with macroeconomic time series is the presence of structural breaks that may bias the results of traditional unit root tests such as those mentioned above. Perron (1989) showed that most macroeconomic variables are not nonstationary; rather they are trend stationary with a structural break. The presence of structural breaks in the series reduces the power of the ADF type tests, and leads to not rejecting the null hypothesis of nonstationarity. Perron (1989)’s approach introduces break dummy variables in the ADF regression, which permits for stationarity with a one-time permanent break in the trend stationary model. The break point dates in this approach are imposed exogenously either by visual inspection of the data or based on a priori information or a combination of both. This approach has been criticized because imposing the breaks exogenously has been shown to bias the results of the unit root tests toward rejecting the unit root null with no structural break (see Christiano (1992)). Even if one knows when a change has occurred (e.g. the adoption of the euro as a common currency), it is very difficult to determine whether the change affected the estimates before, during, or after the break. To address these shortcomings Zivot and Andrews (1992) proposed a modified version of Perron’s test that allows for the break dates to be determined endogenously. Zivot and Andrews (1992) formulate three different models following the work of Perron (1989) to test for a unit root against the alternative of trend-stationarity with an unknown break point. In our case, these models can be stated as follows:

\[
B_t = \alpha_0 + \alpha_1 B_{t-1} + \alpha_2 t + \mu_1 D_L + \sum_{i=1}^{k} \beta_i \Delta B_{t-i} + \epsilon_t
\]  
(3.14)

\[
B_t = \alpha_0 + \alpha_1 B_{t-1} + \alpha_2 t + \mu_2 D_P + \sum_{i=1}^{k} \beta_i \Delta B_{t-i} + \epsilon_t
\]  
(3.15)

\[
B_t = \alpha_0 + \alpha_1 B_{t-1} + \alpha_2 t + \mu_1 D_L + \mu_2 D_P + \sum_{i=1}^{k} \beta_i \Delta B_{t-i} + \epsilon_t
\]  
(3.16)
where $D_L = 1$ if $t > \tau$ (0 otherwise) is a level dummy that represents a one-time permanent change in the mean, and $D_P = t - \tau$ (0 otherwise) is a slope dummy, which again represents a one-time permanent change. Consequently, Model A permits a one-time permanent change in the mean of the series, Model B allows a shift in the trend, while Model C combines both one-time changes in the mean and trend. Equations (3.14), (3.15) and (3.16) correspond to Model A, Model B and Model C of the original paper. The null hypothesis in all three models is that $\alpha_1 = 1$. The Zivot and Andrews (1992) method regards every point as a potential break point ($\tau$), and each model is estimated for all possible break points successively in an interval that excludes the endpoints of the sample, typically specified as $[0.15,0.85]$. The trimming of the region in which the break dates can occur is deemed necessary because as the authors point out, if the breaks occur outside of the $[0.15,0.85]$ region, the test suffers power loss. The ADF $t$-statistics for testing the null hypothesis that $\alpha_1 = 1$ are computed for each possible break point within the specified region. For each model, I picked the $t$-statistic that maximized the rejection of the null hypothesis. The decision rule was to reject the unit root null if the minimum $t$-statistic was less than the critical value from the asymptotic distribution provided by Zivot and Andrews (1992) for each of the three models.

### 3.4.2 Fiscal policy sustainability using government revenues and expenditures: Cointegration tests

Another way to approach the issue of fiscal sustainability is by examining the relationship between government revenues and expenditures. Start by rewriting equation (3.4) as follows:

$$B_t = \sum_{s=1}^{\infty} \frac{1}{(1+r)^s}(R_{t+s} - G_{t+s}) + \lim_{s \to \infty} \frac{1}{(1+r)^s} B_{t+s}$$

(3.17)
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Taking first differences of equation (3.17) gives:

\[ GG_t - R_t = \sum_{s=1}^{\infty} \frac{1}{(1+r)^s} (\Delta R_{t+s} - \Delta G_{t+s}) + \lim_{s \to \infty} \frac{B_{t+s}}{(1+r)^s} \]

(3.18)

where \( GG_t = G_t + rB_{t-1} \). The term \( GG_t - R_t \) is the total gross deficit and \( GG \) represents primary expenditures plus interest payments. Starting with the RHS of equation (3.17), we need to check the stationarity of the first difference of the \( R \) and \( G \) series. If these two series are nonstationary in levels and their first differences are stationary, then \( R \) and \( G \) are integrated of order one (I(1) in levels). Maintaining the assumption of the no-Ponzi-game condition ensures then the stationarity the RHS of equation (3.17). Clearly for the equation to hold the LHS must also be stationary. This in turn implies that the series \( GG_t \) and \( R_t \) should be cointegrated so their first differences are stationary. More specifically, the two series should be cointegrated with cointegrating vector (1,-1). This is the approach of Hakkio and Rush (1991) who argue that cointegration between \( R_t \) and \( GG_t \) is a necessary condition for the intertemporal budget constraint to hold and the cointegrating vector should be (1,-1) in order to rule out bubble terms.

To summarize, starting with the government revenues and expenditures series there are three possible scenarios. In the first one unit root test show that one of the series is an I(0) process while the other is an I(1). In this case, there is no sustainability. In the second scenario, both series are found to be I(0) and we have fiscal sustainability. The third possibility is when both series are found to be I(1). In this case, we proceed with the cointegration tests between the two series, \( R \) and \( GG \). If we conclude that the two series are not cointegrated, then according to Hakkio and Rush (1991) there is no sustainability and the government would need to alter its fiscal stance.

Quintos (1995) proposed weak and strong sustainability conditions and argued that it might be possible for fiscal policy to be sustainable even if the two series are not cointegrated provided that government revenues are higher than expenditures\(^{22}\). To illustrate Quintos (1995) weak and strong

\[^{21}\Delta B_t = -S_t + rB_{t-1} = G_t - R_t + rB_{t-1} \]
\[^{22}\text{This however is generally uncommon for most countries} \]
form sustainability conditions consider the cointegrating regression that we wish to test:

\[ R_t = \alpha + \beta GG_t + u_t \]  

(3.19)

Quintos (1995) shows that if \( 0 < \beta < 1 \) then the intertemporal budget constraint is satisfied in the weak sense regardless of whether \( R_t \) and \( GG_t \) are cointegrated. Moreover, there is also weak sustainability when \( \beta = 1 \) and the two series are not cointegrated. The case where \( \beta = 1 \) and \( R_t \) and \( GG_t \) are cointegrated then corresponds to the Hakkio and Rush (1991) sustainability condition, which Quintos (1995) defines as strong form sustainability. Finally, if \( \beta = 0 \) and the series are not cointegrated, then there is no sustainability. The strong form sustainability implies then that the limit term in equation (3.17) converges to zero as opposed to the no sustainability case. Weak sustainability implies that while the limit term converges to zero, it does so at a slower rate compared to the one under strong form sustainability. Moreover, under weak sustainability the limit term will converge to zero faster is the series are cointegrated.

Quintos (1995) discusses a very important point regarding the policy implications of sustainability in the weak sense. More specifically, she states that a debt process which is found to be sustainable in the weak sense may lead to financing constraints for the government in the long run because it will face difficulties in marketing its debt. In other words, when government spending is continuously higher that revenues, the risk of default coming from a rising debt increases. This point is particularly important in the case of Greece. In fact, in the absence of strong form sustainability, weak form sustainability would seem to explain the ongoing crisis in Greece rather well. Government expenses have exceed government revenues for almost the entire period 1970 to 2015, as can be seen in Figure 3.4, which might be evidence of weak form sustainability. Evidence of weak sustainability in the case of Greece would indicate that it has in fact led to financing constraints and a strangling of the economy with an explosive debt (as evidenced in Figure 3.1).

In light of the above discussion, mt approach in this paper will be to consider the strong form
sustainability condition as a necessary and sufficient condition for the IBC to hold. Thus sustain-
ability in the cointegration framework will require that both the series are cointegrated and that
the cointegrating vector is (1,-1). Moreover, if there is evidence of weak form sustainability my
interpretation is that it is actually a sign of looming unsustainability unless the government changes
its policy. I discuss these points in more detail in Section 3.5 where I present my results.

With respect to the econometric methodology, there are several approaches that can be used
to test for cointegration. For example, one way is to use the Engle-Granger and Phillips-Ouliaris
cointegration tests, which are both essentially unit root tests on the residuals from a regression of
government revenues and expenditures. More specifically, to conduct the Engle-Granger test one
starts by estimating the following regression:

\[ R_t = a + bG_t + u_t \]  

Then the test uses the parametric ADF approach to estimate the following regression:

\[ \Delta \hat{u}_t = \alpha \hat{u}_{t-1} + \sum_{j=1}^{p} \delta_j \Delta \hat{u}_{t-j} + \epsilon_t \]  

The Phillips-Ouliaris cointegration test differs from the Engle-Granger in the way it accounts for
serial correlation in the residual series \( u_t \). More specifically, the Phillips-Ouliaris method uses the
nonparametric Phillips-Perron methodology to examine whether the residual series are stationary.
Thus, the auxiliary regression is estimated by running the unaugmented version of equation (3.21):

\[ \Delta \hat{u}_t = \alpha \hat{u}_{t-1} + w_t \]  

Given that the series \( R \) and \( GG \) are found to be I(1) sustainability requires that the residuals from
this regression be stationary and not have a unit root. Then \( R \) and \( GG \) are cointegrated.

One can also test for cointegration by estimating an error correction model. We start by esti-
mating the long run equilibrium relationship in equation (3.20). We then test that the residuals are stationary using any standard unit root test. The next step is to estimate the error correction model (ECM) of the following form:

$$\Delta R_t = \alpha_0 + \sum_{i=1}^{k_1} \gamma_i \Delta R_{t-i} + \sum_{i=1}^{k_2} \delta_i \Delta GG_{t-i} + \lambda ECM_{t-1} + \epsilon_t$$  \hspace{1cm} (3.23)

where $k_1$ and $k_2$ are the number of lags and the term ECM is the saved residual series from the previous step. The number of lags to include in equation (3.23) is determined using information criteria. As Argyrou (2004) notes a nonsignificant parameter $\lambda$ suggests lack of cointegration between the two series, $R_t$ and $GG_t$, which contradicts the sustainability hypothesis.

An important defect with either the Engle-Granger or the Phillips-Ouliaris method is that the estimation of the long-run equilibrium regressions in equation (3.20) requires us to place one variable on the LHS and use the other one as a regressor on the RHS. This implicitly assumes that the two variables, $GG$ and $R$ are jointly determined and therefore one can use the residuals from either of the two long-run equilibrium regressions in conducting the tests. If the test for cointegration depends on the variable choice, then it is possible to reach different conclusions depending on the long-run equilibrium regression used. Another important limitation of the two methods is that because of the two-step process, any misspecification introduced in the first step, i.e. the estimation of the long-run equilibrium relationship, is consequently carried over to the second step, i.e. the estimation of the auxiliary regression using the estimated errors from the first step. The cointegration test based on the estimation of the ECM, like the Engle-Granger and Phillips-Ouliaris tests, also depends on the choice of variable we use as the dependent one. Finally, another problem with the ECM approach is that the inclusion of the error correction term\(^{23}\) in equation (3.23) might introduce estimation error as a form of measurement error in the regression model. To circumvent these issues, I consider instead two alternative approaches, which are presented next.

\(^{23}\)As opposed to inserting directly $R_{t-1}$ and $GG_{t-1}$. 
The first approach to testing cointegration is with the use of an Autoregressive Distributed Lag (ARDL) model. This approach was developed by Pesaran and Shin (1999) and Pesaran, Shin and Smith (2001). One starts by considering the following Autoregressive Distributed Lag (ARDL) representation of equation (3.20) in first differences:

$$\Delta R_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} \Delta R_{t-i} + \sum_{i=0}^{q} \alpha_{2i} \Delta GG_{t-i} + \beta_1 R_{t-1} + \beta_2 GG_{t-1} + \epsilon_t$$

(3.24)

where $\epsilon_t$ is a white noise error. The first part of equation (3.24) represents the long run relationship, whereas the terms $\beta_1 R_{t-1} + \beta_2 GG_{t-1}$ correspond to the short run dynamics of the model. Testing for cointegration using the Bounds Test involves testing the null hypothesis that $H_0: \beta_1 = \beta_2 = 0$ against the alternative that the null is not true using an F-test. The null hypothesis is therefore that there is no cointegration among the variables. The Bounds Test of procedure of Pesaran and Shin (1999) and Pesaran, Shin and Smith (2001) has several advantages over other testing procedures for cointegration. In my case, the most important advantage is that it involves only one equation set-up, more specifically equation (3.24), and therefore the estimation of the short-run and long run coefficients is achieved simultaneously. This makes both implementation and interpretation easier.

The second approach is the Johansen methodology, which starts by considering the vector autoregression (VAR) of order $p$ given below:

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + B x_t + \epsilon_t$$

(3.25)

where $y_t$ is an $n \times 1$ vector of non-stationary I(1) variables, $x_t$ is a $d \times 1$ vector of deterministic terms, $\epsilon_t$ is an $n \times 1$ vector of innovations, $A_1$ to $A_p$ and $B$ are coefficient matrices. The VAR in equation (3.25) is in level form. We can reparametrize it and express it as a Vector Error Correction Model.

\(^{24}\)The distribution of the test statistic in this case is non-standard. We discuss this point in more detail in our results using this test.

\(^{25}\)Another very important advantage of this test is that it can be applied to series that are either I(0) or I(1) or a mixture of both.
(VECM) to get:

\[ \Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + B x_t + \epsilon_t \]  

(3.26)

where:

\[ \Pi = \sum_{i=1}^{p} A_i - I_n, \quad \Gamma_i = -\sum_{j=i+1}^{p} A_j \]  

(3.27)

The coefficient matrix \( \Pi \) \((n \times n)\) is called the impact matrix and determines whether the variables in \( y_t \) are cointegrated. To see this, note that in the VECM the term \( \Delta y_t \) and all its lags are I(0), therefore the only term that can potentially include I(1) variables is \( \Pi y_{t-1} \). For equation (3.26) to hold (i.e. for \( \Delta y_t \) to be I(0)) it must be the case that \( \Pi y_{t-1} \) is also I(0). It follows that the term \( \Pi y_{t-1} \) must contain the cointegrating vectors if they exist. The Johansen approach to cointegration is based on the relationship between the rank (\( r \)) of the \( \Pi \) matrix and its characteristic roots. There are three cases to consider. The first case is for \( r = 0 \). This implies that the variables in \( y_t \) are not cointegrated, all rows are linearly dependent and there is no combination of variables that leads to stationarity. If this is the case, then estimation should be done by first differencing all the variables in \( y_t \) to make them stationary. The VECM in equation (3.26) is thus reduced to a simple VAR in first differences:

\[ \Delta y_t = \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + B x_t + \epsilon_t \]  

(3.28)

The second case, is for \( r = n \) (the number of variables). This implies that \( \Pi \) has full rank and is therefore non-singular. This means that it has \( n \) linearly independent rows (columns) and all variables are stationary. In this case the level VAR is consistent. Note that this case is essentially excluded from our discussion above since we have assumed that the variables in \( y_t \) are nonstationary. The two previous cases can be viewed as extreme cases. The last case is when \( \Pi \) has reduced rank, with \( 0 < r < n \). This implies that \( y_t \) is I(1) and the system is nonstationary, but that there are \( r \) linearly independent cointegrating vectors and \( n - r \) common stochastic trends. Moreover,
given that \( \Pi \) has reduced rank, it can be expressed as:

\[
\Pi = \alpha \beta'
\]  \hspace{1cm} (3.29)

where \( \alpha \) and \( \beta \) are \( n \times r \) matrices both of which have rank \( r \). The elements of \( \alpha \) are known as the adjustment parameters in the VECM and each column of \( \beta \) is a cointegrating vector. The VECM becomes:

\[
\Delta y_t = \alpha \beta' y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + Bx_t + \epsilon_t
\]  \hspace{1cm} (3.30)

where \( \beta' y_{t-1} \sim I(0) \) since \( \beta \) is a matrix of cointegrating vectors.

The Johansen procedure involves estimating equation (3.30) via maximum likelihood for different values of the rank \( r \) of the matrix \( \Pi \), under the assumption that the errors follow a multivariate normal distribution for each \( t \) and are independent across observations. Testing the number of cointegrating vectors is equivalent to testing the rank of \( \Pi \). Since the rank of a matrix is equal to the number of its characteristic roots that are different from zero, we can get the number of distinct cointegrating vectors by checking the characteristic roots (i.e. the eigenvalues) of \( \Pi \). Given the eigenvalues of \( \Pi \), Johansen proposed two likelihood ratio tests to determine the number of cointegrating vectors. In the trace test the null hypothesis is that \( r = r_1 \) and the alternative is that \( r = r_2 \), for \( r_1 < r_2 \leq n \). The trace statistic is computed as:

\[
\lambda_{trace}(r_1, r_2) = -T \sum_{i=r_1+1}^{r_2} \ln(1 - \hat{\lambda}_i)
\]  \hspace{1cm} (3.31)

where \( T \) is the sample size and \( \hat{\lambda}_i \) is the \( i \)-th largest estimated eigenvalue of the \( \Pi \). This is a sequential test in the sense that we start from the null of at most 0 cointegrating vectors and up to at most \( r_1 \) against the alternative. In the maximum eigenvalue test the null hypothesis is that there are at most \( r \) cointegrating vectors against the alternative of at most \( r + 1 \). The maximum
eigenvalue statistic is computed as:

\[ \lambda_{max}(r, r + 1) = -T \ln(1 - \hat{\lambda}_{r+1}) \]  (3.32)

For this test, we also start from the null that \( r = 0 \) against the alternative that \( r = 1 \), and proceed until the null hypothesis of an eigenvalue equal to zero cannot be rejected. The asymptotic distributions of both the trace and the maximum eigenvalue statistics are nonstandard but have been tabulated for different values of \( r \). The critical values depend on the choice of deterministic terms that are included.

From our previous analysis we know that the government revenue and expenditure series are both I(1) thus \( y_t = [R_t, GG_t]' \). To implement the Johansen methodology in my setting I first determine the optimal number of lags to be included in the unrestricted VAR in equation (3.25). The AIC and the SBC both indicated one lag.\(^{26}\)

My next step is to specify and estimate the VECM model of equation (3.30). Johansen (1995) considers five cases for the deterministic terms. Here I will only consider three of these specifications since the other two are either too restrictive (Case 1: no deterministic components in the level data and all intercepts in the cointegrating equations are zero), or they are not appropriate given my data (Case 5: the level data have quadratic trends and the cointegrating equations have linear trends). In Case 2 there are no linear trends in neither the data nor in the cointegrating equations, but the cointegrating equations have non-zero means \( \rho_0 \). The VECM model in this case is:

\[ \Delta y_t = \alpha(\beta'y_{t-1} + \rho_0) + \epsilon_t \]  (3.33)

Case 3 allows for linear trends in the level data (\( \gamma \)) but only intercepts in the cointegrating relations

\(^{26}\)I checked different specifications for the deterministic component in the VAR, namely no constant, constant and constant and linear trend. In all three cases the optimal lag was one based on the multivariate generalizations of the AIC and SBC.
\[
\Delta y_t = \alpha (\beta' y_{t-1} + \rho_0) + \gamma + \epsilon_t
\]

(3.34)

Finally, in Case 4 both the level data and the cointegrating relations have linear trends. The VECM in this case is:

\[
\Delta y_t = \alpha (\beta' y_{t-1} + \rho_0 + \rho_1 t) + \gamma + \epsilon_t
\]

(3.35)

where \(\rho_1 t\) is the linear trend term of the cointegrating relation.

Unlike the residual based tests (Engle-Granger and Phillips-Ouliaris) and the ECM test for cointegration, the Johansen test for cointegration does not depend on which variable is selected as the dependent one since in the VAR specification no variable is singled out. There is however another limitation of the cointegration tests that we have reviewed so far, namely not accounting for structural changes. In the Johansen procedure one could include additional strictly exogenous variables (such as break points) other than the ones spelled out in the five cases of the Johansen procedure. However, because the critical values for the trace and maximum eigenvalue statistics change depending on the choice of deterministic terms, tabulated critical values for these tests would not be usable but would need to be estimated using for example bootstrap techniques. In this paper, instead I have chosen to address this issue by performing two tests that account for cointegration in the presence of structural breaks. I discuss these tests in the following section.

3.4.3 Fiscal policy sustainability using government revenues and expenditures: Cointegration tests in the presence of structural breaks

In this section, I discuss my approach in testing for cointegration between government revenues and expenditures in the presence of structural shifts. Given my data, this step is deemed necessary. I consider two different approaches. In the first approach, I use the Gregory and Hansen (1996a) residual based test for cointegration. In the second approach, I use Dynamic Ordinary Least Squares
(DOLS) to model the relationship between government revenues and expenditures without breaks. I then test for shifts in fiscal policy by conducting tests of structural breaks in the cointegrating relationship between $R_t$ and $GG_t$ and $\rho_t$ and $gg_t$. The break dates were identified using the Bai (1997) and Bai and Perron (1998), Bai and Perron (2003a) methodology for structural change and parameter stability by allowing for multiple breaks that are determined endogenously.

My first approach is based on that of Gregory and Hansen (1996a) who examine tests for cointegration that allow for possible structural breaks. They consider four models that differ on their assumptions regarding the structural breaks, which I outline below in the case of two variables:

- **Model 1: Standard Cointegration**

\[
y_t = \mu + \alpha x_t + e_t
\]  

This model describes the long-run equilibrium relationship between $y_t$ and $x_t$ where the parameters $\mu$ and $\alpha$ are constant over time ($t = 1, \cdots, n$). Structural changes in the above long run equilibrium relationship are reflected as changes in the intercept $\mu$ and/or changes in the slope $\alpha$. In Gregory and Hansen (1996a) the time that the break occurs is unknown and determined endogenously. To model the structural change the authors define a dummy variable $\phi_{t\tau}$ as follows:

\[
\phi_{t\tau} = \begin{cases} 
0 & \text{if } t \leq \lfloor n\tau \rfloor \\
1 & \text{if } t > \lfloor n\tau \rfloor
\end{cases}
\]

where $\tau \in (0, 1)$ is the relative timing of the break point, and $[\ ]$ is the integer part. The next three models are considered to account for structural changes:

- **Model 2: Level shift (C)**

\[
y_t = \mu_1 + \mu_2 \phi_{t\tau} + \alpha x_t + e_t
\]  

In this model there is only a change in the intercept $\mu$, thus $\mu_1$ is the intercept before the
break and $\mu_2$ is the change in the intercept when the break occurs. In this level shift model the equilibrium relationship shifts in a parallel fashion as the result of the break.

- Model 3: Level shift with trend (C/T)

$$y_t = \mu_1 + \mu_2 \phi_{t\tau} + \beta t + \alpha x_t + e_t$$  \hspace{1cm} (3.38)

The level shift with trend model as the name implies includes a time trend ($\beta t$) as well as a level shift in the long run equilibrium relationship.

- Model 4: Regime shift (C/S)

$$y_t = \mu_1 + \mu_2 \phi_{t\tau} + \alpha_1 x_t + \alpha_2 x_t \phi_{t\tau} + e_t$$  \hspace{1cm} (3.39)

This model allows changes in slope in addition to the intercept changes of Model (3.37), where $\alpha_1$ is the cointegrating coefficient before the break and $\alpha_2$ is the change in the slope coefficients. This parametrization allows for both rotation and parallel shift of the equilibrium relationship.

To test the null hypothesis of no cointegration against the alternative of cointegration based on the above models, Gregory and Hansen (1996a) have constructed three test statistics that are modified versions of the traditional ADF and Phillips residual based unit root tests. These test statistics are as follows:

$$Z_{\alpha^*} = \inf_{\tau \in T} Z_{\alpha}(\tau)$$

$$Z_{t^*} = \inf_{\tau \in T} Z_{t}(\tau)$$

$$ADF^* = \inf_{\tau \in T} ADF(\tau)$$

where $\tau$ is the relative timing of the break point, or regime shift, with $\tau \in T$ and $T$ being the set
of all possible break points, with $T = (0.15, 0.85)$. In my case, the implied specification of the three Gregory and Hansen (1996a) models is:

$$R_t = \mu_1 + \mu_2 \phi_{tT} + \alpha GG_t + e_t \quad (3.40)$$

$$R_t = \mu_1 + \mu_2 \phi_{tT} + \beta t + \alpha GG_t + e_t \quad (3.41)$$

$$R_t = \mu_1 + \mu_2 \phi_{tT} + \alpha_1 GG_t + \alpha_2 GG_t \phi_{tT} + e_t \quad (3.42)$$

The Gregory and Hansen (1996a) approach is essentially an extension of similar approaches for unit root tests with structural breaks, such as the Zivot and Andrews (1992) tests. The break date is determined by estimating the cointegration equations for all possible break dates in the sample. Then, the chosen break date is the one where the test statistics are minimized. There are two points worth mentioning: 1) the Gregory and Hansen (1996a) approach allows only one break, and 2) the tests do not examine whether there is a structural change per se; rather the alternative hypothesis is that there is cointegration with a possible change in regime. I thus proceed with my second approach that allows to examine multiple breaks, and then use my findings to test for cointegration separately.

The starting point for the second approach is the cointegrating relationship in equation (3.20). For convenience, this is reproduced here:

$$R_t = \alpha + \beta GG_t + u_t$$

The cointegration analysis is done with the DOLS method as presented in Stock and Watson (1993). In particular, I estimate the following model:

$$R_t = \alpha + \beta GG_t + \sum_{j=-q}^{r} \gamma_j \Delta GG_{t+j} + v_t \quad (3.43)$$

\footnote{As the authors point out, $T$ can be any compact subset of $(0,1)$; however, it will need to be small enough so that all of the statistics discussed can be calculated. The choice for $T = (0.15, 0.85)$ follows the earlier literature.}
The long-run dynamic equation (3.43) augments equation (3.20) by including \( q \) lags and \( r \) leads of the differenced explanatory variables, \( GG \) in our setting.

My next step is to incorporate structural breaks. To do so I employ the methodology of Bai (1997) and Bai and Perron (1998), Bai and Perron (2003\textit{a}). The authors have developed several statistics in order to identify the possible break points. The authors start by considering the multiple linear regression model with \( T \) periods and \( m \) breaks (leading to \( m + 1 \) regimes) below:

\[
y_t = x_t'\beta + z_t'\delta_j + u_t \quad (t = T_{j-1} + 1, \cdots, T_j) \tag{3.44}
\]

where regime \( j = 1, \cdots, m + 1 \), \( x_t \) and \( z_t \) are the explanatory variables whose parameters are constant across \( j \) in the former case or change in the latter. The break points \( (T_1, \cdots, T_m) \) are explicitly treated as unknown with endpoints \( T_0 = 0 \) and \( T_{m+1} = T \). In estimating equation (3.44), the authors develop global optimization procedures that identify \( m \) multiple breaks for which the sum of squared residuals in equation (3.44) is minimized using standard least squares. The procedure is termed global because it produces the \( m \) break points and the corresponding coefficient estimates that minimize the sum of squared residuals across all possible sets of \( m \) partitions. Bai and Perron (1998) use the global breakpoint estimates from the above procedure to form several breakpoint tests and their corresponding test statistics. These are briefly outlined below:

- To test the null hypothesis of no break \((m = 0)\) against the alternative of some fixed number of breaks \((m = k)\) a sup\textit{F} type test is used. The null hypothesis of no breaks is tested using the full sample and for every partition \((T_1, \cdots, T_k)\). The alternative hypothesis is tested against the pre-specified number of \( k \) breaks that involves estimation of every subsample with \( T_i = [T\lambda_i] (i = 1, \cdots, k) \). To evaluate the null hypothesis that the coefficients \( \delta_s \) in equation (3.44) are constant across regimes \((\delta_1 = \delta_2 = \cdots = \delta_{k+1})\) Bai and Perron (2003\textit{a})
propose the following test statistic:

\[
F_T(\lambda_1, \cdots, \lambda_k; q) = \frac{1}{T} \left( \frac{T - (k + 1)q - p}{kq} \right)^{\frac{k}{2}} R' \hat{V}(\hat{\delta}) R^{-1} R \hat{\delta}^{(3.45)}
\]

where \( \hat{\delta} \) is the optimal \( k \)-break estimate of \( \delta \), \( (R\delta)' = (\delta_1 - \delta_2', \cdots, \delta_k - \delta_{k+1}') \), and \( \hat{V}(\hat{\delta}) \) is an estimate of the variance covariance matrix of \( \hat{\delta} \) that may be robust to serial correlation and heteroskedasticity.

- To test the null hypothesis of no breaks against the alternative of an unknown number of \( m \) breaks up to some upper bound \( M \), Bai and Perron (1998) formulate a class of tests termed double maximum tests because in this setting the maximization is done both for a given \( m \) and across different values of the test statistic for \( m \). In the equal-weighted version of the test, called \( UDmax \), the procedure choses the alternative that maximizes the test statistic across the number of breakpoints. The second test, called \( WDmax \), applies weights such that the marginal \( p \)-values of the test statistics are equal across \( m \), where \( 1 \leq m \leq M \).

The previous two approaches are presented in Bai and Perron (1998). The next approach is a sequential procedure presented in Bai (1997).

- Bai (1997) develops a sequential testing methodology to estimate multiple breaks. The starting point is to test for parameter stability using the full sample. If the null is rejected, the break date is determined and then the sample is split into two subsamples each of which is again tested for parameter stability. Break points are added whenever there is a rejection of the null. The procedure is repeated until the null hypothesis of \( l = 1 \) vs. the alternative of \( l + 1 = 2 \) breaks cannot be rejected.

Going back to Bai and Perron (1998) I outline the last two approaches as follows:

- To test the null hypothesis of \( l \) vs. \( l + 1 \) breaks instead of following the previous sequential methodology that performs a parameter constancy test in each subsample that results from
the procedure, I only test the single subsample where the sum of squared residuals is lowest.

- The last approach which also tests the null hypothesis of $l$ vs the alternative of $l + 1$ breaks combines the sequential and the global optimization methodologies. The possible $l$ breakpoints for each step in the sequential procedure are obtained by global minimization of the sum of squared residuals, and each subsample is tested for parameter constancy.

Finally, information based criteria can be used to determine the appropriate number of breaks. More specifically, Yao (1988) suggests the Bayesian Information Criterion (BIC) and Liu, Shiyung and Zidek (1997) proposes a modified version of the Schwarz criterion termed (LWZ). These criteria can be used in conjunction with the procedures described earlier to guide the choice of the optimal number of breaks. The optimal number of breaks is given when these criteria are minimized. To the best of my knowledge this is the first paper that uses the Bai (1997) and Bai and Perron (1998) methodology to determine structural breaks using Greek data for the study of fiscal sustainability.

Having determined the break dates, my next step is to test for cointegration by incorporating the breaks into my analysis, and more specifically, I incorporate the breaks directly into the model and use the DOLS methodology described earlier.

I begin by defining a slope dummy variable for every break identified using the Bai (1997) and Bai and Perron (1998) method. In this part, I follow Arghyrou (2004) and Arghyrou and Luintel (2007) and define the slope dummies as:

$$D_{it} = \begin{cases} 
0 & \text{if } t \in (1, \cdots, T_i) \\
1 & \text{if } t \in (T_{i+1}, \cdots, N) 
\end{cases}$$

where $i = 1, \cdots, k$ with $k$ being the number of the identified breaks, and $T_i$ is the date that break $i$ occurred. The DOLS regression in equation (3.43) is augmented by including the break dummies.
and takes the following form:

\[ R_t = \alpha + \beta GG_t + \sum_{i=1}^{k} \delta_i D_{it} GG_t + \sum_{j=-q}^{r} \gamma_j \Delta GG_{t+j} + v_t \]  

(3.46)

and more specifically,

\[ R_t = \alpha + \beta GG_t + \delta_1 D_{1t} GG_t + \delta_2 D_{2t} GG_t + \sum_{j=-q}^{r} \gamma_j \Delta GG_{t+j} + v_t \]  

(3.47)

As Arghyrou and Luintel (2007) point out, defining the dummy variables this way allows us to determine the long-run effect of each regime change, and when these are jointly estimated, their significance can be evidence of the distinct effect of each one. Moreover, a positive sign on the slope dummies implies a move towards strong-form sustainability, whereas a negative sign a move away.\(^{28}\)

### 3.4.4 Data description and sources

All data were collected from the European Commission Annual Macroeconomic Data (AMECO) database. As I mentioned previously, while the AMECO database is a single source, it still relies on data collected and provided by member states, and more precisely data provided to Eurostat by member states. Thus, possible data inconsistencies might still be present. However, given that the alternative of using multiple sources might amplify this problem, and with the hope that both Eurostat and AMECO data managers have been diligent in removing the inconsistencies, I believe that justifies my choice of source.

More specifically I obtained annual data on general government public debt, general government revenues and expenditures, the price deflator of final private consumption expenditure, and GDP at market prices. My sample covers the period from 1970 to 2015, using annual observa-

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\(^{28}\)This is because when \( \beta \approx 1 \) the bubble term in equation 3.3 converges faster to zero, compared to when \( \beta < 1 \).
tions. For my empirical analysis, the general government debt, general government revenues and general government expenditures are all expressed in real terms using the price deflator of final private consumption expenditure. For the unit root tests, I use two different debt series: real general government debt in national currency, and real general government debt as a percentage of GDP. For the cointegration analysis I use the real general government revenue and real general government expenditure in levels as well as a percentage of GDP.

3.5 Results

3.5.1 Unit Root tests

I begin by considering the lag structure of the debt series. While with annual data typically two lags are used, in my case I used only one lag based on the Akaike, Schwarz, and Hannan-Quinn information criteria. Table 3.2 below presents all three information criteria for the government debt series both with one and two lags. Real debt is denoted by $B_t$ and debt as a share of GDP is denoted by $b_t$. As we can see all three criteria are minimized when using only one lag. I therefore proceed with the unit root tests including one lag, and more specifically, the ZA test for a unit root test against the alternative of stationarity with structural change at a single unknown breakpoint.

As discussed earlier, there are three different models that vary according to the null hypothesis regarding the break. I estimate all three models and I report the results on Tables 3.3, 3.4, and 3.5. Unlike some of the previous studies that have used the ZA test, I am not able to reject the null hypothesis of a unit root at conventional levels using any of the three models. More specifically, Papadopoulos and Sidiropoulos (1999) were able to reject the null hypothesis of a unit root using Model A and their result is significant at the 5% level. Their finding however is based on total public deficit, rather than debt, and their data are from 1963 to 1994. Makrydakis, Tzavalis and

\footnote{\text{For 2014 and 2015 values we used the official forecasts of the European Commission, contained in the AMECO database}}
Bafoussias (1999) reject the null hypothesis of a unit root for the debt-to-GDP ratio using Model B using data from 1958 to 1995. Their result is significant at the 5% level. Their estimated coefficient on the trend term, \( \mu_2 \), is however positive and equal to 0.185. Moreover, the sum of the coefficients on the trend term and the slope dummy (\( \alpha_2 \) and \( \mu_2 \) in my notation in equation (3.15)) sum up to a 0.26. As Uctum, Thurston and Uctum (2006) argue, there are three possible cases that are compatible with the concept of sustainability in small samples. As they point out, in the case where \( \alpha_2 > 0 \) (increasing trend), then \( \alpha_2 + \mu_2 \) must be negative to ensure sustainability. In other words, if there is an increasing trend initially it must be followed by a decreasing one after the break for sustainability to hold, which is not the case in the paper by Makrydakis, Tzavalis and Bafoussias (1999). In my results, the coefficient of the trend term is always positive and the coefficient on the slope dummy in Models B and C is also positive, which suggest an increasing trend, and is inconsistent with sustainability. The breakpoints in Model B and Model C are identical (1989), but there is a substantial difference with that of Model A (2004) for my real debt measure, \( B_t \). For the debt-to-GDP ratio (\( b_t \)) we observe the opposite pattern, the breakpoints are identical in Models A and B (2008), but Model C the breakpoint is much earlier (2003).

Before closing this section, it should be noted that results above are based on the undiscounted debt and debt-to-GDP ratio. However, as Hamilton and Flavin (1986) and Uctum and Wickens (2000) have argued, among others, to properly assess the fiscal sustainability hypothesis, the discounted market value of debt should be used instead. To consider this case, I followed Uctum and Wickens (2000) in constructing the discounted market value of the debt series based on debt and the debt-to-GDP ratio. More specifically, I first multiplied each series by its implicit market price, \( (1+i_t)^{-1} \), where \( i_t \) is the return on government debt. I used the 12-month Treasury bond rate, which I obtained from the AMECO database. The discounted debt and debt-to-GDP ratio at market value were subsequently obtained by multiplying the debt and debt-to-GDP series at market value, by the backward discount factor, \( q_t \). The backward discount factor is defined as \( q_t = \prod_{j=1}^{t} (1+r_j)^{-1} \). A final point that should be mentioned, is that real interest rates on Greek government debt were
negative over an extended period of time in my sample. More specifically, adjusting the 12-month nominal rate for inflation and real output growth results in a real rate that is negative from 1973 to 1988. Makrydakis, Tzavalis and Balfoussias (1999) argue that even though real interest rates have been negative over an extended period of time, the reversal into positive territory should guarantee that the economy is not dynamically inefficient, in the sense that it is not possible to make one generation better off without making another worse off. Following their argument I conducted the ZA unit root test on the discounted market value of real debt and the debt-to-GDP ratio. For both series I was not able to reject the null hypothesis of a unit root at conventional levels using any of the three models.

To summarize, my results from the univariate tests with breaks indicate that fiscal policy in Greece during the period examined has violated the conditions for sustainability.

### 3.5.2 Cointegration tests

In this section, I present our results on the sustainability of fiscal policy through cointegration tests between government revenues, inclusive of interest, and government expenditures both in real terms and as shares of GDP. As with the government debt series, I determine the appropriate lag length using the information criteria of Akaike, Schwarz, and Hannan and Quinn. Table 3.7 presents these results. Based on these results, I proceed using only one lag for both series. My next step in this process is to determine whether the series are I(0) or I(1) via unit root tests. If both series are I(0) then we know that the sustainability condition is satisfied. If one of the series is I(0), while the other is I(1), then there is no sustainability. In my case, as we will see, both series were found to be I(1) in levels, and therefore I(0) in first differences. This allows us to proceed with the cointegration tests between government revenues and government expenditures.

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30I also examined discounted debt and the debt-to-GDP ratio in nominal terms, adjusting the series only for the nominal rate of output growth. My conclusions did not change.

31I have also used the traditional Augmented Dickey-Fuller and Phillips-Perron tests, both of which do not account for breaks. My results, in line with the ZA tests, point to the rejection of sustainability.
The ADF and PP tests were used to examine the stationarity of the two series. Table 3.8 presents the results for the series in levels, while Table 3.9 for the first differences. As we can see, both tests reject the null hypothesis of a unit root for the series in levels for both when using both real variables or ratios to GDP. Stationarity is not rejected however for the first differences of the two series. More specifically, as we can see in Table 3.9, both tests reject the null hypothesis on a unit root at the 1% level. Thus, government revenues and expenditures are both found to be integrated of order one. Having determined that both series are I(1) in levels and therefore I(0) in first differences, I now turn to the cointegration tests between the two series.

The results for the Bounds Test for cointegration using the ARDL model described earlier are reported in Table 3.10. I estimated equation (3.24) and used the Akaike Information Criterion (AIC) and the Schwarz Criterion (SBC) to determine the appropriate number of lags. Both the AIC and SBC indicated an ARDL(1,0) for the variables expressed as ratios to GDP and an ARDL(2,1) for the variables in real terms.\(^{32}\) The null hypothesis of the Bounds Test is that there is no long run relationship between the variables, in my case \(R_t\) and \(GG_t\), and \(\rho_t\) and \(gg_t\). The asymptotic distribution of the test statistic is non-standard under the null hypothesis of no cointegration. Pesaran, Shin and Smith (2001) provide asymptotic critical value upper and lower bounds for the F-statistic. The lower bound corresponds to the case where all variables are I(0) and the upper bound to the case where all variables are I(1). If the test statistic is below the lower bound, then there is no cointegration. In my case, the test indicates that the null hypothesis of no cointegration cannot be rejected; the F-statistics (0.04 for using the variables in real terms and 2.59 using the variables expressed as ratios of GDP) are well below even the lower bound at the 10% level, 4.04.

The results from the Johansen test for cointegration are presented in Table 3.11. The top panel presents the results using the variables in real terms, whereas the bottom panel presents the results for the variables as shares of GDP. As we can see both the trace test and the maximum eigenvalue test indicate that there is no cointegration between the two series, both when using real measures.

\(^{32}\)I have also experimented with different lag orders and our results were unchanged.
and as ratios of GDP. Moreover, this is true regardless of which specification I tested for the deterministic part corresponding to Cases 2, 3 and 4. I have also compared the estimated values for the test statistics with the 10% critical values and our conclusions are unchanged. Since none of the results is significant I do not report the cointegrating vectors. Thus, the Johansen test agrees with the all the previous tests that I have considered.

As I have discussed earlier, absence of cointegration between $R$ and $GG$ or $\rho_t$ and $gg_t$ implies no sustainability in the strong sense, which is the definition I adopt in this paper. Therefore, my results from the cointegration tests agree with my results from the univariate unit root tests on the debt measures.

### 3.5.3 Cointegration tests in the presence of structural breaks

The results of performing the Gregory and Hansen (1996a) tests are presented in Table 3.12. For the ADF type tests I used the Akaike information criterion and the Schwarz Criterion to determine the appropriate number of lags by allowing a maximum of 8 lags. The lags selected where (0,1,4) for models C, C/T, and C/S respectively for the variables expressed as shares of GDP. For the variables in real terms the lags selected where (0,0,1) for models C, C/T, and C/S respectively. Irrespective of which model is used (C, C/T, or C/S), the null hypothesis of no cointegration is not rejected.\(^{33}\) Moreover, this result is true for both the real measures as well as the measures as ratios to GDP.

As I argued earlier there are two shortcomings of this approach. The first one is that it only accounts for one break, and the second one that it does not examine whether there is a structural change per se. My next step therefore is to use the DOLS approach. I first estimate equation (3.43) for the whole sample without breaks. Then I use the Bai (1997) and Bai and Perron (1998) methodology to identify the breaks and incorporate them into the analysis. In estimating equation (3.43) I experimented with different values for leads and lags. Table 3.13 presents my results on

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\(^{33}\)While I only report the 5% critical values, the null hypothesis is not rejected at the 10% either.
the estimated coefficients on $GG_t$ and $gg_t$ ($\beta$s) along with the $t$-statistics. As I have discussed in Section 3.4.2, fiscal sustainability requires that the two series are cointegrated and that $\beta = 1$ (strong form sustainability). Moreover, if $0 < \beta < 1$ implies weak sustainability irrespective of whether the two series are cointegrated. Moreover, if $\beta = 1$ and the series are not cointegrated, then weak sustainability is again satisfied. If $\beta = 0$ then there is no sustainability. My view is that strong form sustainability is the only appropriate definition for fiscal policy sustainability. Weak form sustainability, either when $\beta = 1$ and the series are not cointegrated or when $0 < \beta < 1$ and the series are or are not cointegrated, is not a sufficient condition for fiscal policy sustainability. In fact, I interpret the evidence of weak sustainability as an indication of potential fiscal unsustainability. Thus, evidence of weak sustainability might be used as an alarming sign by the policy makers. It implies that the government might face financing constraints in the future if it continues its current fiscal policy stance.

To test the restriction that $\beta = 1$ I use a Wald test, which is $\chi^2$ distributed. The Wald test statistics are also reported on Table 3.13. My results indicate a strong rejection of the null hypothesis that $\beta = 1$ and thus strong form sustainability is rejected. Moreover, a Wald test on the restriction that $\beta = 0$ also rejects the null hypothesis. The rejection of the null that $\beta = 1$ together with the rejection that $\beta = 0$ which suggests evidence of weak form sustainability. My results again agree with my previous analysis since strong form sustainability is rejected.

Table 3.14 presents my results on the determination of the breakpoints. For my analysis I have chosen to use the sequential procedure in Bai (1997) and Bai and Perron (1998) that tests the null hypothesis of $l$ breaks against the alternative of $l + 1$ and information criteria.\footnote{I have used the same procedure to examine multiple breaks in my debt measures. However, the test did not identify more than one break. As a robustness check I conducted the Lumsdaine and Papell (1997)unit root test which allows for up to two breaks that are endogenously determined. Since I was not able to reject the unit root null and therefore my results are unchanged, I do not report these findings.} I use equation (3.20) to determine the breaks but I also checked the DOLS specifications with up to 3 leads and lags and my results regarding the break dates were not changed. The method identifies two breaks
in 1994 and 2010 when the estimation is done using the series expressed as shares of GDP. For the series in real terms the test also identifies two breaks; one in 1997 and another one in 2008. The BIC and LWZ criteria also confirm this finding. This results in three regimes; a first one from 1970 to 1993, a second one from 1994 to 2009 and a third one from 2010 to 2015 for the ratios. Accordingly, for the series in real terms the first regime is from 1970 to 1996, the second from 1997 to 2007, and the third one from 2008 to 2015. Despite the differences, the resulting regimes are fairly close with respect to the measure of the data (real vs. ratios). Going back to my discussion in Section 3.2.2 these break dates broadly coincide with some of my proposed periods, specifically the beginning of the third period and the entire last period. The breaks in 1994 and 1997 can be explained by the fiscal consolidation efforts that were put into force and resulted in a reduction of the deficit. As for the second break points, they coincide with the beginning of the fiscal crisis. More specifically, the break in 2008 can be justified with the sharp deterioration of fiscal magnitudes and more importantly of the deficit, whereas the break in 2010 coincides with the agreement of the First Economic Adjustment Program.

Having determined the break dates, my next step is to test for cointegration by incorporating the breaks into my analysis. Given that the estimated break dates result in three subsamples with very few observations in each, performing the cointegration analysis in individual subsamples does not seem plausible. Instead I incorporate the breaks directly into the model and use the DOLS methodology described earlier. In my case where I have identified two breaks in 1993 and 2009 (recall that 1994 and 2010 are the dates of the new regime), when variables are expressed as ratios to GDP, the dummies take the form:

\[
D_1 = \begin{cases} 
0 & \text{from 1970 to 1993} \\
1 & \text{from 1994 to 2015} 
\end{cases}
\]

\[35\text{Note that this is the date of the new regime, based on the way EViews carries out the tests.}\]

\[36\text{24, 16 and 6 for the first, second and third regime respectively when the variables are expressed as ratios to GDP and 27, 11, and 8 when the variables are in real terms.}\]
Accordingly, for the variables in real terms the dummies are:

\[ D_1 = \begin{cases} 
0 & \text{from 1970 to 1996} \\
1 & \text{from 1997 to 2015} 
\end{cases} \]

\[ D_2 = \begin{cases} 
0 & \text{from 1970 to 2007} \\
1 & \text{from 2008 to 2015} 
\end{cases} \]

I estimated the DOLS regressions with the inclusion of the two dummy variables for up to three leads and lags, and for comparison purposes I also estimated the following simple OLS model:

\[
R_t = \alpha + \beta GG_t + \delta_1 D_1 GG_t + \delta_2 D_2 GG_t + v_t \tag{3.48}
\]

I then test the null hypothesis that the coefficient on \(GG_t\) and the slope dummies is equal to one and equal to zero, using a Wald test. In other words the null tested is \(H_0 : \beta + \delta_1 + \delta_2 = 1\). A rejection of the null implies that there is no strong-form sustainability and in line with my previous discussion, is interpreted as no sustainability. I also test the null \(H_0 : \beta + \delta_1 + \delta_2 = 0\). Since \(\beta + \delta_1 + \delta_2 = 0\) imply no sustainability (neither strong nor weak), rejecting the null of zero together with a rejection of the null of overall unity, is evidence in favor of weak form sustainability, and as argued earlier Table 3.15 presents my results for testing for cointegration by including the two breaks. More specifically, as described in Section 3.4.3, Table 3.15 shows our DOLS estimates from equations (3.47) with up to three leads and lags, as well as from equation (3.48). My results indicate that the null hypothesis \(H_0 : \beta + \delta_1 + \delta_2 = 1\) is strongly rejected. Therefore, strong form sustainability is rejected. Moreover, the null hypothesis \(H_0 : \beta + \delta_1 + \delta_2 = 0\) is also strongly rejected. The two rejections when considered together point to weak form sustainability. As I have argued, I
consider fiscal policy as sustainable only if the strong sustainability conditions are satisfied. Weak sustainability implies that the government runs the danger of potentially violating its intertemporal budget constraint. As Quintos (1995) acknowledges, the implication of weak sustainability is that the government has a higher risk of default and would have to offer higher interest payments to service its debt. This implication in the case of Greece is in line with the current situation.

An examination of the coefficients on the break dummies offers intuitive economic and policy implications. As I mentioned earlier, Arghyrou and Luintel (2007) points out that a positive sign on the break dummies implies a move towards strong form sustainability, whereas a negative sign is a move away from it. This is because when the coefficients on the slope dummies are positive, the bubble term in equation (3.3) converges to zero faster compared to when the coefficients are negative. For example, consider $\delta_1$ and $\delta'_1$ in Table 3.15. These are the coefficients associated with the first break, with $D_1 = 1$ from 1997 to 2015 and zero otherwise for the series in real terms and $D_1 = 1$ from 1994 to 2015 and zero otherwise for the ratios to GDP. The positive and significant coefficient in both cases can be explained by the fiscal consolidation efforts prior to securing membership in the eurozone and therefore a move towards strong sustainability. Consider next the coefficients on the second break dummies, $\delta_2$ and $\delta'_2$ for the series in real terms and the ratios to GDP respectively. The associated second breaks are $D_2 = 1$ from 2008 to 2015, zero otherwise for the series in real terms and $D_2 = 1$ from 2010 to 2015 and zero otherwise for the ratios to GDP. Note that while $\delta^*_2$ is negative, $\delta'_2$ is positive. These coefficients might appear to be harder to interpret because the breaks are very close yet have opposing signs. However, one possible interpretation is that the positive coefficient, $\delta'_2$ may be associated with the start of the first economic adjustment program in 2010, and at least in principle should help Greece move toward strong sustainability. The negative coefficient $\delta'_2$ of the break in 2008 is consistent with the marked deterioration of the deficit that started that year, as evidenced in Fig. 3.3 and Fig. 3.4, which in turn implies a move away from strong sustainability.
3.6 Conclusion

In this paper, I have examined the issue of fiscal sustainability in Greece using the two most common approaches in the literature; namely unit root tests on government debt series, and cointegration tests between government revenues and expenditures. Since, as it has been well documented in the literature, the traditional unit root tests are prone to over rejecting the null hypothesis of a unit root, I employed the Zivot Andrews unit root test to account for possible structural breaks. Accounting for breaks lead to a rejection of the sustainability hypothesis. More specifically, the Zivot Andrews tests showed a positive and significant trend which is inconsistent with the concept of sustainability.

In my cointegration analysis I distinguished between the weak and strong forms of sustainability as first proposed by Quintos (1995). My approach was to consider the strong form sustainability condition as a necessary and sufficient condition for the IBC to hold, or in other words the weak form sustainability is only a necessary but not a sufficient condition. Moreover, evidence of weak form sustainability was interpreted as a sign of looming unsustainability. I chose to follow this definition because as Quintos (1995) points out weak sustainability implies that the government runs a higher risk of default and may face financing constraints regarding its debt. I have argued that this approach is appropriate for the case of Greece since it describes the actual situation rather well.

In my cointegration analysis without breaks the two tests that I used confirmed the absence of a long run relationship between my two measures of revenues and expenditures. Overall, my results from the cointegration analysis without breaks are consistent with our univariate analysis - strong form sustainability was rejected. In the Dynamic OLS framework I found evidence suggesting weak form sustainability which I interpret as a warning sign for fiscal authorities. While the deficit process might be sustainable in the context of weak sustainability, the long run implications for sustainability are worrisome.
When I allowed for structural breaks my results were unchanged regarding strong form sustainability, but I reached several other important implications related to the concept of weak sustainability. The Bai (1997) and Bai and Perron (1998) methodology was used to test for multiple structural breaks that are endogenously determined. I was able to identify two breaks for each pair of fiscal variables (real vs. ratios); the first one in 1994 and the second one in 2010 for ratio measures and 1997 and 2008 for the real measures. All breaks can be justified by the economic and political developments in Greece during the specified period. More specifically, the breaks in 1994 and 1997 can be explained by the fiscal consolidation efforts that were put into force and resulted in a reduction of the deficit. As for the second break points, they coincide with the beginning of the fiscal crisis. More specifically, the break in 2008 can be justified with the sharp deterioration of fiscal magnitudes and more importantly of the deficit, whereas the break in 2010 coincides with the agreement of the First Economic Adjustment Program.

Finally, Dynamic OLS was used with the inclusion of break dummy variables. In this last part of my analysis, strong form sustainability was once again rejected, but I found evidence that might be interpreted as indicative of weak form sustainability. As I argued, weak sustainability is worrisome for the long run. Moreover, while the inclusion of breaks did not change the rejection of strong sustainability, it allowed me to study the policy implications of weak sustainability in more depth. More specifically, the signs of the coefficients on the break dummies provided rather satisfactory implications on the move either towards or away strong form sustainability.

It should be noted that my analysis is based on a rather small number of observations due to the limited availability of fiscal data. This can have a non-trivial impact on the power of the tests that I have used in this paper. Moreover, even though I use a single source for my data, fiscal variables, and especially for Greece, are notorious for not being consistent and adequate. Nevertheless, I believe that the present analysis has combined several methodologies, some of which have not been previously used in this setting. Future research might prove insightful by using quarterly data and by testing for cointegration with multiple structural breaks that are determined endogenously.
and specified explicitly in the null and alternative hypotheses. In addition, it would be interesting to further explore the case of weak sustainability and examine how countries that have satisfied sustainability in the weak sense performed in subsequent periods and formally examine whether weak sustainability could be used by policy makers as a warning indicator for unsustainability.
Table 3.1: Descriptive statistics of the series

<table>
<thead>
<tr>
<th></th>
<th>Debt</th>
<th>Revenues</th>
<th>Expenditures</th>
<th>Debt (%)</th>
<th>Revenues (%)</th>
<th>Expenditures (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>106.5</td>
<td>36.2</td>
<td>43.2</td>
<td>76.6</td>
<td>34.4</td>
<td>41.1</td>
</tr>
<tr>
<td>Max</td>
<td>356</td>
<td>98.4</td>
<td>128.4</td>
<td>194.8</td>
<td>48.3</td>
<td>60.8</td>
</tr>
<tr>
<td>Min</td>
<td>0.2</td>
<td>0.3</td>
<td>0.2</td>
<td>15</td>
<td>22.5</td>
<td>22.6</td>
</tr>
<tr>
<td>Std. Dev</td>
<td>119.2</td>
<td>35.9</td>
<td>43.1</td>
<td>50.2</td>
<td>7.4</td>
<td>9.6</td>
</tr>
<tr>
<td>Obs.</td>
<td>46</td>
<td>46</td>
<td>46</td>
<td>46</td>
<td>46</td>
<td>46</td>
</tr>
</tbody>
</table>

*Debt, Revenues and Expenditures are all in billions of national currency. Percentage figures are % of GDP.*
Table 3.2: Lag selection using Information Criteria

<table>
<thead>
<tr>
<th>Two lags</th>
<th>One lag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akaike</td>
<td>Schwarz</td>
</tr>
<tr>
<td>$B_t$</td>
<td>8.032</td>
</tr>
</tbody>
</table>

$^a$ $B_t$ and $b_t$ stand for the real general government public debt in national currency and as a percentage of GDP respectively.

Table 3.3: Zivot-Andrews Unit Root tests for Public Debt - Model A

<table>
<thead>
<tr>
<th>Variable</th>
<th>Break date</th>
<th>Lags</th>
<th>$\alpha_1$</th>
<th>$\alpha_2$</th>
<th>$\mu_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B_t$</td>
<td>2004</td>
<td>0</td>
<td>-0.15</td>
<td>1.14</td>
<td>17.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(-2.61)</td>
<td>(3.09)</td>
<td>(2.01)</td>
</tr>
<tr>
<td>$b_t$</td>
<td>2008</td>
<td>0</td>
<td>-0.18</td>
<td>0.56</td>
<td>12.46</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(-2.29)</td>
<td>(2.13)</td>
<td>(3.43)</td>
</tr>
</tbody>
</table>

$^a$ Model A:

$B_t = \alpha_0 + \alpha_1 B_{t-1} + \alpha_2 t + \mu_1 D_L + \sum_{i=1}^{k} \beta_i \Delta B_{t-i} + \epsilon_t$

$^b$ $B_t$ and $b_t$ stand for the real general government public debt in national currency and as a percentage of GDP respectively.

$^c$ Values in parentheses are test statistics. The test statistic of $\alpha_1$ is for testing the null hypothesis that $\alpha_1 = 1$.

$^d$ The 1%, 5%, and 10% asymptotic critical values for Model A are -5.34, -4.8 and -4.58, from Table 2 in Zivot and Andrews (1992).
### Table 3.4: Zivot-Andrews Unit Root tests for Public Debt - Model B

<table>
<thead>
<tr>
<th>Variable</th>
<th>Break date</th>
<th>Lags</th>
<th>$\alpha_1$</th>
<th>$\alpha_2$</th>
<th>$\mu_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B_t$</td>
<td>1989</td>
<td>0</td>
<td>-0.31</td>
<td>0.40</td>
<td>3.74</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(-3.06)</td>
<td>(1.00)</td>
<td>(2.59)</td>
</tr>
<tr>
<td>$b_t$</td>
<td>2008</td>
<td>0</td>
<td>-0.33</td>
<td>1.04</td>
<td>3.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(-3.24)</td>
<td>(3.34)</td>
<td>(3.55)</td>
</tr>
</tbody>
</table>

*Model B:*

\[
B_t = \alpha_0 + \alpha_1 B_{t-1} + \alpha_2 t + \mu_2 D_P + \sum_{i=1}^{k} \beta_i \Delta B_{t-i} + \epsilon_t
\]

$b_t$ and $B_t$ stand for the real general government public debt in national currency and as a percentage of GDP respectively.

*Values in parentheses are test statistics. The test statistic of $\alpha_1$ is for testing the null hypothesis that $\alpha_1 = 1$. 

$d$ The 1%, 5%, and 10% asymptotic critical values for Model B are -4.93, -4.42 and -4.11, from Table 3 in Zivot and Andrews (1992).

### Table 3.5: Zivot-Andrews Unit Root tests for Public Debt - Model C

<table>
<thead>
<tr>
<th>Variable</th>
<th>Break date</th>
<th>Lags</th>
<th>$\alpha_1$</th>
<th>$\alpha_2$</th>
<th>$\mu_1$</th>
<th>$\mu_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B_t$</td>
<td>1989</td>
<td>0</td>
<td>-0.28</td>
<td>0.24</td>
<td>-6.47</td>
<td>3.41</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(-2.88)</td>
<td>(0.35)</td>
<td>(0.78)</td>
<td>(2.49)</td>
</tr>
<tr>
<td>$b_t$</td>
<td>2003</td>
<td>0</td>
<td>-0.34</td>
<td>1.17</td>
<td>-13.32</td>
<td>2.59</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(-3.38)</td>
<td>(3.32)</td>
<td>(-2.52)</td>
<td>(3.80)</td>
</tr>
</tbody>
</table>

*Model C:*

\[
B_t = \alpha_0 + \alpha_1 B_{t-1} + \alpha_2 t + \mu_1 D_L + \mu_2 D_P + \sum_{i=1}^{k} \beta_i \Delta B_{t-i} + \epsilon_t
\]

$b_t$ and $B_t$ stand for the real general government public debt in national currency and as a percentage of GDP respectively.

*Values in parentheses are test statistics. The test statistic of $\alpha_1$ is for testing the null hypothesis that $\alpha_1 = 1$. 

$d$ The 1%, 5%, and 10% asymptotic critical values for Model B are -5.57, -5.08 and -4.82, from Table 4 in Zivot and Andrews (1992).
Table 3.6: Zivot-Andrews Unit Root tests for the First Difference of Public Debt

<table>
<thead>
<tr>
<th></th>
<th>Model A</th>
<th></th>
<th></th>
<th>Model B</th>
<th></th>
<th></th>
<th>Model C</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Break date</td>
<td>t-stat</td>
<td>lags</td>
<td>Break date</td>
<td>t-stat</td>
<td>lags</td>
<td>Break date</td>
<td>t-stat</td>
</tr>
<tr>
<td>$\Delta B_t$</td>
<td>1990</td>
<td>$-6.384^{***}$</td>
<td>0</td>
<td>2007</td>
<td>$-6.831^{***}$</td>
<td>0</td>
<td>2005</td>
<td>$-7.166^{***}$</td>
</tr>
<tr>
<td>$\Delta b_t$</td>
<td>1994</td>
<td>$-7.948^{***}$</td>
<td>0</td>
<td>2004</td>
<td>$-7.382^{***}$</td>
<td>0</td>
<td>1995</td>
<td>$-8.031^{***}$</td>
</tr>
</tbody>
</table>

$^{a}$ $***$ indicates significance at the 1%

$^{b}$ $\Delta B_t$ and $\Delta b_t$ stand for the changes in real general government public debt in national currency and as a percentage of GDP respectively.

$^{c}$ The results on the first differences are merely for comparison purposes. They are not used as a test for sustainability and rejection of the null is not interpreted as such.
Table 3.7: Lag selection using Information Criteria: 2

<table>
<thead>
<tr>
<th></th>
<th>Two lags</th>
<th>One lag</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Akaike</td>
<td>Schwarz</td>
</tr>
<tr>
<td>$GG_t$</td>
<td>6.32</td>
<td>6.39</td>
</tr>
<tr>
<td>$R_t$</td>
<td>5.15</td>
<td>5.23</td>
</tr>
<tr>
<td>$gg_t$</td>
<td>4.79</td>
<td>4.88</td>
</tr>
<tr>
<td>$\rho_t$</td>
<td>3.59</td>
<td>3.72</td>
</tr>
</tbody>
</table>

$^a$ $GG_t$ are real government expenditures inclusive of interest and $R_t$ are real government revenues, whereas $gg_t$ and $\rho_t$ are respectively government expenditures inclusive of interest and government revenues both expressed as percentages of GDP.
Table 3.8: Unit Root tests: ADF and PP for Government Revenues and Expenditures

<table>
<thead>
<tr>
<th></th>
<th>Intercept, No Trend</th>
<th>Intercept and Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ADF</td>
<td>PP</td>
</tr>
<tr>
<td>$R_t$</td>
<td>-0.39</td>
<td>-0.22</td>
</tr>
<tr>
<td>$GG_t$</td>
<td>-1.48</td>
<td>-1.42</td>
</tr>
<tr>
<td>$\rho_t$</td>
<td>-0.10</td>
<td>0.29</td>
</tr>
<tr>
<td>$gg_t$</td>
<td>-1.22</td>
<td>-1.03</td>
</tr>
</tbody>
</table>

*The ADF and PP regressions shown are both estimated with one lag but the results are robust to lag specification.*

*GG*$_t$ are real government expenditures inclusive of interest and $R_t$ are real government revenues, whereas $gg_t$ and $\rho_t$ are respectively government expenditures inclusive of interest and government revenues both expressed as percentages of GDP.

$t_{ADF}$ and $t_{PP}$ are the test statistics for testing the null hypothesis that $\alpha = 0$ and $t_{\mu_1}$ is the test statistic on the trend term.

MacKinnon’s 1%, 5%, and 10% critical values for the ADF-$t$-statistic in the intercept only model are -3.59, -2.93 and -2.6, whereas for the intercept and trend model are -4.18, -3.52, and -3.19. The critical values based on the Phillips-Perron model are insignificantly different.
Table 3.9: Unit Root tests: ADF and PP for the First Differences of Government Revenues and Expenditures

<table>
<thead>
<tr>
<th></th>
<th>Intercept, No Trend</th>
<th>Intercept and Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ADF</td>
<td>PP</td>
</tr>
<tr>
<td>(\Delta R_t)</td>
<td>-4.53***</td>
<td>-5.65***</td>
</tr>
<tr>
<td>(\Delta GG_t)</td>
<td>-4.96***</td>
<td>-9.14***</td>
</tr>
<tr>
<td>(\Delta \rho_t)</td>
<td>-4.86***</td>
<td>-6.05***</td>
</tr>
<tr>
<td>(\Delta gg_t)</td>
<td>-5.66***</td>
<td>-10.72***</td>
</tr>
</tbody>
</table>

\(t_{ADF}\) and \(t_{PP}\) are the test statistics for testing the null hypothesis that \(a = 0\) and \(t_{\mu_1}\) is the test statistic on the trend term.

**Notes:**

- a The ADF and PP regressions shown are both estimated with one lag but the results are robust to lag specification.
- b \(GG_t\) are real government expenditures inclusive of interest and \(R_t\) are real government revenues, whereas \(gg_t\) and \(\rho_t\) are respectively government expenditures inclusive of interest and government revenues both expressed as percentages of GDP.
- c MacKinnon’s 1%, 5%, and 10% critical values for the ADF-\(t\)-statistic in the intercept only model are -3.59, -2.93 and -2.6, whereas for the intercept and trend model are -4.18, -3.52, and -3.19. The critical values based on the Phillips-Perron model are insignificantly different.
- d *** indicates significance at the 1% level.
Table 3.10: ARDL Bounds Test for Cointegration

<table>
<thead>
<tr>
<th>ARDL</th>
<th>$F$-stat</th>
<th>$k$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_t$</td>
<td>0.04</td>
<td>1</td>
</tr>
<tr>
<td>$\rho_t$</td>
<td>2.59</td>
<td>1</td>
</tr>
</tbody>
</table>

$^a$ $R_t$ and $\rho_t$ are real government revenues and government revenues expressed as a percentage of GDP.

$^b$ The asymptotic critical value bounds for the ARDL Bounds Test are 4.04-4.78 at 10%, 4.94-5.73 at 5%, and 6.84-7.84 at 1%. These are obtained from Table CI(iii), case III (unrestricted intercept, no trend) for lag order, $k=1$ on page 300 in Pesaran, Shin and Smith (2001).
Table 3.11: Johansen Cointegration tests

<table>
<thead>
<tr>
<th></th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_t - GG_t )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypothesized # of CEs</td>
<td>( \lambda_{trace} )</td>
<td>( \lambda_{max} )</td>
<td>( \lambda_{trace} )</td>
</tr>
<tr>
<td>None</td>
<td>10.37</td>
<td>7.37</td>
<td>6.63</td>
</tr>
<tr>
<td>At most 1</td>
<td>3.00</td>
<td>3.00</td>
<td>0.13</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \rho_t - gg_t )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypothesized # of CEs</td>
<td>( \lambda_{trace} )</td>
<td>( \lambda_{max} )</td>
<td>( \lambda_{trace} )</td>
</tr>
<tr>
<td>None</td>
<td>16.45</td>
<td>11.71</td>
<td>10.31</td>
</tr>
<tr>
<td>At most 1</td>
<td>4.75</td>
<td>4.75</td>
<td>1.01</td>
</tr>
</tbody>
</table>

\( GG_t \) are real government expenditures inclusive of interest and \( R_t \) are real government revenues, whereas \( gg_t \) and \( \rho_t \) are respectively government expenditures inclusive of interest and government revenues both expressed as percentages of GDP.

The 5% asymptotic critical values are from Osterwald-Lenum (1992).

Case 2: The 5% critical values for \( \lambda_{trace} \) are 19.96 and 9.24 and for \( \lambda_{max} \) are 15.67 and 9.24, where the two values correspond to the hypothesized # of CEs, in our case 0 and 1.

Case 3: The 5% critical values for \( \lambda_{trace} \) are (15.41, 3.76) and for \( \lambda_{max} \) are (14.07 and 3.76).

Case 4: The 5% critical values for \( \lambda_{trace} \) are (25.32, 12.25) and for \( \lambda_{max} \) are (18.96 and 12.25).
### Table 3.12: Gregory-Hansen cointegration test with regime shifts

<table>
<thead>
<tr>
<th></th>
<th>$R_t - GG_t$</th>
<th>ADF type test</th>
<th>Phillips type test</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>ADF*</td>
<td>Break date</td>
<td>$Z^*_a$</td>
<td>Break date</td>
<td>$Z^*_t$</td>
<td>Break date</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 2 (C)</td>
<td>-4.23</td>
<td>1996</td>
<td>-32.69</td>
<td>1996</td>
<td>-4.56</td>
<td>1996</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 3 (C/T)</td>
<td>-4.92</td>
<td>1996</td>
<td>-33.52</td>
<td>1996</td>
<td>-4.78</td>
<td>1996</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 4 (C/S)</td>
<td>-4.46</td>
<td>1996</td>
<td>-33.87</td>
<td>1996</td>
<td>-4.75</td>
<td>1996</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$\rho_t - gg_t$</th>
<th>ADF type test</th>
<th>Phillips type test</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>ADF*</td>
<td>Break date</td>
<td>$Z^*_a$</td>
<td>Break date</td>
<td>$Z^*_t$</td>
<td>Break date</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 2 (C)</td>
<td>-3.59</td>
<td>1994</td>
<td>-23.96</td>
<td>1994</td>
<td>-3.68</td>
<td>1994</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 3 (C/T)</td>
<td>-3.71</td>
<td>2002</td>
<td>-19.72</td>
<td>1994</td>
<td>-3.63</td>
<td>2002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 4 (C/S)</td>
<td>-3.75</td>
<td>1990</td>
<td>-24.82</td>
<td>1994</td>
<td>-3.78</td>
<td>1994</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^a$ $GG_t$ are real government expenditures inclusive of interest and $R_t$ are real government revenues, whereas $gg_t$ and $\rho_t$ are respectively government expenditures inclusive of interest and government revenues both expressed as percentages of GDP.

$^b$ The 5% asymptotic critical values are from Gregory and Hansen (1996a), Table 1 on page 109 for $m = 1$, where $m$ is the number of regressors excluding a constant and/or trend. Note that the critical values for $ADF^*$ and $Z^*_t$ are the same.

$^c$ 5% critical values for the $ADF^*$ and $Z^*_t$ are -4.61, -4.99, and -4.95, whereas for $Z^*_a$ are -40.48, -47.96, and -47.04 for models C, C/T, and C/S respectively.

### Table 3.13: DOLS estimates - Full sample without breaks

<table>
<thead>
<tr>
<th></th>
<th>DOLS(0,0)</th>
<th>DOLS(1,1)</th>
<th>DOLS(2,2)</th>
<th>DOLS(3,3)</th>
<th>OLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.83</td>
<td>0.84</td>
<td>0.85</td>
<td>0.87</td>
<td>0.83</td>
</tr>
<tr>
<td>$t$-stat</td>
<td>32.41</td>
<td>59.94</td>
<td>83.07</td>
<td>30.82</td>
<td>34.38</td>
</tr>
<tr>
<td>Wald $\chi^2 (\beta = 1)$</td>
<td>43.7*</td>
<td>130*</td>
<td>227.2*</td>
<td>21.57*</td>
<td>49.7*</td>
</tr>
<tr>
<td>Wald $\chi^2 (\beta = 0)$</td>
<td>1,050.6*</td>
<td>3,593*</td>
<td>6,000*</td>
<td>950*</td>
<td>1,181.8*</td>
</tr>
</tbody>
</table>

### Table 3.14: Bai-Perron sequential break point tests

<table>
<thead>
<tr>
<th></th>
<th>F-stat</th>
<th>Scaled F-stat</th>
<th>Critical Value</th>
<th>Break date</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_t - GG_t$</td>
<td>0 vs. 1**</td>
<td>66.00</td>
<td>132.0</td>
<td>11.47</td>
</tr>
<tr>
<td></td>
<td>1 vs. 2**</td>
<td>16.67</td>
<td>33.35</td>
<td>12.95</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>F-stat</th>
<th>Scaled F-stat</th>
<th>Critical Value</th>
<th>Break date</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho_t - gg_t$</td>
<td>0 vs. 1**</td>
<td>37.48</td>
<td>74.97</td>
<td>11.47</td>
</tr>
<tr>
<td></td>
<td>1 vs. 2**</td>
<td>8.32</td>
<td>16.63</td>
<td>12.95</td>
</tr>
</tbody>
</table>

*a* All models estimated using a constant.

*b* *GG*$_t$ are real government expenditures inclusive of interest and $R_t$ are real government revenues, whereas $gg_t$ and $\rho_t$ are respectively government expenditures inclusive of interest and government revenues both expressed as percentages of GDP.

*c* * denotes significance at the 1% level.

---

*a* * denotes significance at the 5% level

*b* *GG*$_t$ are real government expenditures inclusive of interest and $R_t$ are real government revenues, whereas $gg_t$ and $\rho_t$ are respectively government expenditures inclusive of interest and government revenues both expressed as percentages of GDP.
### Table 3.15: DOLS estimates with breaks

<table>
<thead>
<tr>
<th></th>
<th>$R_t - GG_t$</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DOLS(0,0)</td>
<td>DOLS(1,1)</td>
<td>DOLS(2,2)</td>
<td>DOLS(3,3)</td>
<td>OLS</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.84***</td>
<td>0.91***</td>
<td>0.70***</td>
<td>0.55***</td>
<td>0.77***</td>
</tr>
<tr>
<td>$\delta_1$</td>
<td>0.07*</td>
<td>0.04*</td>
<td>0.13*</td>
<td>0.20*</td>
<td>0.10*</td>
</tr>
<tr>
<td>$\delta_2$</td>
<td>-0.13**</td>
<td>-0.18**</td>
<td>-0.03**</td>
<td>-0.09**</td>
<td>-0.06**</td>
</tr>
<tr>
<td>Wald $\chi^2 (\beta + \delta_1 + \delta_2 = 1)$</td>
<td>274.5***</td>
<td>572.5***</td>
<td>197.5***</td>
<td>497.6***</td>
<td>127.1***</td>
</tr>
<tr>
<td>Wald $\chi^2 (\beta + \delta_1 + \delta_2 = 0)$</td>
<td>487.3***</td>
<td>121.8***</td>
<td>413.6***</td>
<td>972.7***</td>
<td>200.2***</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$\rho_t - gg_t$</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DOLS(0,0)</td>
<td>DOLS(1,1)</td>
<td>DOLS(2,2)</td>
<td>DOLS(3,3)</td>
<td>OLS</td>
</tr>
<tr>
<td>$\beta'$</td>
<td>0.41***</td>
<td>0.43***</td>
<td>0.42***</td>
<td>0.39***</td>
<td>0.38***</td>
</tr>
<tr>
<td>$\delta'_1$</td>
<td>0.14***</td>
<td>0.13***</td>
<td>0.13***</td>
<td>0.13***</td>
<td>0.15***</td>
</tr>
<tr>
<td>$\delta'_2$</td>
<td>0.03*</td>
<td>0.02*</td>
<td>0.02*</td>
<td>0.02*</td>
<td>0.03*</td>
</tr>
<tr>
<td>Wald $\chi^2 (\beta' + \delta'_1 + \delta'_2 = 1)$</td>
<td>196.1***</td>
<td>193.8***</td>
<td>122.2***</td>
<td>101.8***</td>
<td>173.9***</td>
</tr>
<tr>
<td>Wald $\chi^2 (\beta' + \delta'_1 + \delta'_2 = 0)$</td>
<td>356.5***</td>
<td>374.1***</td>
<td>221.1***</td>
<td>141.3***</td>
<td>277.6***</td>
</tr>
</tbody>
</table>

---

$a$ All models estimated using a constant.

$b$ $GG_t$ are real government expenditures inclusive of interest and $R_t$ are real government revenues, whereas $gg_t$ and $\rho_t$ are respectively government expenditures inclusive of interest and government revenues both expressed as percentages of GDP.

$c$ ****, ***, * indicate significance at the 1%, 5% and 10% level respectively.
Appendix A

Data sources for Chapter 2

For the unemployment rate (%) I used the Annual Macroeconomic (AMECO) database of the European Commission’s Directorate General for Economic and Financial Affairs, as well as Eurostat for the period from 1960 to 2015. The CPI inflation rate (%) from 1960 to 2015 was obtained from the National Statistical Service of Greece (ELSTAT) for Greece and from Eurostat for the rest of the Euro area. The general government consolidated gross debt (as a % of GDP) was obtained from AMECO and Eurostat and from 1970 to 2015. For the general government deficit (as a % of GDP) I used AMECO, Eurostat, and various issues of OECD’s Economic Outlook, covering the period from 1970 to 2015. The quarterly GDP growth rate (%) was obtained from Eurostat and ELSTAT from 1996 to 2015, whereas per capita GDP (in 2010 euros) was obtained from Eurostat from 1995 to 2006. Deposits in and liabilities of Greek banks were retrieved from the Bank of Greece, in millions of euros and from 2001 to 2015. The main aggregates of the general government (as a % of GDP) from 1995 to 2015 were obtained from ELSTAT’s publication The Greek Economy and from various issues of OECD’s Economic Outlook. Finally, the main macroeconomic indicators were obtained from ELSTAT for the period 2014Q1 to 2015Q4.
Bibliography


Adrian, Tobias, and Marcus Brunnermeir. 2010. “CoVaR.” Federal Reserve Bank of New York Staff Reports, Staff Report No. 348.


