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**"THE DETERMINANTS OF EUROZONE SOVEREIGN SPREADS:
A LONG-RUN PERSPECTIVE"**

RELATORE:

CH.MO PROF. GRECO LUCIANO GIOVANNI

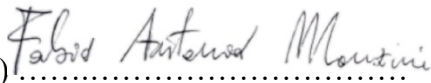
LAUREANDO: MANZINI FABIO ANTONIO

MATRICOLA N. 1209727

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Introduction

The study of sovereign bond spreads in the Eurozone has gained significant attention in economic and financial research, particularly in the wake of the financial and sovereign debt crises that have shaped the European economic landscape over the past two decades. The behaviour of yield differentials of the Eurozone countries government bonds with respect to Germany has been put under the microscope of researcher and financial analyst as a crucial indicator of market perceptions of the financial stability of a country in relation to the credit risk, liquidity conditions, and broader macroeconomic and political stability. Understanding the determinants of these spreads is essential for policymakers and investors, as they offer insights about the degree of sustainability of public finances, the effectiveness of fiscal and monetary policy, and the overall cohesion of the Economic and Monetary Union (EMU).

This work aims to investigate the low frequency determinants of Eurozone sovereign spreads, examining both fundamental economic variables and external factors influencing investor sentiment, trying to identify the impact of these variable across a long-run perspective. Indeed, the research spans a period from 2002 to 2022, a timeframe encompassing significant economic events, including the Global Financial Crisis of 2007-2008, the European Sovereign Debt Crisis, and the more recent economic disruptions caused by the COVID-19 pandemic. Moreover, the relevant shocks impacting the Eurozone economies in that period were accompanied by considerable fiscal and monetary policy changes in the whole euro area. By adopting a rigorous econometric approach, this study seeks to disentangle the effects of various macroeconomic, fiscal, and financial variables on sovereign bond spreads across the main nine Eurozone countries.

A key focus of this research is the role played by macroeconomic fundamentals in determining sovereign risk premia. The traditional view posits that countries with higher levels of public debt and persistent fiscal imbalances tend to face higher borrowing costs due to heightened default risk. However, in the context of the Eurozone, where a common currency eliminates exchange rate risk and monetary policy is centralized at the European Central Bank (ECB), the influence of fiscal variables on spreads is often intermediated by market perceptions, investor sentiment, and the actions of European institutions.

In addition to fiscal determinants, we explores the impact on sovereign spreads of market liquidity and global risk aversion. Liquidity conditions in government bond markets can significantly affect yield differentials, as investors demand higher risk premia for bonds that are less liquid and more difficult to trade. Moreover, periods of heightened global financial uncertainty—often captured through indicators such as the VSTOXX index—can exacerbate

sovereign risk premia, as investors shift towards safe-haven assets, typically favouring German Bunds over bonds issued by peripheral Eurozone countries.

Moreover, the analysis investigate the influence that European Central Bank (ECB) policies might have on sovereign spreads determination. The introduction of unconventional monetary policy measures, including the Securities Markt Programme (SMP), Outright Monetary Transactions (OMT), large-scale asset purchase programs such as the Public Sector Purchase Programme (PSPP) and the Pandemic Emergency Purchase Programme (PEPP), have played a crucial role in stabilizing sovereign debt markets. By purchasing government bonds and ensuring liquidity in the financial system, the ECB has mitigated the risk of fragmentation within the Eurozone, reducing yield differentials across member states. Understanding the effectiveness and limitations of these interventions is a central theme of this research.

Methodologically, this study employs a dynamic panel regression framework, exploiting quarterly data in the period 2002-2022 across the main nine Eurozone countries.¹ The econometric strategy is designed to address key statistical challenges commonly encountered in sovereign spread analysis, including heteroskedasticity, serial correlation, and cross-sectional dependence. By utilizing techniques such as the Prais-Winsten Panel-Corrected Standard Errors (PCSE) model, the analysis ensures robust and reliable estimates, accounting for the complex interactions between fiscal, financial, and macroeconomic determinants.

Moving from the historical context and the theoretical foundations to the empirical analysis and policy implications of the estimated results, the thesis proceeds as follows. Chapter 1 sets the stage by providing a historical overview of sovereign spreads in the Eurozone. It examines key economic and financial developments that have influenced yield differentials over time, offering a contextual foundation for the empirical investigation. By tracing the evolution of spreads, this chapter highlights the major crises, policy responses, and structural factors that have shaped the Eurozone sovereign bond market. Chapter 2 presents an extensive literature review, discussing the theoretical foundations of sovereign spread determination from the early stage of economic discussion on the sovereign spreads more oriented towards the impact of the fiscal and liquidity variable until most recent papers investigating the role played the ECB with unconventional monetary policy. This chapter synthesizes competing perspectives on the role of fiscal, financial, and macroeconomic factors in explaining spread movements, positioning this study within the broader academic research.

Chapter 3 describes the empirical analysis conducted, from the description of the dataset to the comments of the results and their implications. The first paragraph details the dataset and

¹ The selection of countries to include in the sample is strictly dependent on data availability. Enlarging the sample to more peripheral Eurozone economics would shrink significantly the time span of our analysis.

variables employed as well as data sources and preliminary descriptive statistics. This analysis provides an initial exploration of the patterns and correlations in the dataset, laying the groundwork for the econometric modelling. The second paragraph turns on the description of the methodological approach, explaining the choice of panel data techniques and detailing the econometric specifications. Special attention is given to potential estimation issues, including heteroskedasticity, serial correlation, and cross-sectional dependence. The strategies employed to address these econometric issues ensure that the model produces robust and reliable results, enhancing the validity of the empirical findings. Finally, the last paragraph presents and interprets the empirical results, systematically examining the impact of fiscal fundamentals, liquidity risk, global uncertainty, and ECB interventions on sovereign spreads, with a particular emphasis on the regional differences and time effects. The findings are analysed in relation to the existing literature, highlighting the connecting elements with previous researches and how they emerge in this work. This chapter also explores the broader policy implications of the results, particularly in terms of fiscal governance, financial stability, and monetary policy effectiveness in the Eurozone. Finally, the conclusion summarizes the key insights and reflecting on the study's limitation and avenues for future research. The final considerations aim to offer critical insights for policymakers, stressing the importance of proactive fiscal and monetary policy in maintaining stable sovereign debt markets.

By providing a systematic examination of sovereign spread determinants, we aim at contributing to the ongoing discussion on financial stability in the Eurozone. The most relevant elements of the existing literature are put in a new and comprehensive perspective, based on a 20-years analysis covering all the different stages of the euro area, from the adoption of the Euro currency to the global financial crisis and debt crisis until the most recent critical period of the COVID-19 pandemics. The results of this study converge towards that branches of the research that highlight the pricing anomalies that occurred on Eurozone sovereign debt markets before and during the sovereign debt crisis, stressing sovereign spreads beyond the impact of fiscal and liquidity fundamentals. In this framework it is emphasized the primary role played by the ECB in stabilizing the markets and bringing the spreads back towards a convergence path to their fundamentals. Final policy considerations point out the relevance of a proactive European Central Bank monetary policy in smoothing markets fragmentations and over-reacting investor sentiments, parallel with a coordinated fiscal policy aiming to carefully monitor the macro-fundamentals connected with countries credit risk.

1. Stylized facts: the evolution of spreads in the Eurozone

In the analysis of the spread determinants of the sovereign bonds in the Eurozone it is worth doing a brief historical digression which highlights the main events that affected the sovereign bond market in the last two decades. The dynamics of the 10-year sovereign bond spreads for the main Eurozone economies in the last decades is reported in Figure 1.

After the adoption of the single currency in 1999, the years up to financial crisis of 2007 were characterized by the so-called “convergence process”. In those years yields on the governments bonds of the euro area converged leaving almost null spreads, giving the illusion that buying Greek or Portuguese government bonds was safe as much as buying the German or French ones. This process was fed by the common belief of the investors that the financial integration consequent to the birth of EMU would have stimulated a convergence of all the euro area economies to the German one (Argyrou and Kontonikas, 2011). For this reason, large capital flows moved from the core countries of the Eurozone, with higher propensity to save as Germany, but also Netherlands and Finland, to the peripheral countries with lower savings and higher propensity to consume and returns to capital. This process brought to large current account imbalances, but it did not put the observers on alert since it was perceived as a normal convergence scheme (CEPR, 2015).

However, the huge capital flows from the core countries to the peripheries did not boost a total factor productivity growth and the fiscal imbalances of the peripheral countries became source of troubles after the outbreak of 2007 financial crisis. Indeed, in absence of a common intervention at the European level, national governments bailed-out the suffering banks recurring to borrowing and thus driving up public deficit and debt. In face of the new financial environment resulted from the crisis, investors began to reassess their international exposures moving funds from the most indebted countries towards safer allocations, in particular Germany which acquired a safe-haven status (Beber et al., 2009). Some countries, starting from Greece and Ireland in 2007 and 2008, experienced authentic “sudden stop” episodes (Merler and Pisani-Ferry, 2012), which consist in a drastic and abrupt change in capital inflows.

The deteriorating fiscal and financial conditions of the peripheral countries together with sudden stops and liquidity constraints were the prodrome of the European sovereign debt crisis, but the authentic trigger event happened in October 2009, when the newly elected Greek government announced that the previous executive had masked the size of the budget deficit which was two times larger than previously announced, accounting for the 12.5% of GDP. According to Micossi (2015) the Greek crisis acted as a “detonator” for the entire Eurozone since it alerted investors and authorities of possible violations of the European treaties and

common fiscal rules and at the same time it made clear that the euro area was not equipped of emergency instruments able to provide liquidity to distressed markets and to ensure the orderly rollover of sovereigns under selling pressure. Yields on Greek government bonds soared, spreading panic on the other sovereign markets and hitting in particular the other countries with compromised fiscal fundamentals. The rise in interest rates expense to finance public debt further deteriorated the fiscal budgets creating a self-fulfilling debt vortex that involved also the national banks which keep in their balance sheets high shares of sovereign debt. One of the main causes of this phenomenon often defined as the “doom-loop” was for sure the absence of a banking union in the Eurozone and the strong home bias of the national banking sectors (Gros, 2015). However, also the absence of a lender of last resort in the Eurosystem able to provide liquidity in last instance was one of the main sources of instability (De Grauwe, 2015) and probably of the inability of the European institutions to tackle down self-fulfilling expectations about the insolvency risk of peripheral countries.

In this framework, the initial response of the European institutions to the widening of spread was completely insufficient. The securities market program (SMP) activated by the ECB on May 2010 appeared to be a too late and too limited in its size instrument to adequately respond to the crisis (Claeys et al., 2022). At the same time, also the rescue programs turned out to be inadequate to stop the Greek crisis and the contagion among the other states. After the first bailout of May 2010 by EU and IMF, Greece needed a second rescue program in 2012, while Ireland and Portugal were bailed out in November 2010 and April 2011. Financial turmoil on sovereign bonds reached also Italy and Spain at the end of 2011, forcing Italy to put in place a national unity government led by Professor Mario Monti and Spain to ask for official funding together with Cyprus in June 2012.

The huge tensions on the sovereign debt markets in the Eurozone were calmed down only in the end of July 2012 with the renowned announcement of the newly appointed president of the ECB Mario Draghi to do “Whatever it takes” to preserve the Euro. This commitment was followed in few weeks by the setting up of two European instruments to be activated in case of asymmetric crisis hitting Eurozone countries: the European Stability Mechanism (ESM) funded by the European national governments, and the Outright Monetary Transactions (OMT). The first consists in an emergency fund at the disposal of the European countries that would have needed financial support conditionally to the sign of a memorandum of understanding about fiscal discipline. The latter consists in the possibility of the ECB to intervene in the markets buying government bonds of distressed countries once they have joined the ESM program.

The combination of these interventions appeased the tensions on the sovereigns pushing down the yields of the GIIPS government bonds and narrowing the spreads. The decreasing trend of

the yields on sovereign bonds continued in the following years also due to the expansive monetary policy adopted by the ECB. Indeed, the European Central Bank lowered the interest rates till below zero to face the deflationary pressures in the euro area coming in particular from the effects of the austerity policies put in place by the peripheral countries. Once reached the “zero-lower-bound”, in face of the impossibility of further lowering the interest rates, the ECB implemented a non-conventional operation of massive purchases of assets called Asset Purchase Programme (APP) intervening directly in the market to sustain the price level near the inflation target of 2%. This program, announced in January 2015, was then followed in March of the same year by the implementation of a new part devoted to the purchase of the public assets such as the government bonds: the public sector purchase programme (PSPP). With these two massive programmes of purchases on the markets including the government assets, the ECB not only sustained the price level in the Eurozone keeping inflation near the target of 2% but also helped keeping low the yields on GIIPS sovereign bonds, thus limiting the problem of fragmentation in the Eurozone born after the Greek crisis.

Fragmentation refers to all the possible issues connected to an uneven transmission of monetary policy in the euro area, from the diverging risk premia in sovereign bonds to financing conditions depending on the specific country risk, disconnected interbank markets and disturbed cross-border capital flows (Gern et al., 2022). In particular, the fragmentation caused by the spreads on sovereign bonds has been one of the main issues of concern for the ECB and the policymakers. According to several authors (De Santis, 2015; Gros, 2018) redenomination risk was the key element in determining the fragmentation on the euro area sovereigns during the debt crisis and thereafter, due to the perceived possibility that the euro area could break-up for the exit of some of their country member in a moment of financial distress or for a political choice. This specific risk, that soared in 2012 before the announcement of OMT, was significantly reduced after the announcement of the APP and PSPP, producing the effect of a strong convergence in yield-spreads in the euro area (Benigno et al., 2022). However, the redenomination risk did not completely disappear, in fact it drove the spread of the Greek bonds during the hard negotiations of the Greek government with the European institutions in 2015 and also in Italy in 2018 in the first months after the formation of the new government between the Eurosceptic parties Lega and 5 Star Movement (Gros, 2018).

New tensions on sovereign spreads arose after the diffusion of the COVID-19 pandemic, but in this case, contrary to what happen with the debt crisis, the prompt response of ECB calmed down the markets with the creation in March 2020 of the Pandemic Emergency Purchase programme (PEPP) to provide liquidity support to firms and sovereigns during the emergency

However, the announcements of the end of PEPP in March 2022 and of PSPP by the end of the third quarter of 2022, together with the new monetary challenges represented by the inflationary pressures given by the increase in the prices of raw materials and energy, put new stress on sovereigns. As long as the monetary policy was expansive, the ECB was able to limit fragmentation sustaining the government bond market with the PSPP and at the same time accomplishing its price stability objective. These two goals are no longer simultaneously achievable in the current context of necessary monetary tightening (Gern et al., 2022). The consequences of the rise of interest rates to contain inflation and the stop of asset purchases of the ECB started to be priced by the markets since the beginning of 2022, with a widening of the spreads for all the euro area countries, in particular for those under the magnifying lens for the political risk (e.g., Italy). The president of the ECB Lagarde declared that the central bank will reinvest flexibly the maturing assets in its balance-sheet to tackle fragmentation and that new eventual instruments will be set up in case of need (Lagarde, 2022). However, how precisely the ECB and the European Institutions could intervene and how effective could be the tool at its disposal is now one of the main topics of discussion of the economic debates.

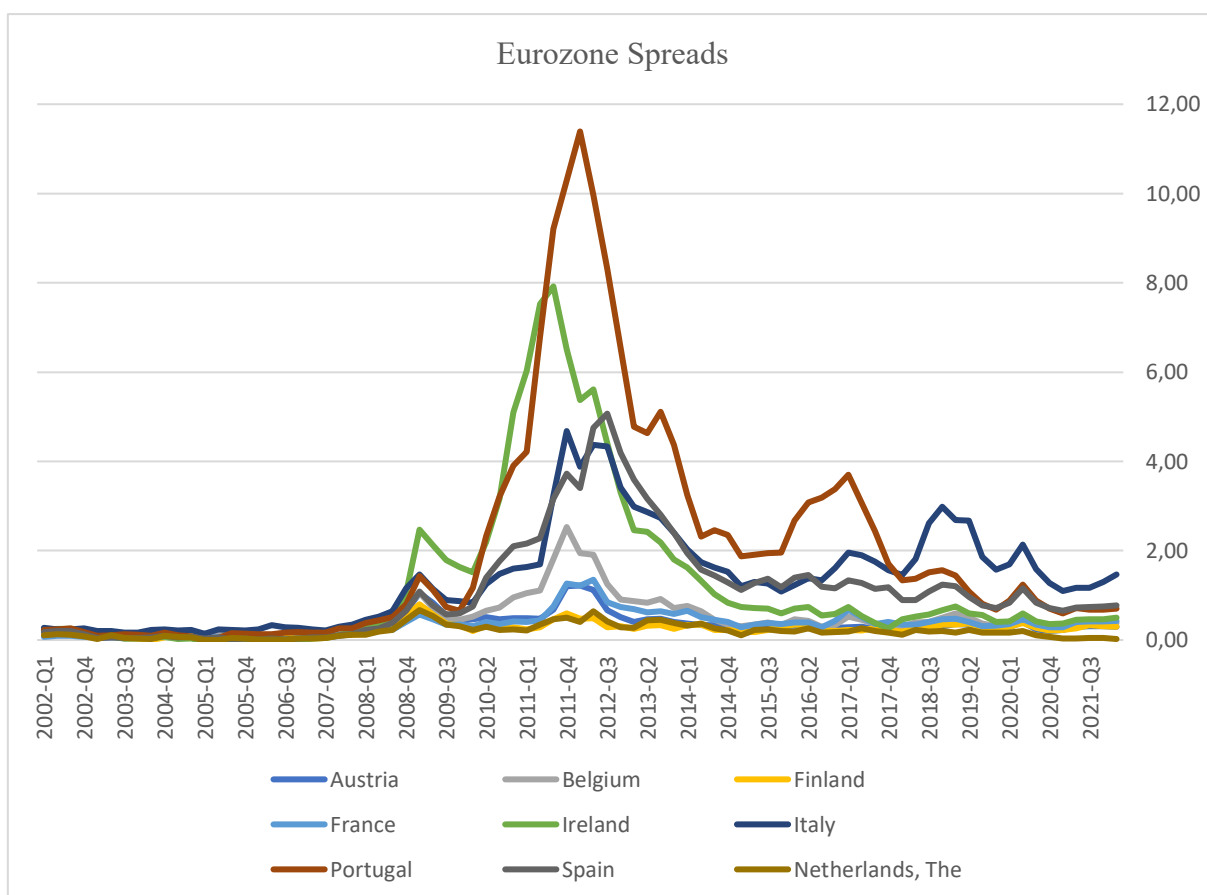


Figure 1 – Sovereign bond spreads for the main nine Eurozone economies in the period 2002 Q1-2022 Q1

2. Literary Review

The determinants of the yield spreads on sovereign bonds have always been a relevant object of the economic research, in particular in the context of the Eurozone, where the adoption of the single currency in 1999 changed the traditional schemes of national monetary policy introducing issues of transmission mechanisms and common policies frameworks.

The literature of the last decades on EU spread determinants can be classified into three macro-groups representing three different periods of time. From the early 2000s to 2008 and 2009 the main studies analyse the role played by the different spread determinants during the so-called convergence process up to the global financial crisis. These years were characterized by the convergence of the yields on sovereign bonds in the Eurozone, a pattern that continued until the broke up of global financial crisis which caused the first turmoil also in the European sovereign bond market. Starting from 2009, authors began investigating the widening of spreads between sovereign bonds in the Eurozone as a first consequence of the stress present on the financial markets (Attinasi et al., 2009; Beber et al., 2009). Whereas, after the dramatic surge of the yields on the sovereign bonds of the peripheral countries between 2011 and 2012, new elements of research inspired studies that took into account the dynamics of the sovereign debt crisis and the subsequent political responses adopted in terms of monetary and fiscal policy (OMTs, ESM, APP).

One of the main efforts of the studies on the yield spreads is to identify and try to measure the impact of the possible determinants that can influence the spreads. Generally, the literature on this topic has focused on three main categories of risk that influence the sovereign bonds market (Manganelli and Wolswijk, 2009; Alfonso et al, 2012): credit risk, liquidity risk and a variable representing the aggregate risk in terms of international risk aversion, often defined as *international risk factor* or global risk.

Credit risk reflects the probability of default of a sovereign borrower, and it is typically measured by indicators of the fiscal or macroeconomic position of the country considered. Debt-to-GDP and deficit-to-GDP ratios are the most investigated variables depicting default risk (Bernoth et al. 2006, Schuknecht et al. 2010), and often are considered in terms of their expectations according to the forecasts of the European Commission (Attinasi et al., 2010; Haugh et al., 2009; Barrios et al., 2009; Sgherri and Zoli, 2009). On the other hand, other authors considered more suitable employing credit ratings (Gomez Puig, 2006; Manganelli and Wolswijk, 2009) or the differentials in CDSs (Beber et al., 2009; Barrios, 2009).

Liquidity risk refers to the size and depth of the government bonds market capturing the risk of capital losses in case of early liquidations or price changes due to a limited number of

transactions. Generally, it is measured with bid-ask spreads (Favero et al., 2010; Barrios et al., 2009) or with shares of transaction volumes of the sovereign bonds (Bernoth et al., 2006; Attinasi et al., 2009; Arghyrou and Kontonikas, 2011).

Finally, international risk is considered for measuring the aggregate or systemic risk, which is mainly proxied by the indexes of volatility in stock markets or with the spread between US corporate bonds and treasury bills.

Studies of the pre-crisis period are not unanimous in assessing the relevance of different variables affecting spreads, but they prevalently recognize a primary role of a common factor linked to international risk aversion. Codogno et al. (2003) point out a prevalence of the international risk factor (proxied by the spread between US corporate and government bonds), since in their seemingly unrelated regression analysis (SUR) of 9 euro-zone countries fluctuations in spreads are attributed to fiscal fundamentals like debt-to-GDP only for Italy and Spain. Pagano and Von Thadden (2004) ascribe to the persistence of interest rates differences on sovereign bonds after EMU the role played by the differentials in fundamental risk, whereas they argue that liquidity has only a small impact only through its interaction with fundamental risk. Geyer et al. (2004) find that long-term yield spreads move according to a common global factor and that liquidity proxies and macroeconomic variables have no impact. Instead, according to Bernoth et al. (2006) fiscal variables do matter in the determination of spreads, with debt-service ratio prevailing on debt and deficit as indicator of creditworthiness after the start of EMU, which can be read as a signal of shift of attention of the market maybe also for the loss of credibility of the Maastricht parameters related to government debt and deficit.

All the aforementioned authors, in addition to the same interpretation of the relevance of the international risk factor, agree to attribute a marginal or irrelevant role to liquidity variables. This is also due to the fact that they work with low frequency data (monthly and quarterly data), which is more appropriate for capturing the macroeconomic variables (Caggiano and Greco, 2011), while liquidity proxies tend to affect yields at higher frequency and are more likely to be caught by daily observations, especially in a period characterized by low spreads and fluctuations as it was in the convergence period. Indeed, using daily data, Gomez Puig (2006) finds out that the liquidity factor expressed in terms of bid-ask spreads and relative market size levels became the main determinants of yield spreads in EMU after the adoption of the euro currency, in face of a disappearance of the default risk. Moreover, her results show evidence of a non-linear relationship between the outstanding debt levels and spreads accentuated by the currency union.

Another important contribution about how liquidity factors affect the sovereign debt market comes from Beber et. al. (2009), who investigate the capital flights rising from the financial

crisis of 2008. According to these authors, during the crisis the destination of large flows is determined mainly by liquidity, even though credit quality generally represents the bulk of sovereign yield spreads. Therefore, despite liquidity becomes crucial during periods of market stress, also in normal times it plays a non-negligible role especially for low credit risk countries. In the principal component analysis conducted by Favero et al. (2010), yields on sovereign bonds tend to comove following a common international factor, captured by the spread between the 10 years Fixed Interest Rate on Swaps and 10 years U.S. Government Bond Yield. These authors develop a model with endogenous liquidity demand depending on transaction costs and investment opportunities. Liquidity differential variables become significant in the interaction with the aggregate risk factor, which has a negative impact on yield differential, indicating an important non-linear effect of liquidity indicators. However, they do not have in their time-series analysis enough variation in the macroeconomic variables to infer conclusions about the fiscal determinants.

Deepening the elements of the existing literature on the aggregate risk determinant of sovereign spreads, Manganelli and Wolswijk (2009) associate the movements in the common risk factor of the yield spreads to the short-term interest rates fixed by the central bank. Furthermore, they find that both liquidity and credit risk are priced by investors in the sovereign bond market. However, they question whether the latter is sufficiently weighted to encourage EMU governments to adopt sustainable fiscal policies.

With the burst of the global financial crisis in 2007 and the consequent surge in sovereign bond yields in the Eurozone, the macroeconomic fundamentals of the EMU countries ended up under the magnifying lens of a specific strand of the literature as potential determinants of sovereign debt spreads. Several authors stress that financial crisis has magnified the impact of fiscal variables (Haugh, 2009; Sgherri and Zoli, 2009; Schuknecht et al., 2010), bringing more relevance to the domestic factors (Barrios, 2009) and widening the set of macroeconomic determinants (Attinasi et al. 2009; Caggiano and Greco, 2011). Using daily and monthly data from 31 July 2007 to 25 March 2009, Attinasi et al. (2009) draw the conclusion that fiscal variables as the expected debt and deficit ratio have a relevant impact on the spreads estimated by the 21% of the overall variation, as well as the liquidity and international risk proxies counting for the 14% and 56% respectively. Moreover, they find evidence of the impact of the announcement of bank rescue packages, supporting the hypothesis of the credit risk transfer from the private to the public sector.

Further research focuses on the role of the banking sector. Gerlach et al. (2010) points out a link between sovereign risk spreads and the dimension of the banking sector of a given country. In particular, periods of crisis and turbulences on the markets induce a widening of spread in

countries with high financial liabilities, while in periods of low aggregate risk this factor seems to be neglected. Countries with low equity buffers tend to pay higher spreads in stressful periods, incorporating the risk of government interventions in the financial sector to finance bail-outs and a the consequent deterioration of public balance that will affect country credit risk. Still recognising a predominant role of the international risk aversion, Barrios et al. (2009) find that government budget and current account balance, as well as liquidity indicators, are highly significant in explaining the evolution of the sovereign spreads. In particular, the impact of the formers tends to grow with the increase in global risk aversion. This pattern mainly penalizes the countries with weak fiscal fundamentals, which experienced the higher increments on sovereign yields. Schucknecht et al. (2010) draw similar conclusions, sustaining that the rise in spreads between 2008 and 2009 can be explained by the basis of the economic principles, even though they notice that markets penalized fiscal imbalances much more strongly after the crush of Lehman Brothers. Evidence of non-linearities in the behaviour of credit risk is also stressed by Haugh et al. (2009).

To capture this time-varying effect of the fiscal fundamentals, several authors divide their samples according to exogenously set structural breaks, differentiating in pre-crisis and crisis subsamples (Arghyrou and Kontonikas, 2011; Barrios et al., 2009; Caggiano and Greco, 2011). In their dataset from 1999 to 2011, Argyrou and Kontonikas (2011) identify three sub-periods with different market pricing behaviour. The authors point out a shift from a pre-crisis “convergence trade” model subsisting before 2007 from another one driven by macroeconomic fundamentals and international risk. Moreover, they recognize an early stage of the Eurozone crisis induced by the international financial crisis from August 2007 to February 2009 and a more severe phase from March 2009 onwards, characterized by the Greek debt crisis and a contagion pattern involving primarily some peripheral countries (Greece, Ireland, Portugal and Spain)

The element of contagion is also investigated by De Santis (2012), who finds evidence of a spillover effects also induced by credit downgrading. He argues for the relevance of regional and idiosyncratic factors in determining the spike of spreads during the European crisis rather than international aggregate risk. Moreover, deepening the role played by credit rating, he stresses the elements that link a credit downgrade to the macro and financial variables of a country, such as the consequent re-assessments of private investors and the impact of the eligibility criteria for the collateral of private banks to access to ECB refinancing operations. Similar conclusions on the role of credit ratings are reached by Alfonso et al. (2012).

The shift in market pricing behaviour individuated by Argyrou and Kontonikas (2011) is also highlighted by Caggiano and Greco (2011). In their model the sign of the proxies for aggregate

risk (the volatility of the Euribor-Repo rate spread and of the bond yield spreads) turned from being negative in the pre-crisis subsample, to positive after 2007. This result conveys further evidence for the convergence trade hypothesis, according to which in the years between 2002 and 2007 investors purchased bond of peripheral countries, even in presence of worse fundamentals, fostering self-fulfilling expectations of convergence of the European economies towards Germany and thus lowering the yields on the bonds of the periphery governments (Alfonso et al., 2014).

Furthermore, Caggiano and Greco (2011) test some interaction terms between fiscal and financial variables and the country-specific variance of sovereign spread, finding significant impact for short-term debt, MFI debt, MFI loans to corporations, MFI loans to foreign debtors, variance of Euribor-repo rate spread, and variance of Euro Stoxx. Hence, they prove the presence of non-linear effects due to the presence of idiosyncratic risk components, that magnified the impact of the macroeconomic variables after the financial crisis.

The presence of non-linearities in the behaviour of the determinants of Eurozone sovereign spreads is also investigated by Favero and Missale (2011) introducing an endogenous time-varying proxy for global risk into their GVAR model.

At the same time, several authors question whether the dramatic market penalizations towards EMU countries with weak fundamentals started from the 2007 crisis were appropriately reflecting the impact of the macroeconomic variables or whether they were overestimated and “mispriced” by the markets (De Santis, 2012; De Grauwe and Ji, 2012; Di Cesare 2012). To this extent, De Grauwe and Ji (2012) claim that markets mispriced sovereign risk, first ignoring debt-to-GDP differences between Eurozone countries in the years between 2001 and 2008, then overestimating credit risks during the crisis for excessive fear. This phenomenon had relevant policy implications, because it can be seen as a clear sign of a lack of disciplinary force of the markets in good times, while in bad times the excessive pricing penalization can induce self-fulfilling solvency crisis reducing the margin to the government to calm the turmoil on the sovereign debt market.

The key idea that sovereign spreads are mispriced by the markets is even stressed by Di Cesare et al. (2012), who finds evidence that the actual spread fell well beyond the levels justified by fiscal fundamentals. According to their analysis, in the peak of the tensions on sovereign bond markets (August 2012) the spread on Italian bonds with respect to German bunds was about 200 basis points higher than the values estimated on the basis of fundamentals. At the same time, in authors’ opinion yields on German bonds decreased significantly having conquered a status of “safe-haven”, in line with what has been predicted by Beber et al. (2009).

The non-linear behaviour of yield spreads across time and the contagion effects of the Greek crisis inspired new elements of research and a re-consideration of the currency risk in front of a growing perceived possibility of a euro area break consequent to a national default of one or more peripheral countries.

Favero (2013) employs a GVAR model to capture instability in the co-movements among bond spreads, adding expected exchange rate devaluation to the traditional factors considered in the literature, such as local fiscal fundamentals and a global market appetite for risk. In the GVAR model the emergence of expectations of exchange rate fluctuations is captured by the presence of the global spreads defined as weighted average of spreads for all the other countries, in which weights are determined by the distance between countries measured in terms of differences in their fiscal fundamentals, similarly to Favero and Missale (2011). In this way, the exchange rate risk turns to be one of the elements of investigation in the field of sovereign spread determinants in the euro area, mainly for the non-negligible risk of exit from the euro area of one or more distressed countries, after a ten-year disappearance followed by the adoption of the single currency.

The currency risk is then analyzed by De Santis (2015) in terms of risk of redenomination, which can occur in case of significant inflation and currency devaluation, or when a currency union is formed or broke up. De Santis (2015) finds an appropriate measure of redenomination risk in the quanto CDS difference of a country with respect to the quanto CDS of a benchmark country (Germany). Quanto CDS are the difference between the CDS quotes in US dollar and euros. This difference should be greater the greater the risk of devaluation of euro currency is perceived in case of a sovereign default. The difference between of the quanto CDS of a country (such as Italy or Spain) with respect to German quanto CDS as benchmark is then introduced in order to account for the intra-euro area currency risk associated with the possibility of a break-up of currency union. According to the results obtained, about 30%, 40% and 50% of the French, Italian and Spanish sovereign yield spreads respectively could be explained by redenomination risk in the moments of the maximum tension in the markets in the first quarter of 2012.

Quanto CDSs are introduced by Favero and Missale (2016) to account for euro devaluation risk (a “euro risk factor”) associated with the probability of a break-up of the euro area, extending the framework presented in Favero and Missale (2012). Estimating a GVAR model, authors find that the euro risk factor has the greatest impact among all the variables for high-yield countries before 2012, while its effect decreases in the last period of time considered, i.e. from the announcement of OMTs by the ECB in August 2012 to 2015. Their findings support the crucial role played in 2012 by the ECB in tackling the risk of a break-up of the euro area. Indeed,

the OMTs announcement decreased considerably the impact of the euro risk factor for the high yielders, even without making those countries totally immune to it as it happened instead in the case of the low yielders.

Further research on the redenomination risk is provided by Gros (2018) who focuses on the specific Italian movements of the sovereign spread on government bonds with respect to Germany. In order to capture the impact of redenomination risk on the Italian spread in 2018 he adopts two methodologies. The first consists in calculating the difference between the value of CDS defined by the International Swaps and Derivatives Association (ISDA) in 2014, which explicitly include a coverage in case of currency redenomination, with the CDS contracts based on the old (2003) ISDA documentation, which do not consider explicitly redenomination as a credit event. The other method considers the difference between the Italian government bonds issued in US-dollars and those issued in euros with the same maturities as an indicator of a premium paid for the risk of currency redenomination. In both methods the impact of redenomination risk clearly emerges in the rise of Italian spread in 2018, and it is ascribable to the political crisis linked to the formation of the new populist government and the so-called Savona's plan to exit from the single European currency. According to the computations of the same author, while in 2018 the correlation between US-dollar denominated and euro-denominated Italian bonds was about one half, during 2011-2012 crisis was about one-to-one, meaning that the primary driver of the spread was the fiscal component (i.e. default risk) and the risk of a currency devaluation was not considered.

Recently, Alfonso and Jalles (2019) test for the impact of the non-standard policy measures in addition to the traditional variables considered for the credit, liquidity and international risk, in the years between 1999 and 2016 for a panel of 10 euro area countries. In order to capture the effects of quantitative easing measures these authors collect the data of the open market operations and of the non-conventional asset purchase programs of the ECB. The former are represented by the main refinancing operations (MROs) and longer-term refinancing operations (LTROs), while the latter by the targeted longer term refinancing operations (TLTROs), the Securities Market Program (SMP), the three Covered Bond Purchase Programme (CBPP1, CBPP2, CBPP3), the Asset-Backed Securities Purchase Programme (ABSPP) and the Public Sector Purchase Programme (PSPP). In line with the existing literature, they find that the baseline determinants of sovereign spreads are the bid-ask spreads (indicating liquidity risk), VIX (as a proxy for international risk, fiscal developments (debt ratios and budget balance ratios), rating developments (credit risk), Real Effective Exchange Rate (REER), and economic growth. Moreover, they assess the impact of the QE measure above mentioned. In particular, by means of the bivariate time-varying coefficient (TVC) analysis they find that the CBPP1 has

contributed to narrow yield spreads in all euro countries particularly in the crisis period 2011-2013 and also LTRO had a relevant impact in reducing spreads in most countries.

The impact of the Quantitative Easing policies is measured also by Eijffinger and Pieterse-Bloem (2022) who test for the significance a wide panel of variables collected into two different model, one more oriented towards the macro-fundamental-based proxies and the other with macro market risk-based variables, finding that the second is able to better explain the evolution of the spread, furthermore in line with the general theory on the bond spreads. Moreover, they test for unknown breaks, finding evidence of structural breaks coinciding with the changes of ECB presidencies and therefore also with the switch to different policies regime. In particular, the break identified in May 2010 coincides with the succession of Draghi to Trichet, and the change of more restrictive monetary policy to a more expansive one, whereas the other break in October 2013 is more than one year later than the “whatever it takes” announcement, that is (that the change of regime verifies) after its subsequent stabilization effect.

3. Empirical Analysis

This chapter provides an in-depth examination of the dataset used in the study, outlining the selection of variables, data sources, and key descriptive statistics. The dataset consists of quarterly observations spanning from 2002 to 2022 for nine Eurozone countries² allowing for a detailed analysis of the factors influencing sovereign bond spreads relative to Germany's 10-year government bond yield. The independent variables capture the different factors which can affect the spreads on sovereign, starting from the macroeconomic fundamentals that move the credit risk of a country, following with the liquidity and international risk proxies and finally also the role of ECB in terms of monetary policy. To ensure the robustness and reliability of the data, this chapter discusses the sources of each variable, drawing from widely recognized databases such as the ECB Data Portal, IMF and OECD data bases. These sources provide comprehensive and consistent data on macroeconomic and financial indicators, ensuring accuracy in the empirical analysis.

In addition to describing the dataset, this chapter conducts an initial statistical exploration, presenting summary statistics and graphical representations of key trends. This preliminary investigation sheds light on the evolution of sovereign spreads over time, along with patterns in fiscal and financial indicators, offering initial insights into their potential influence on sovereign risk premia.

The chapter then moves in discussing the key econometric challenges that affect the estimation of sovereign spread determinants given the panel structure of the dataset. Heteroskedasticity, serial correlation, and cross-sectional dependence are explored using formal statistical tests and preliminary diagnostics. Identifying these challenges at an early stage allows for the implementation of appropriate econometric techniques in later chapters, ensuring that the empirical analysis produces robust and reliable results. By combining exploratory data analysis with an assessment of econometric considerations, this chapter not only validates the choice of variables but also lays a strong foundation for the methodological approach that follows in the subsequent empirical investigation. Finally, we present the results of the estimation models with some relevant policy implications.

² Austria, Belgium, Finland, France, Ireland, Italy, the Netherlands, Portugal, and Spain.

3.1 Data

Following the existing literature, the main concern of this thesis is to detect the long-term determinants of the spreads on the sovereign bonds in the euro area, with a particular focus on the macroeconomic determinants and the impact of the action of the ECB.

For this purpose, we employ a panel dataset of nine Eurozone countries on a timespan of 20 years by quarterly observations from the first quarter of 2002 to the first quarter of 2022. As mentioned in the previous chapter, quarterly data are more adapted to detect the impact of the macroeconomic variables, which are mainly released on quarterly base, while high frequency data, like daily observations, are preferred in the studies focused on the proxies related to liquidity or market factors (Acharya et al., 2014). Some authors prefer to work with monthly data, proceeding by linearly interpolating on a monthly frequency the data released by quarters (Arghyrou and Kontonikas, 2012; Afonso et al., 2014), however we decided to directly use the quarterly data, following Caggiano and Greco (2011), De Grauwe and Ji (2012).

The countries selected all belong to the group of the founding countries which first adopted the Euro Currency since it was introduced in 2002, with the exception of Luxemburg that we excluded for the small dimension of its economy, following the approach of De Grauwe et al. (2017). Greece also adopted the Euro since 2002, even if it joined the Eurozone on January 1st 2001 in a second moment with respect to the 11 founding countries that created the currency union in 1999, but following Eijffinger and Bloem (2023) it was excluded from the model since it can be considered as a sort of “outlier” given the debt restructuring faced and for the extremely exacerbated behaviour of its spread that could cause instability in the model.

All the variables are measured their absolute terms, following Eijffinger and Pieterse-Bloem (2022) and D’Agostino and Ehrmann (2014) who find that the same variables kept in relative terms to Germany perform worse.

The dependent variable of the regression model is represented by the difference in the bond yields of the countries of the sample with respect to Germany, which serves as a benchmark for risk-free borrowing within the Eurozone. Since the focus of this analysis is on the spread determinants in the long-run perspective, we took as reference the bond yields with 10-year maturities at the end of each quarter considered. Consequently, the dependent variable is defined as:

$$Spread_{itm} = YTM_{itm} - YTM_{btm}$$

where SPR stands for the spread, YTM for the yield to maturity, i represents the Eurozone countries, b is the benchmark for the Eurozone (i.e., Germany), t is time, and m is the 10-year maturity. We collect yield data from the ECB Data Warehouse on a quarterly basis, selecting the end-of-month observation for the period from March 2002 to March 2022. Figure 2 displays the sovereign spreads by country. Eurozone peripheral countries (Ireland, Italy, Portugal and Spain) exhibit high maximum spread values, with higher standard deviations, compared to Eurozone core countries which show a different behaviour of their spreads, noticeably more restrained.

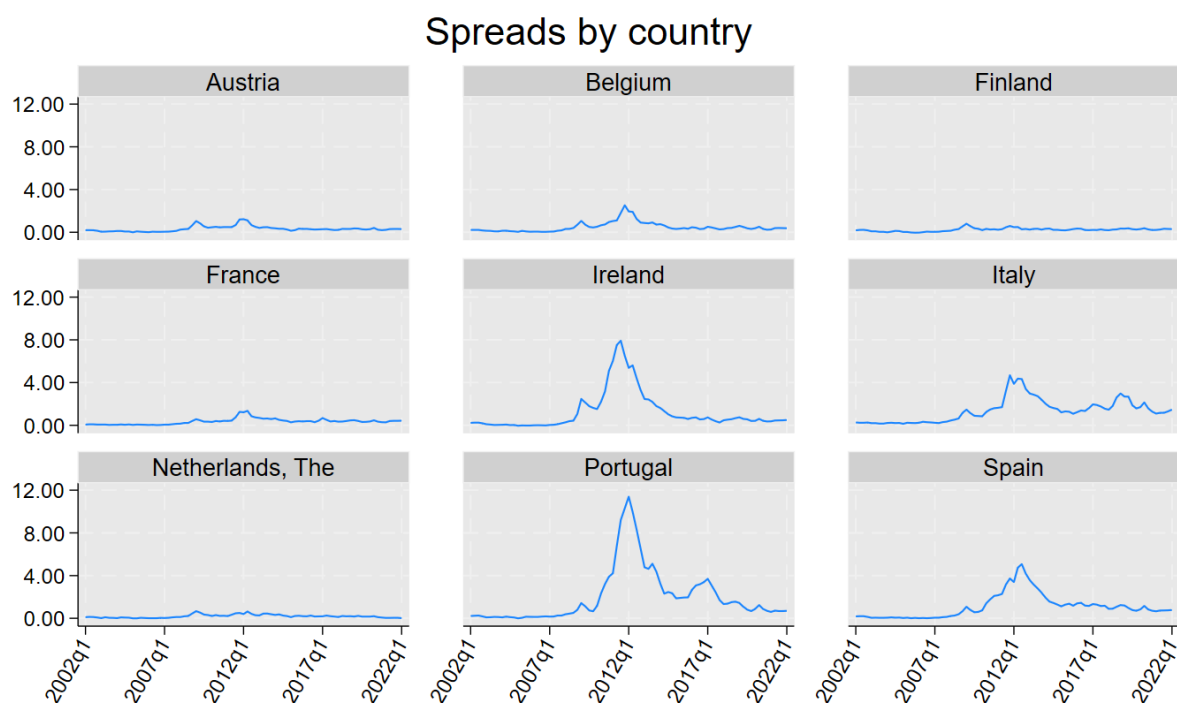


Figure 2 – 10-year sovereign bond spreads in each country in the sample (2002 Q1 – 2022Q1)

Following the existing literature, the explanatory variables have been selected with the aim of capturing the different elements which can affect the sovereign spreads: credit and liquidity risk associated to the country, the global risks and the impact of the ECB monetary policy.

Credit Risk

In order to measure the impact of credit risk on the sovereign spread, several country-specific variables that could affect the country's creditworthiness and its ability to repay its debts. The factors used for this analysis were chosen because of their relevance in the literature, in assessing risk and overall economic stability in countries. These include indicators like debt to GDP and deficit to GDP ratios that indicate fiscal health, and economic indicators such as GDP growth rate, current account balance and Real Effective Exchange Rate were also taken into

account to understand the conditions and factors influencing spreads. These factors come together to create a collection of elements, for evaluating the impact of macroeconomic conditions, on the risk premium of government bonds over time.

Since the behaviour of spreads strictly depends on the yields on sovereign bonds, the dimension of sovereign debt relative to its GDP is one of the most indagated macroeconomic variable in the literature on Eurozone spreads (Codogno et al., 2003; Bernoth et al., 2004; Schuknecht et al., 2011; Arghyrou and Krontonikas, 2012; Caggiano and Greco, 2012).

Indeed, the debt-to-GDP ratio is a key indicator of a country's fiscal sustainability, providing insights into its ability to service debt in relation to the size of its economy. According to theoretical models of sovereign risk, high debt levels increase investor concerns about a possible default or restructuring, inducing higher sovereign bond yields due to increased credit risk perceptions. So, high public debt may raise the cost of debt repayment, especially during economic downturns.

Theoretically, the relationship between debt-to-GDP and sovereign spreads should be positive; the higher the debt, the more expensive it becomes to borrow. As such, we expect higher debt-to-GDP ratios to lead to wider spreads in my model—especially, of course, among those countries whose debt levels are already quite high.

In the dataset, the mean debt-to-GDP ratio is 82.57%, with a range from 23.6% to 158.9% (see Table 1). This wide range reflects the varying fiscal conditions across countries and over time, particularly highlighting the elevated debt burdens of peripheral Eurozone countries during crisis periods. As it can be seen in Figure 3, countries exhibit quite different debt positions between countries across the entire period considered, but all show a similar pattern of debt growth during the sovereign debt crisis until 2012, when debts start declining in the entire Eurozone, even if in different magnitudes. Moreover, all the sample countries display a further increase in their debt-to-GDP ratios in 2020 after the outbreak of COVID pandemics. This analysis finds evidence also in the standard deviation of the variable, which is equal to 30.05%, suggesting the presence of significant fluctuations, which can be driven both by a reduction of the country GDP and by an increase of the government debt given the nature of ratio. The data were collected from ECB data portal directly on a quarterly basis.

The deficit-to-GDP ratio is another important indicator of fiscal health largely studied in the literature together with debt-to-GDP (Bernoth et al., 2004; Schuknecht et al., 2011; Costantini et al., 2014), since it represents the extent to which government spending exceeds revenue generation and so its ability to repay its debt. In fundamental models of fiscal policy and sovereign risk, sustained budget deficits tend to be seen as a prelude to rising public debt due to forced borrowing against fiscal shortfalls. As this raises the supply of government bonds, it

can push yields upwards. Large fiscal deficits could also reflect fiscal indiscipline or structural weaknesses in government finances, raising concerns over long-term debt sustainability. To investors, a large deficit could signal future tax increases or spending cuts, either of which would slow economic growth and increase sovereign risk. For these reasons, it is plausible to expect a positive correlation between the deficit-to-GDP ratio and sovereign spreads, with higher deficits resulting in wider spreads due to the increased perception of fiscal risk.

The data of fiscal deficit are retrieved from the ECB data portal, where they are published on a quarterly basis as a ratio of government deficit to the annual moving sum of GDP. In this representation fiscal deficit are registered with a positive sign, while surpluses have minus sign. The mean deficit-to-GDP ratio is 3.19%, with a range from 32.12% to -5.60%. This wide range, especially the extreme negative values, reflects periods of significant fiscal distress, particularly during the global financial crisis and the Eurozone debt crisis and it is more accentuated in the peripheral countries, with a peak for Ireland in 2011 at the height of the debt crisis. In general, Eurozone fiscal deficits exhibit similar patterns as also the coordinated fiscal policy suggested, however there are significant differences between countries in the magnitude of the fiscal behaviours with core countries showing the more rigid fiscal discipline. The standard deviation of 3.79% confirms considerable variability, with deficits widening significantly during recessionary periods.

Economic growth, defined in terms GDP, is a fundamental macroeconomic variable of a country's economic health with a strong impact on its ability to service debt. Indeed, an underlying strong and sustained economic growth theoretically strengthens the fiscal capacity of governments through enlarged tax revenues and reduced borrowings, hence obtaining higher debt sustainability. In contrast, low or negative growth could undermine fiscal stability, as the slower growth is associated with lower revenues for the government, further exacerbating fiscal deficits and accumulation of debt. GDP growth is largely employed in literature, both in terms of actual data (De Grauwe and Ji, 2013; De Grauwe et al., 2017; Schuster, 2023) and of expectations (Attinasi et al., 2009; Caggiano and Greco, 2011; De Santis, 2012; D'Agostino, 2014), whereas other authors prefer to use the data about industrial production to measure economic growth (Arghirou and Kontonikas, 2011; Afonso et al, 2014).

Theoretical expectations from fiscal solvency and growth dynamics theories therefore suggest a negative relationship between GDP growth and sovereign spreads. Higher growth rates signal greater economic resilience and, therefore, lower default probabilities—a declining risk premium by investors. Conversely, slow growth or recessionary periods heighten perceived sovereign risk as economic contractions make it more difficult for governments to manage sustainable levels of debt. I thus expect stronger GDP growth to be associated with narrower

sovereign spreads in the model. The data are retrieved from the ECB Data Portal on a quarterly basis. The growth rate of GDP is computed as the ratio Annual growth rate of Gross Domestic Product, in terms of Domestic currency (incl. conversion to current currency made using a fixed parity). Countries exhibit a period of good economic performance until global financial crisis of 2008, when it occurred a general economic downturn with a recovery progression in 2010 followed by new downturns in 2011 and 2012 more pronounced in the peripheral countries. During the outbreak of the pandemics in 2020 all the Eurozone countries showed a rapid V-shaped GDP collapse and recovery.

In the dataset, the mean GDP growth rate is 1.58%, with a range from -21.7% to 26.2% and a standard deviation of 4.15%. The extreme values, particularly the negative growth rates, reflect the sharp contractions experienced during the financial and Eurozone crises.

Another macroeconomic variable often considered in the literature to value the credit risk position of a country is the current account (CA) balance relative to the GDP (De Grauwe et al., 2017; Eijffinger and Pieterse-Bloem, 2022), which measures a country's net trade position, reflecting the difference between exports and imports of goods, services, and financial flows. According to the economic theory, a CA surplus would imply the ability of a country to generate excess savings that can be used either to pay down external debt or invest abroad, thus cutting a country's dependence on external borrowing and decreasing its vulnerability to sudden capital outflows and external shocks. The consequence is lower perceived default risk and thus narrower sovereign spreads. On the other hand, a current account deficit implies that a country is borrowing in order to finance consumption and investment, with increased dependence on external financing. The 'sudden stop' theory suggests that countries with large current account deficits are more sensitive to sudden reversals in capital flows (Merler and Pisani-Ferry, 2012); hence, they face a higher possibility of destabilizing their financial system and pushing up their own sovereign spreads.

Following this theoretical framework, we expect that the current account balance will show a negative relation with sovereign spreads. Countries in surplus position should enjoy the benefit of lower spreads, as their external risk has diminished, while countries with deficits could expect higher spreads to apply, as this economy is much more exposed to volatility in global finance.

Data of Current Accounts have been collected from OECD Main Economic Indicators on a quarterly basis in terms of percentage of Gross Domestic Product. The mean current account balance in the dataset is 0.43% of GDP, with a range from -60.28% to 20.04%. The standard deviation of 5.87% shows substantial variability, with some countries running large deficits and others enjoying surpluses, especially during the post-crisis recovery. Indeed, we can notice

some countries that exhibit persistent CA surpluses like Netherlands, Finland and Austria, while peripheral countries – especially Portugal, Spain and Ireland – reveal CA deficits until the beginning of 2010 when start a path of improvement of their commercial balance. The Real Effective Exchange Rate (REER) captures the relative price of a country's goods and services compared to those of its trading partners, adjusted for inflation differences, making it a key indicator of competitiveness and economic health in the global market. Countries with an overvalued REER can face slower export growth, trade imbalances, and potentially weaker fiscal positions, as reduced competitiveness can dampen economic growth and limit debt service capacity.

For these reasons, several studies investigate the possible correlations between REER fluctuations and sovereign spreads (Arghyrou and Kontonikas, 2012; and Afonso et al. 2014). An appreciated REER signals reduced competitiveness and can increase investor concerns about debt sustainability. In such cases, investors may demand higher spreads on bonds from countries where an overvalued REER suggests potential economic imbalances. This relationship holds particular relevance for Eurozone countries, which cannot independently adjust exchange rates due to the single currency. In this sense, some authors interpret it as a proxy of redenomination risk (Afonso, 2018). Including REER in the dataset thus provides a more comprehensive view of the factors influencing sovereign spreads, particularly those related to global competitiveness and external imbalances. This addition aligns with findings in the literature, such as those by De Grauwe and Ji (2012), who emphasize the importance of REER alongside core fiscal indicators like debt-to-GDP and deficit-to-GDP ratios in explaining spread variations. Real Effective Exchange Rate data are collected from the International Finance Statistics of the International Monetary Fund in the form of quarterly observations.

Liquidity Risk

Liquidity is one the main element considered in the literature in relation to the sovereign spread determinants. To account for the liquidity risk, we compute the ratio between the outstanding amount of debt of each country considered and the total amount of debt of the Eurozone following Arghyrou and Kontonikas (2012). The data of the government debts are collected from the ECB Data Portal.

The outstanding debt of a country relative to the whole euro area is a measure of market depth largely used in literature as proxy of liquidity risk (Bernoth, 2004; Gomez Puig, 2006; Attinasi, 2009; Arghyrou and Kontonikas, 2012; D'Agostino, 2014; Eijffinger and Pieterse-Bloem, 2022; Schuster, 2023). Indeed, a higher stock of outstanding debt in the markets can be viewed as a signal also of higher liquidity of the relative sovereign bonds, thus it can incorporate a

premium since it has a wider market of buyers and sellers. For these reasons we expect a negative relationship between the liquidity proxy and the dependent variable.

Another option to account for liquidity risk, as also employed by Gómez-Puig (2006), could have been to utilize bid-ask spreads. These spreads offer the advantage of being available at higher frequencies and enable straightforward comparisons across markets, as opposed to nominal amounts, which require currency conversion. While Gómez-Puig (2006) has demonstrated the similarity of both proxies, we favour outstanding amounts for our sample (Eijffinder and Pieterse-Bloem, 2022). This preference arises from the fact that bid-ask spreads experienced significant growth during the sovereign debt crisis, indicating that they may not serve as an objective proxy for market liquidity but could be influenced by an increased pricing of liquidity risk.

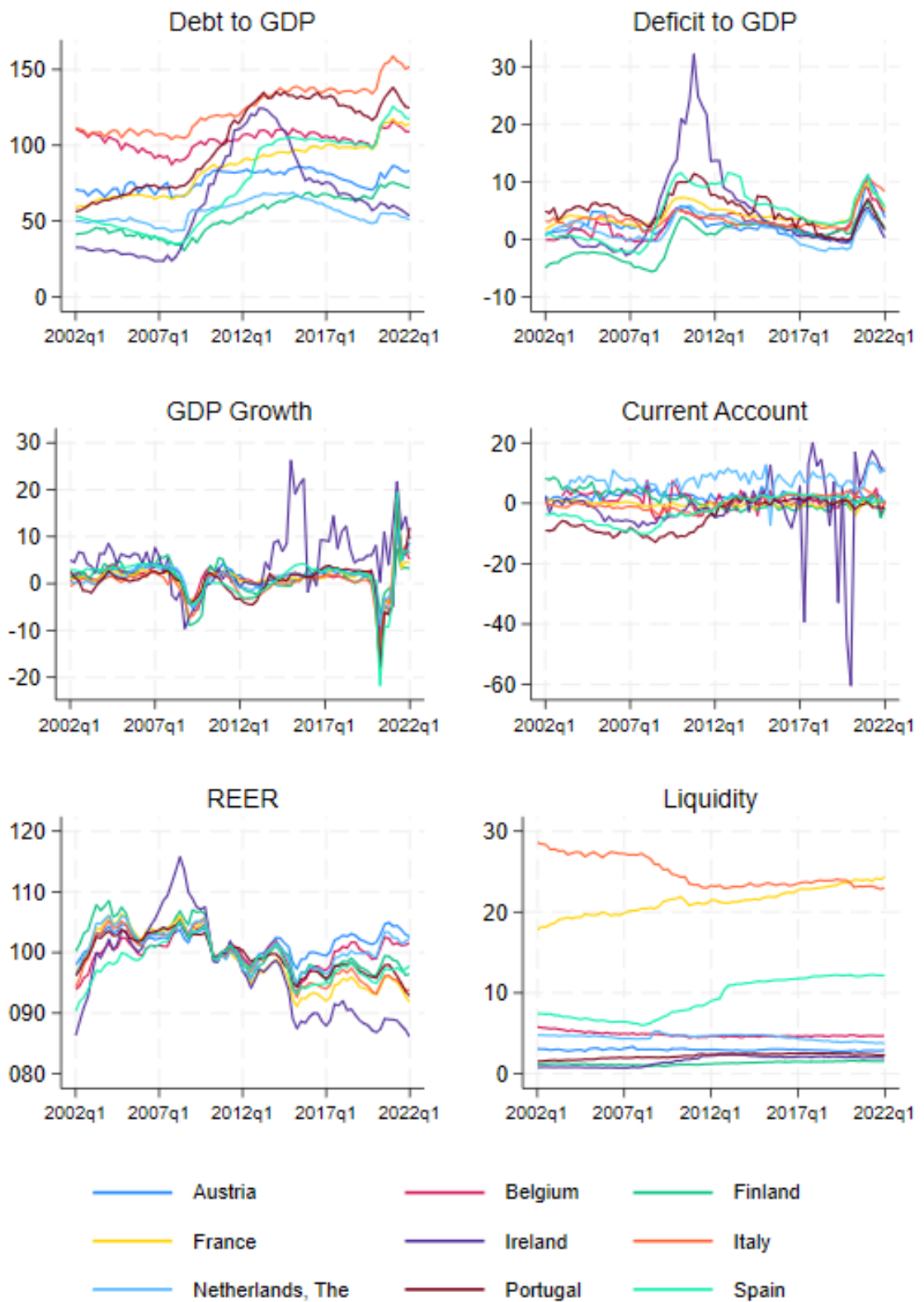


Figure 3 - Credit risk and liquidity risk variables

Monetary Policy - Quantitative Easing Variable

The effects of monetary policy are generally indagated in the literature by measuring the impact of the reference interest rates set by the central bank (Manganelli and Wolswijk, 2009), and or looking at the evolution of the ECB balance sheet items related to the open market operations. Afonso and Jalles (2019) test a large set of several variables including the holdings of the different asset purchase programs like the securities market programme (SMP) and the covered bond purchase programme (CBPP) as well as the longer-term refinancing operations (LTRO), while Eijffinger and Pieterse-Bloem (2022) tests for the effects of the TARGET 2 balance.

Taking inspiration from Afonso et al. (2018), who used the logarithm of the securities held by the ECB for monetary policy purposes (SHMP) and the logarithm of the overall ECB balance sheet in order to seize the impact of non-conventional monetary policy, we introduced a new proxy with the aim of capturing the effects of the ECB Quantitative Easing, represented by the percentage of public debt of each country detained by the ECB from the beginning to the end of the timespan considered. With respect to Afonso et al. (2018) this variable is country-specific and has been constructed as the ratio between the amount of government debts held by the Eurosystem and the total outstanding government debt reported in the ECB Data Portal.

Looking at the time-series we clearly see the changes of Eurozone monetary policy from the beginning of the monetary union, when only small fraction of public debt smaller or equal to 1% was detained by national central banks, to the end of our data-set in 2022 which coincides also with the end of QE and PEPP policies when the share owned by the Eurosystem is about 30% on average (Figure 4).

According to the theory, the intervention of the central bank in the financial markets with the purchase of sovereign bonds with the Quantitative Easing should lower the interest rates, granting a sort of “umbrella” during financial turmoil, for these reasons we expect a negative sign for the coefficient of this variable.

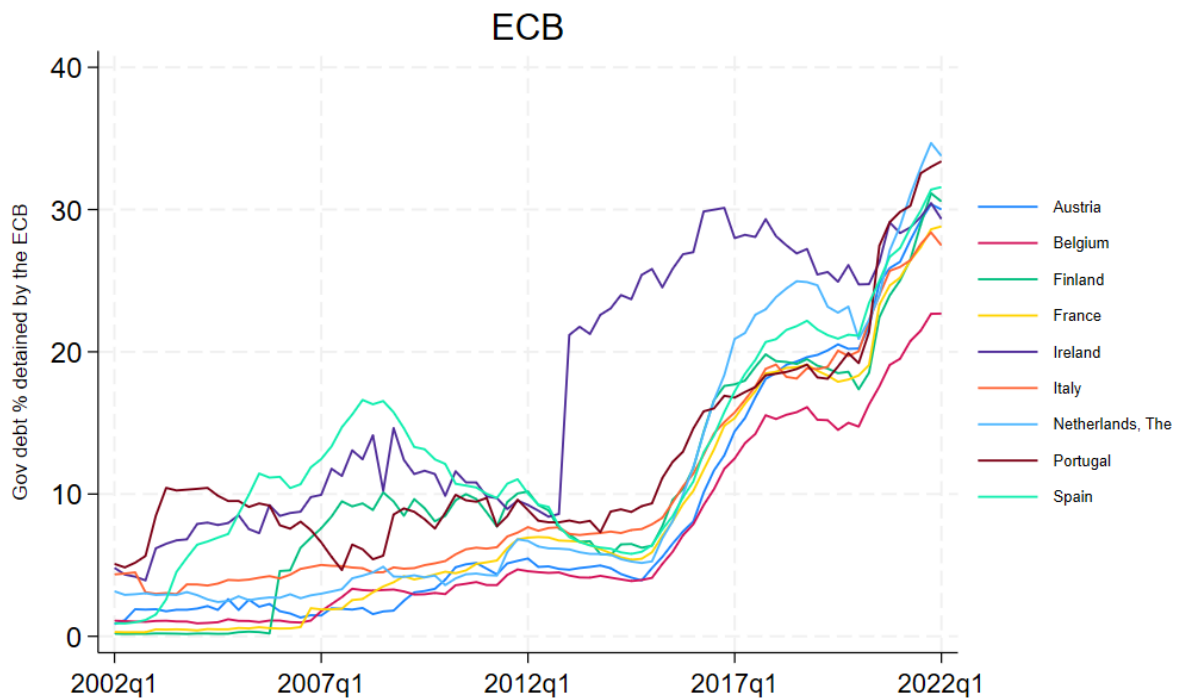


Figure 4 - ECB Monetary Policy variable

International risk factor variable - VSTOXX (European Volatility Index)

In literature, international risk is generally captured by Chicago Board Options Exchange (CBOE) Volatility Index (VIX), also known as “Fear Index”, since it is a real-time market index which represents the market’s expectations for volatility of S&P500 over the coming 30 days and it is considered a good proxy for the general market sentiment (Beber et al., 2009; Afonso et al., 2015) and common international risk (Arghyrou and Kontonikas, 2011). However, in this thesis it has been privileged the use of VSTOXX, which is a volatility index built similarly to VIX but it is based on EURO STOXX 50, so it is more specific to the European area and it is considered a sort of European volatility benchmark (Gomez-Puig et al., 2014; Eijffinger and Pieterse-Bloem, 2023).

VSTOXX measures the expected volatility of the Eurozone’s stock market, serving as a proxy for overall financial market uncertainty. Theoretical models of sovereign risk suggest that during periods of high volatility or global financial stress, investors become more risk-averse, shifting their portfolios towards those which are considered “safe assets” such as German bonds. This “flight-to-safety” dynamic causes the yields on safe assets to decline, while yields on riskier assets—such as the bonds of peripheral Eurozone countries—rise. This leads to an increase in sovereign bond spreads.

Moreover, in times of financial turmoil, concerns about liquidity and the availability of funding can exacerbate the widening of spreads, particularly for countries with weaker fiscal positions. Theoretical models, such as those based on the "global financial cycle," highlight how external shocks to risk perception can amplify sovereign risk in interconnected markets like the Eurozone. As such, I expect a positive relationship between VSTOXX and sovereign spreads, with higher volatility leading to wider spreads as investors price in greater uncertainty and risk aversion.

In the dataset, the average VSTOXX is 23.70, with a range from 12.12 to 61.34, and a standard deviation of 9.90, reflecting market uncertainty spikes during events like the 2008 financial crisis and Eurozone debt crisis (see Figure 5). Higher volatility likely correlates with wider spreads, especially in peripheral Eurozone countries where risk is higher. Data are collected from Investing.com, where they are registered on daily base. The quarterly observations are thus retrieved as the end of each period daily data.

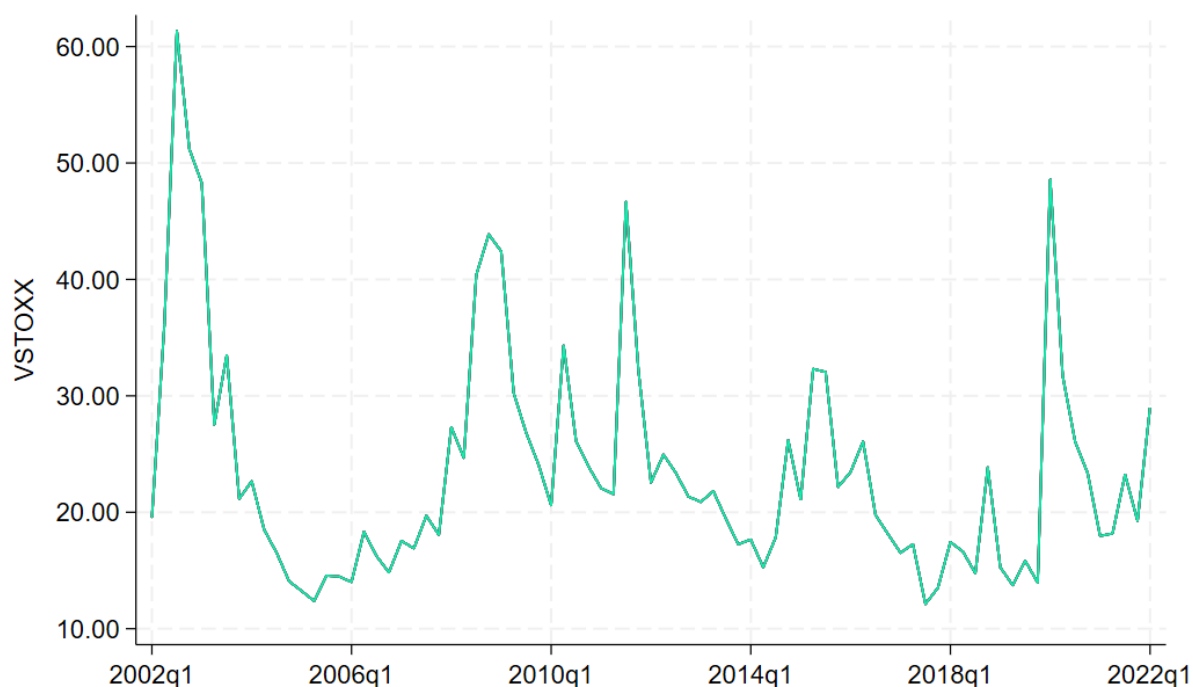


Figure 5 - International Risk Variable

Table 1 - Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Spread	729	.814	1.329	-.04	11.39
Debt	729	82.574	30.054	23.6	158.9
Deficit	726	3.189	3.794	-5.604	32.119
GDPGrowth	729	1.582	4.148	-21.7	26.2
CA	720	.434	5.867	-60.282	20.04
REER	729	99.533	4.29	86.077	115.751
VSTOXX	729	23.701	9.902	12.12	61.34
Liq	729	8.102	8.465	.718	28.592
ECB	729	10.783	8.504	.167	34.679

Table 2 - Variables Summary

Variable Name	Description	Frequency	Source
Spread	Spread between yields on government bonds with a ten-year maturity of euro area countries and Germany	Quarterly data retrieved from monthly observations (average of observations through the period)	ECB Data Portal
Debt-to-GDP	Government debt as % of GDP	Quarterly data	ECB Data Portal
Deficit	Government deficit (-) or surplus (+) (as % of GDP), ratio to the annual moving sum of GDP	Quarterly data	ECB Data Portal
GDP Growth	Annual growth rate of Gross Domestic Product, in terms of Domestic currency (incl. conversion to current currency made using a fixed parity)	Quarterly data	ECB Data Portal
CA	Current account balance as % of GDP	Quarterly data	OECD Main Economic Indicators
REER	Real Effective Exchange Rate, based on Consumer Price Index	Quarterly data	International Finance Statistics – IMF Data Portal
VSTOXX	EURO STOXX 50® Volatility Index	Quarterly data retrieved from daily observations (end of the period)	Investing.com
Liq	Outstanding government debt ratio to the total euro area government debt as a proxy for liquidity risk	Quarterly data	Own elaborations from ECB Data Portal data
ECB	Percentage of government debt owned by the Eurosystem	Quarterly data retrieved from monthly observations (end of the period)	Own elaborations from ECB Data Portal data

3.2 Methodology

Our dataset exhibits the characteristics of panel data, also known as longitudinal or cross-sectional time-series data, where we collect the observations of nine countries ($N=9$) along a time-period 80 quarters ($T=80$) from the first quarter of 2002 to the first quarter of 2022, so for a period of 20 years.

In so-called time series cross section (TSCS) data we deal with panel data with large time observations (T) and small number of individual observed (N) across time, so we have a panel where N is typically smaller than T by far. This is also the case of our dataset where $N=9$ and $T=80$ since we follow 9 Eurozone countries for 80 time periods (4 quarters for 20 years).

3.2.1 Econometric Techniques and Models for Panel Data

Panel data techniques are employed to assess how these variables influence sovereign bond spreads. A primary challenge in panel data analysis is accounting for unobserved differences between countries while modelling time-varying relationships.

In examining the determinants of sovereign bond spreads in Eurozone countries, choosing the right econometric model is crucial to accurately address the data's cross-sectional (between-country) and temporal (within-country) elements. The Pooled Ordinary Least Squares (Pooled OLS), Fixed Effects (FE), and Random Effects (RE) models offer different methods for analyzing panel data, each with its own assumptions and implications for interpretation.

Pooled OLS

The basic model to deal with this kind of dataset is the Pooled OLS. This model assumes that all countries are homogeneous with respect to unobservable factors. This means that country-specific factors influencing the dependent variable are captured by the intercept and are identical across all entities. Furthermore, the error term is assumed to be uncorrelated with the independent variables.

By pooling the data and ignoring country-specific effects, pooled OLS does not account for unobserved heterogeneity across entities, such as political or economic differences between countries. If these unobserved factors are correlated with the independent variables, the estimates will be biased and inconsistent. Moreover, by assuming no country-specific variation, it overlooks key dynamics in the data, making it inappropriate for most panel datasets.

For these reasons, following Eijffinger and Pieterse-Bloem (2022), I refrain from conducting a pooled-OLS regression and I analyse more suitable models for panel data, like Fixed Effects and Random Effects Model, to address heterogeneity across entities.

Fixed Effects (FE) Model

The Fixed Effects (FE) model addresses some limitations of Pooled OLS by accounting for unobserved, time-invariant characteristics unique to each country. This is highly relevant in macroeconomic studies, where each country likely has stable, country-specific traits (e.g., policy structure, geographical advantages) that have a non-negligible impact on its macroeconomic dynamics. The key assumption in the FE model is that the entity-specific effects can be correlated with the independent variables, and it remains constant over time for each entity. Indeed, the FE model controls for these specific factors by introducing a separate intercept for each country, capturing time-invariant, unobserved influences, thus eliminating the bias from omitted time-invariant variables.

By demeaning the data (i.e., subtracting each country's mean from its observations) the FE model isolates the effect of independent variables on the dependent variable within each country over time. This approach is particularly useful when we suspect a correlation between these fixed, unobserved factors and our independent variables. For instance, a country's persistent high debt-to-GDP ratio might reflect specific fiscal policies that also affect bond spreads. Fixed Effects helps control for these country-specific influences, resulting in more reliable estimates. In the case of Eurozone countries, factors like long-term economic policies, institutional quality, or geographic traits could influence sovereign spreads and can be correlated with independent variables like debt-to-GDP. The FE model helps control for these country-specific features, ensuring more reliable estimates. In other terms, this configuration controls for country-specific characteristics that remain constant over time, such as institutional quality, legal frameworks, or political stability, which may influence sovereign spreads but are not directly observable or measurable. This model is useful as it captures variations within countries over time, controlling for unobserved country-level differences. The FE model assumes that unobserved country-specific factors are correlated with the independent variables, which is a reasonable assumption in macroeconomic analysis. As noticed by De Grauwe and Ji (2012), a fixed effect model helps to control for unobserved time invariant variables and produces unbiased estimates of the 'fundamental variables'.

Random Effects (RE) Model

Like the FE model, the Random Effects (RE) model accounts for unobserved heterogeneity but assumes that these country-specific effects are random and uncorrelated with the independent variables. Instead of introducing separate intercepts, the RE model includes these effects as part of the error term, utilizing both within-country and between-country variation, making it more efficient if the assumption holds.

The RE model is beneficial for studying both time-variant and time-invariant variables, which can be valuable for analysing factors like geography or institutional traits that do not change over time. However, the RE model's efficiency depends on the assumption that these random effects are uncorrelated with the independent variables; if this assumption is violated, RE estimates will be biased. In macroeconomic studies, unobserved characteristics like economic conservatism or openness often influence both the dependent and independent variables, potentially invalidating this assumption. Best practice is to test for this, using the test developed by Hausman (Farkas, 2005).

Choosing Between Fixed and Random Effects: The Hausman Test

The Hausman test provides a systematic approach for choosing between the FE and RE models. The test examines whether the unique errors in the RE model correlate with the independent variables. If the test statistic is significant, it suggests that the FE model is more appropriate due to potential correlation between unobserved country-specific effects and the explanatory variables. If not, the RE model, which uses both within- and between-country variation, may offer greater efficiency.

Once performed on our data, the Hausman test results strongly support the use of the fixed effects model for analysing sovereign bond spreads in this dataset as previously hypothesized. With a test statistic of 178.58 and a p-value of 0.0000, the null hypothesis—that the differences in coefficients between the fixed effects and random effects models are not systematic—can be rejected with confidence. This outcome indicates that the core assumption of the random effects model, namely the lack of correlation between unobserved country-specific effects and the explanatory variables, does not hold in this context.

The significant differences observed in coefficients for key variables, including Debt-to-GDP, fiscal deficit, REER, and liquidity, highlight the critical role of controlling for unobserved heterogeneity across countries. These differences emphasize that country-specific factors, such as institutional frameworks, long-term economic policies, or structural characteristics, are likely influencing both sovereign bond spreads and the explanatory variables. Ignoring these effects, as the random effects model does, could lead to biased and inconsistent estimates.

By contrast, the fixed effects model addresses this issue by incorporating country-specific characteristics that remain constant over time. This allows the model to focus exclusively on within-country variations, ensuring that the estimated relationships between sovereign spreads and their determinants are both consistent and unbiased. The Hausman test results underscore the importance of this approach, affirming that the fixed effects model provides a more reliable framework for understanding the dynamics of sovereign bond spreads in the Eurozone. It

underscores the necessity of prioritizing within-country variation and accurately accounting for unobserved heterogeneity to draw meaningful insights into the determinants of sovereign risk.

3.2.2 Key Econometric Concerns and Solutions for Modelling Sovereign Bond Spreads in the Eurozone

In analysing sovereign bond spreads across Eurozone countries, it's essential to consider three common econometric issues in panel data: heteroskedasticity, serial correlation, and cross-sectional dependence. These concepts can significantly influence the reliability of our statistical findings, so addressing each one carefully is critical.

Without accounting for heteroskedasticity, serial correlation, and cross-sectional dependence, there's a risk of overstating or understating the significance of key economic variables, leading to flawed insights. By using advanced econometric techniques tailored for panel data, we can obtain robust standard errors, which allow for more precise and meaningful interpretations of the factors influencing sovereign bond spreads in the Eurozone. These adjustments are essential for ensuring that standard errors in our model are reliable, which in turn impacts the accuracy of statistical inference.

Heteroskedasticity

Heteroskedasticity occurs when the variance of the error terms—essentially, the spread or “noise” in the data—is not consistent across different observations. In simpler terms, we expect the “error” in our model to be about the same for each country and time period, but when this isn't the case, our results can become distorted. For instance, in the Eurozone dataset, countries with varying economic profiles may show different levels of volatility in bond spreads, stemming from their unique economic conditions or policy frameworks. This variation can lead to biased confidence intervals and test statistics, making it challenging to interpret results accurately. Detecting heteroskedasticity typically involves tests like the *Modified Wald test*, and once identified, we can adjust for it using techniques like robust standard errors or Panel-Corrected Standard Errors (PCSE).

Serial Correlation

Serial correlation, also known as autocorrelation, refers to a situation where error terms within a country are correlated over time—essentially, when what happens in one period influences subsequent periods. For example, sovereign bond spreads today might be affected by spreads from previous quarters due to persistent economic factors or investor sentiment.

Correlation can be generated by global factors that affect all the countries at the same time, such as an economic crisis. In this case we could have correlation at the same time point across the countries observed, but we can also have correlation at different time points when contagion effects are present over time. Our dataset potentially can be affected by both the cases mentioned, since we had some economic crisis that hit all the countries at the same time as the global financial crisis in 2008 or the covid crisis in 2020 and also we have potential contagion effects during the sovereign debt crisis.

Detecting this pattern is commonly done through the *Wooldridge test*. If serial correlation is present, methods such as Driscoll-Kraay standard errors or an AR(1) correction can help adjust for it, providing more reliable estimates. Indeed, ignoring serial correlation leads to underestimated standard errors, which can exaggerate the statistical significance of explanatory variables.

Cross-Sectional Dependence

Cross-sectional dependence refers to the correlation of error terms across entities at a given time, typically due to shared external shocks or economic linkages. Cross-sectional dependence is particularly relevant in sovereign spread analysis, as global financial conditions, monetary policy decisions, and crises can influence multiple countries simultaneously, especially in a context like the European Monetary Union, where the national economies are strictly interconnected, and shocks can easily propagate between countries due to spillover effects.

For these reasons it is plausible that the variables of the models feature cross-sectional dependence (CD) (Costantini et al. 2014). In this case standard OLS regression fails, since it is not able to capture the cross-sectional correlation between the independent variables and the error term.

If left unaddressed, cross-sectional dependence can lead to inefficient estimates and biased test statistics, resulting in misleading conclusions about variable significance. To detect this issue, we can use tests like Pesaran's CD test or the Breusch-Pagan LM test. When cross-sectional dependence is present, applying adjustments like Panel-Corrected Standard Errors (PCSE) or Driscoll-Kraay standard errors can provide more accurate results.

Tests results

The Modified Wald test results, with a chi-squared statistic of 3132.41 and a p-value of 0.0000, strongly reject the null hypothesis of homoskedasticity across countries (Table 3). This means the variance of the error terms varies significantly across the panels, reflecting heteroskedasticity. Such differences in error variance across countries could arise from structural disparities in economic size, fiscal policies, or credit risk perceptions. The presence

of heteroskedasticity undermines the reliability of standard errors, leading to potential misinterpretations of the statistical significance of the explanatory variables. To address this, it is recommended to use robust standard errors or alternative techniques such as *Panel-Corrected Standard Errors* (PCSE) or *Driscoll-Kraay* standard errors, which account for panel-specific heteroskedasticity, thereby ensuring accurate inference.

The Wooldridge test for autocorrelation produced an F-statistic of 133.766 with a p-value of 0.0000, indicating strong evidence of first-order autocorrelation within the panels. This suggests that the error terms in one period are correlated with those in previous periods, a common occurrence in time-series data. In the context of sovereign spreads, this could reflect the persistence of economic conditions or investor sentiment over time. While autocorrelation does not bias the estimated coefficients, it reduces their efficiency and leads to biased standard errors, increasing the likelihood of overstating the significance of variables.

Finally, The Breusch-Pagan LM test results, with a chi-squared statistic of 765.331 and a p-value of 0.0000, reveal strong evidence of cross-sectional dependence in the residuals. This indicates that shocks or unobserved factors in one country are systematically affecting others, which is expected in the highly interconnected sovereign bond markets of the Eurozone. For example, a fiscal crisis in one country can have spillover effects on the perceived risk of other countries. This interconnectedness violates the assumption of residual independence across panels and requires adjustments to prevent biased estimates. Techniques such as PCSE or Driscoll-Kraay standard errors can account for these dependencies.

Table 3 - Test results

Econometric issue	Test	Stata command	Results
Heteroskedasticity	Modified Wald Test	xttest3	Rejection of the null
Serial correlation	Wooldridge Test	xtserial	Rejection of the null
Cross-sectional dependence	Breusch-Pagan LM Test	xttest2	Rejection of the null

3.2.3 An Econometric Model for sovereign spreads determinants

Given the considerations discussed above about the structure of this data-set and the relative issues about heteroskedasticity, serial correlation and cross-sectional dependence that affect our panel, we decided to estimate a Prais-Winsten regression model with Panel-Corrected Standard Errors (PCSE). Prais-Winsten model provides a feasible generalized least squares (FGLS) approach, correcting for serial correlation within each panel by assuming an autoregressive process of AR(1) type for the error terms, and adjusting standard errors for panel-specific serial correlation and heteroskedasticity (“Appendix A – Stata Implementation”).

The Prais-Winsten Panel-Corrected Standard Errors (PCSE) model is a versatile regression technique designed specifically to address the challenges associated with panel data, particularly heteroskedasticity, serial correlation, and cross-sectional dependence in error terms. Unlike ordinary least squares (OLS), which assumes constant variance and independence in errors, the Prais-Winsten PCSE approach adjusts standard errors to accommodate these deviations, ensuring more reliable statistical inference. Central to this methodology is the Prais-Winsten transformation, which iteratively adjusts the dependent and independent variables to account for serial correlation within panels. However, the model’s standout feature lies in its use of robust Panel-Corrected Standard Errors, which are designed to handle heteroskedasticity and partially account for cross-sectional dependence, making it particularly appealing for empirical studies involving panel data.

The model offers flexibility by allowing for heteroskedasticity across panels, meaning that the variance of error terms can differ across countries or other cross-sectional units. It also accommodates AR(1) serial correlation within panels, allowing the autocorrelation parameter to vary by panel, which is useful for datasets where temporal dependence within individual units is a concern. While the model does not explicitly model cross-sectional dependence, it adjusts for contemporaneous correlations between panels by providing robust standard errors, especially when using the `rhotype(tscorr)` option in Stata. This flexibility makes the PCSE model highly practical for applied research in settings where error structures are complex and difficult to model explicitly.

In general, PCSE may be preferred when cross-sectional dependence is a matter of concern.

We define our model as:

$$Spread_{it} = \alpha_i + \beta_k X_{it} + \gamma_2 VSTOXX_t + u_{it}$$

where:

- *Spread_{it}* is the dependent variable defining the spreads on the sovereign bonds of the country *i* at time *t*

- a_i are the country-specific fixed effects
- β_k are the coefficients of the country-specific explanatory variables X_{it} defined as:
 - *Debt* – Debt-to-GDP ratio
 - *Deficit* – overall general government budget deficit (+)/ surplus (-)
 - *GDPGrowth* – Gross Domestic Product growth
 - *CA* – Current Account Balance with respect to GDP
 - *REER* – Real Effective Exchange Rate
 - *Liq* – Liquidity risk proxy
 - *Ecb* – proxy for the ECB monetary policy
- γ_2 is the coefficient of the time-variant, country invariant, proxy for international market risk $VSTOXX_t$

The error term, u_{it} , is assumed to follow a panel-specific AR(1) process:

$$u_{it} = \rho_i u_{it-1} + \varepsilon_{it}$$

where ρ_i is the autoregressive parameter specific to each country i , and ε_{it} is a white noise error term. The model assumes heteroskedasticity across panels (each country has its own error variance) and adjusts the standard errors for panel-specific time-series correlation.

The Prais-Winsten Panel-Corrected Standard Errors (PCSE) is a powerful alternative to feasible generalized least squares (FGLS) for estimating linear cross-sectional time-series models when disturbances are not assumed to be independent and identically distributed (i.i.d.). FGLS focuses on estimating efficient coefficients by explicitly modeling the structure of the error terms. It assumes a known or correctly specified pattern of heteroskedasticity, serial correlation, and, if needed, cross-sectional dependence. This explicit modeling allows FGLS to provide efficient parameter estimates, minimizing the variance of the estimators under the assumption that the specified error structure is correct. However, this reliance on strong assumptions about the error structure can be a limitation. If the assumed heteroskedasticity, serial correlation, or cross-sectional correlation is incorrectly specified, the estimates and standard errors from FGLS can become biased and inconsistent.

The fundamental difference between the Prais-Winsten PCSE model and FGLS lies in the trade-offs between robustness and efficiency. The PCSE model prioritizes robustness by correcting standard errors to ensure valid inference even when the error structure is mis-specified. This robustness is particularly valuable in empirical research, where the complexity of error dynamics often makes precise modelling challenging. However, this robustness comes at the cost of efficiency, as PCSE parameter estimates may have higher variance compared to those from FGLS. Conversely, FGLS achieves efficiency by explicitly accounting for the error

structure but sacrifices robustness, as its performance deteriorates quickly if the assumed error structure is inaccurate.

Both estimators—`xtpcse` and FGLS—are consistent as long as the conditional mean is correctly specified. However, if the assumed covariance structure is correct, the FGLS estimates from `xtgls` are more efficient. Nonetheless, research by Beck and Katz (1995) has shown that full FGLS variance-covariance estimates tend to be overly optimistic (anticonservative) when applied to typical datasets used in social sciences—often with 10–20 panels and 10–40 periods per panel. Their findings suggest that Ordinary Least Squares (OLS) or Prais-Winsten estimates with Panel-Corrected Standard Errors (PCSE) provide coverage probabilities that are closer to nominal, making them more reliable for inference in such contexts.

Unlike a fixed effects model, Prais-Winsten PCSE model does not automatically control for time-invariant, panel-specific characteristics (such as country-specific traits). In a fixed effects framework, individual effects are removed by demeaning or differencing, isolating within-panel variation and removing unobserved, stable heterogeneity. However, PCSE retains all observed data without demeaning or differencing, so it does not inherently account for these unique, panel-specific effects. However, we add dummy variables for each panel (e.g., country) to capture these unobserved characteristics and approximate a fixed effects model. In this way we can control for individual-specific effects.

3.3 Results

The results from the Prais-Winsten PCSE regression using the xtpcse methodology reveal compelling relationships between key economic variables and sovereign bond spreads across the Eurozone, providing valuable insights into how investors perceive and price sovereign risk among countries. In particular, the model shows the significant impact on the spreads of the macro variables like debt-to-GDP and deficit-to-GDP, and of the proxies for the liquidity and international risk. Furthermore, the variable representing the impact of ECB monetary policy exhibits a significant effect on the spreads.

Table 4 - Estimation results Model 1

Spread	Model 1a	Model 1b	Model 1c
Debt-to-GDP	0.024 *** (0.006)	0.024 *** (0.006)	0.023 *** (0.006)
Deficit-to-GDP	0.037 ** (0.016)	0.037 ** (0.016)	0.035 ** (0.016)
GDP Growth	-0.003 (0.005)	-0.004 (0.005)	
CA	0.001 (0.003)		
REER	0.007 (0.010)	0.007 (0.010)	0.007 (0.010)
Liquidity	-0.197 *** (0.061)	-0.196 *** (0.061)	-0.214 *** (0.066)
ECB%	-0.016 ** (0.008)	-0.016 ** (0.008)	-0.017 * (0.009)
VSTOXX	0.007 *** (0.002)	0.006 *** (0.001)	0.006 *** (0.001)
Intercept	-1.779 (1.172)	-1.696 (1.144)	-1.668 (1.144)
Number of observations	717	726	726
R-squared	0.12	0.12	0.10

*** p<.01, ** p<.05, * p<.1

We estimated three models following a general-to-specific approach (Gomez-Puig, 2014; Eiffinjer and Pieterse-Bloem, 2022), starting with the full set of variables individuated to ensure that all potentially relevant factors were included in the initial specification (model 1a), then eliminating the non-significant variables in order to obtain a more focused specification stressing also the robustness of the results (model 1b and 1c). This iterative process strengthened the model by ensuring that only the most significant determinants were retained, resulting in a final specification that yields more interpretable and robust findings.

First, we see the significant and positive impact of debt-to-GDP and deficit-to-GDP on the spread as a fundamental macroeconomic driver as theory suggested. Looking at the results in model 1a, the findings for debt-to-GDP indicate a positive and highly significant relationship,

with an estimated coefficient of approximately 0.024 (Table 4). This suggests that higher public debt levels are seen as a marker of increased default risk, driving up sovereign spreads. Specifically, a one percentage point increase in the debt-to-GDP ratio is associated with a rise of 2.4 basis points in the spread, holding all other factors constant. This outcome supports the notion that markets view high debt as a warning signal regarding a government's capacity to meet its obligations, which results in a higher premium demanded by investors.

The deficit-to-GDP ratio similarly demonstrates a positive and significant impact on spreads, with a coefficient around 0.037. This relationship implies that markets are equally attuned to fiscal deficits as indicators of fiscal health, linking larger deficits with a greater likelihood of fiscal distress. Economically, this means that a one percentage point increase in the deficit-to-GDP ratio corresponds to a 3.7 basis point increase in the spread. The statistical significance of this variable highlights how closely investors monitor fiscal imbalances, which are interpreted as a potential signal of instability in the country's fiscal outlook.

On the other hand, following the analysis of the macro-economic variables, the results indicate that Real Effective Exchange Rate (REER), GDP growth and the current account balance do not have a significant impact in this model. Their coefficient estimates reflect the expectation made, but they are not statistically significant. This lack of significance suggests that these economic fundamentals do not have a direct effect on sovereign spreads when fiscal and market risk variables are taken into account. It is possible that within the Eurozone, investors place greater emphasis on indicators of fiscal health and market sentiment over short-term economic growth when assessing sovereign risk.

Moving to the proxy of liquidity risk, we notice that liquidity emerges as an influential factor in the analysis, with a negative and statistically significant coefficient of approximately -0.197. This finding underscores that improved liquidity conditions contribute to reducing spreads, likely by making bond markets more accessible and decreasing transaction costs. A one-unit improvement in liquidity corresponds to a reduction in spreads by roughly 19.7 basis points, indicating that increased liquidity bolsters investor confidence and reduces the perceived risk premium. Better liquidity lowers entry barriers and reduces concerns about market access, providing a stabilizing influence on bond yields.

This analysis demonstrates also the impact of the European Central Bank monetary policy in reducing the spreads. Indeed, the "ECB" coefficient is both negative and significant, estimated at around -0.016, reflecting the stabilizing role of monetary policy, with the purchase of outstanding sovereign debt in the secondary marketing serving as a commitment to economic stability and inflation control. A one percentage point increase in the ECB holdings of national debts leads to a 1.6 basis point reduction in the spread, suggesting that investors interpret the

role of ECB monetary policy in terms of non-conventional monetary policies as a stabilizing influence, reducing the risk premium demanded on sovereign bonds.

The VSTOXX index, which captures market volatility as a proxy of international risk, is another significant determinant of sovereign spreads, following the results seen in the literature. The positive and highly significant coefficient of approximately 0.007 indicates that heightened market uncertainty translates into increased spreads. Specifically, a one-unit increase in the VSTOXX index results in a 0.7 basis point rise in the spread, reflecting investor caution during periods of elevated risk. The statistical significance of this variable demonstrates the strong sensitivity of sovereign spreads to broader financial market conditions and underscores the role of market sentiment in driving investor behavior. It is worth noting that in this model the VSTOXX is the only country-invariant and time-varying regressor, so it can be interpreted also as a variable which incorporates the time effects (Afonso et al., 2020).

Overall, the final model provides a robust estimation of the primary drivers of sovereign bond spreads in the Eurozone, highlighting the primary role played by the macro-fundamentals that firstly relates with countries indebtedness such as debt-to-GDP and deficit-to-GDP, but also the impact of market factors such as liquidity and international risk, and the relevant impact of ECB monetary policy.

3.3.1. Introducing time fixed effects in modelling Sovereign Bond Spreads

In the context of econometric modelling, time effects are used to capture variations over time that are common across all cross-sectional units. For panel data analysis, time effects can be particularly useful for addressing unobserved shocks or changes that influence the countries observed. These effects are typically implemented through time dummy variables, which absorb the influence of these temporal dynamics and ensure that the estimated coefficients for country-specific factors reflect more accurately the cross-sectional differences rather than time-driven commonalities.

From an econometric perspective, ignoring time effects may result in coefficient bias and inconsistency estimates, if they are actually present. Time effects capture unobserved temporal shocks that affect all cross-sectional units —for example, policy changes, global economic conditions, or macroeconomic shocks like the 2008 financial crisis or the European debt crisis. With this approach it is possible to better isolate the impact of the country-specific variables, such as debt-to-GDP or fiscal deficit, on sovereign spreads.

The inclusion of time effects is also a way to handle cross-sectional dependence. Sovereign spreads of different countries are often influenced by common factors, like changes in global

investor sentiment or shifts in European Central Bank policy, which can lead to correlated error terms across countries in any given time. With the time dummies included in the model, this particular problem will be greatly reduced because the unobserved common components will be caught and otherwise unaccounted for, hence reducing the chances of spurious correlation among country-specific covariates.

The sample period of 2002-2022 includes several major economic and financial shocks to the Eurozone, such as the 2008 global financial crisis, the subsequent European sovereign debt crisis, and most recently the COVID-19 pandemic. All these events significantly impacted the spreads of sovereign bonds across all the countries of the Eurozone. By introducing time effects, we can capture such global influences and carefully distinguish country-specific risk factors from general temporal influences exogenous to the individual countries.

For example, during the European debt crisis, spreads for almost all Eurozone countries dramatically increased, driven by a general systemic risk as perceived by investors rather than by country-specific fiscal considerations alone. With the time effects included in the model, it can thereby control for these systemic factors and allow a more accurate estimate of how fiscal metrics—that is, deficit-to-GDP or debt-to-GDP—affect spreads. It is in this way that the introduction of time effects helps distinguish between the influence of structural domestic variables and that of external shocks common to all countries.

Implementation of Time Effects in the Model

To introduce time effects in the econometric model, dummy variables representing each time period (e.g., each quarter or year) can be added. This general approach involves estimating the model with the inclusion of a set of time dummies and it is also used by De Grauwe et al. (2012, 2017). The time dummies absorb the effects of any time-varying shocks that hit all countries and thus prevent the coefficient estimates for being biased by such common shocks. Formally, the model can be represented as:

$$Spread_{it} = \alpha_i + \beta_k X_{it} + \gamma_2 VSTOXX_t + \delta_t + u_{it}$$

The model follows the previously discussed specification, with the addition of a time varying country invariant dummy variable for each quarter of observation.

When both time effects and country-specific effects are introduced, the model becomes a two-way fixed effects model. In this specification, country fixed effects (α_i) are added alongside time fixed effects (δ_t), allowing for the control of both unobserved heterogeneity across countries and unobserved time-varying shocks. Indeed, α_i captures unique, time-invariant characteristics for each country, like institutional quality or economic structure, while

δt captures time-specific effects that impact all countries simultaneously, such as global financial crises or changes in international monetary policy.

The inclusion of both country and time effects helps the model account for factors constant over time but different across countries, as well as those varying over time but constant across countries. This approach strengthens the model's capacity to address omitted variable bias from unobserved factors that could otherwise distort sovereign bond spread estimates. By controlling for these two dimensions, the two-way fixed effects model allows for a more robust identification of the impact of the explanatory variables on sovereign bond spreads.

Incorporating time effects in the model offers several benefits. It enhances coefficient precision, minimizes omitted variable bias, and strengthens the model's robustness against global shocks. Additionally, time dummies improve model fit by explaining common data variations across countries over time.

3.3.2. Analysis of the Estimation Results with Time Effects

Following a general-to-specific methodology, the analysis identifies significant variables and ensures the robustness of findings. The approach includes four models estimated using the Prais-Winsten PCSE method, providing consistency checks through heteroskedasticity and autocorrelation adjustments. By incorporating both quarterly time dummies and broader period dummies across the models, this chapter delves into how different temporal resolutions impact the understanding of sovereign bond spreads.

In developing an understanding of how time influences sovereign bond spreads, the models employ varying approaches to represent time. Models 2a and 2b rely on quarterly time dummies (Table 5), which allow for a detailed look at how specific events and cyclical shifts within each quarter impact bond spreads. This granularity helps in isolating the effects of seasonal trends, economic fluctuations, and unexpected financial disruptions on the Eurozone countries.

On the other hand, in model 2c period dummies replace quarterly dummies as an alternative to test the robustness of the results, providing a different way to estimate time effects. This adjustment aims to reduce the model's complexity by grouping multiple quarters or years into single periods which follow the main structural breaks of the entire time period considered. Such an approach aims to capture the effects of prolonged structural shifts—such as major economic crises or enduring policy changes—that can be represented by aggregated time spans.

Table 5 - Estimation results Model 2 with time effects

Spread	2a		2b		2d	
Debt-to-GDP	0.017	***	0.016	***	0.027	***
	(0.004)		(0.005)		(0.005)	
Deficit-to-GDP	0.078	***	0.074	***	0.033	**
	(0.014)		(0.015)		(0.015)	
GDP Growth	0.003					
	(0.007)					
CA	0.001					
	(0.002)					
REER	0.054	***	0.061	***	0.006	
	(0.019)		(0.021)		(0.011)	
Liq	-0.159	***	-0.153	***	-0.223	***
	(0.040)		(0.042)		(0.059)	
ECB%	-0.037	***	-0.035	**	-0.009	
	(0.014)		(0.014)		(0.009)	
VSTOXX	-0.004				0.008	***
	(0.004)				(0.002)	
globcrisis					0.138	
					(0.102)	
debtcrisis					0.292	**
					(0.131)	
qeperiod					-0.155	
					(0.149)	
covid					-0.466	**
					(0.197)	
Intercept	-6.139	***	-6.767	***	-1.881	
	(1.861)		(2.046)		(1.180)	
Country FE	YES		YES		YES	
Time FE	YES		YES		NO	
Number of observations	717		726		726	
R-squared	0.55		0.52		0.17	
*** p<.01, ** p<.05, * p<.1						

Analysis of Significant Variables

Across all models, the debt-to-GDP ratio demonstrates a consistently positive and statistically significant relationship with sovereign bond spreads. This alignment suggests that as debt levels increase relative to GDP, markets interpret this as a signal of heightened credit risk, leading to higher spreads. The coefficient for the debt-to-GDP ratio varies from 0.016 to 0.027 across models, translating into a 1.6 to 2.7 basis-point increase in spreads per one-point rise in the debt-to-GDP ratio.

The fiscal deficit variable maintains a positive and significant association with spreads, remaining a crucial factor in determining bond spreads. This outcome supports the view that

fiscal imbalances are perceived by investors as an indication of increased sovereign risk, which, in turn, leads to higher borrowing costs.

As seen in the previous model, also in this specification the estimators for the GDP Growth and Current Account Balance are not statistically significant. However, in this case the Real Effective Exchange rate variable became significant (model 2a and 2b), affecting the sovereign spreads. Indeed, its positive coefficient suggests that an appreciation in the real effective exchange rate, signalling reduced competitiveness, induce higher spreads.

The proxy for liquidity risk emerges as a notably important factor with a negative and highly significant relationship to spreads across all models. The coefficient for liquidity is -0.153, indicating that higher liquidity of the bond market lowers spreads by reducing transaction costs and enabling smoother trading. These findings reinforce the view that liquid markets are seen as less risky by investors, who value the reduced barriers to buying and selling.

The ECB interest rate variable initially holds a significant, negative relationship with spreads, implying that higher percentage of sovereign debt hold by the central bank provide a stabilizing effect on spreads. However, this effect loses significance in the more model 2c being absorbed by the period dummies. This could possibly reflect shifts in the monetary policy landscape like the introduction of non-standard measures like quantitative easing.

Differently from Model 1 discussed in the previous chapter, in model 2a and 2b the VSTOXX index, which captures market volatility, becomes not significant when introducing time dummies, suggesting that in the other specification it captures also the time effects as hypothesized (Afonso et al., 2020). This hypothesis is reinforced by the fact that the VSTOXX coefficient turns out to be positive in model 2c when the broader period dummies are employed, so that its fluctuations reflect the international risk and also the general time effects on a quarterly base, while the period dummies express a general trend in the period individuated.

Time Dummies vs. Period Dummies

The choice between quarterly and broader period dummies has meaningful implications for the analysis of temporal effects. In the first two models, quarterly dummies capture short-term, time-specific fluctuations in sovereign spreads. The results of estimated coefficient for quarterly dummies validate important hypothesis relative to the time effects on sovereign spreads. Indeed, especially during quarters involved in the Eurozone debt crisis we can notice largely positive and highly significant coefficients, underscoring the heightened economic stress in these periods. Quarterly dummies thus provide a highly detailed lens for observing the immediate effects of time-specific shocks. Moreover, the strong impact of the quarterly dummies in the quarters of specific stress, like the period between 2010 and 2012 during the

sovereign debt crisis, indicates a sort of “mispricing” of the sovereign spreads and a predominant role played by market sentiment in those periods with respect to the macro-economic and fiscal fundamentals, as also abundantly stressed in the literature (De Grauwe and Ji, 2012).

Conversely, the broader period dummies applied in Models 2c reflect the five main structural breaks of 20 years quarters periods observed, following also De Grauwe et al. (2017):

- Pre-crisis period, from 2002-Q1 to 2007Q4;
- Global crisis period, from 2008Q1 to 2009Q4;
- Debt crisis period, from 2010Q1 to 2012Q2;
- Quantitative easing period, from 2012Q3 to 2019Q4;
- Covid period, from 2020 Q1 to 2022Q1.

Pre-crisis period corresponds to the time period preceding the global financial crisis starting at the end of 2007. The debt crisis dummy considers the timespan starting from the begging of the Greek sovereign debt crisis in the first quarter of 2010 until the “whatever it takes” statement of ECB President Mario Draghi in July 2012. The period named “QE” correspond to the quarters of unconventional monetary policy of the ECB until the first quarter 2020 when it occurs the last break characterized by the outbreak of the COVID pandemics.

Thus, period dummies exhibit the influence of substantial, prolonged events, such as the global financial crisis, the European debt crisis, and the COVID-19 pandemic. These significant dummy coefficients underscore the importance of recognizing structural breaks and major macroeconomic disruptions when examining sovereign bond spread dynamics.

Interestingly our model captures a positive and significant impact of the debt crisis period on the sovereign spread, confirming that during the European Sovereign Debt Crisis the sovereign spreads were affected by an overpricing caused by market sentiment. Conversely the coefficient of the period dummy of QE period is negative but not significant, while the coefficient of COVID period is negative and significant, probably reflecting the reduction of spreads incurred after the outbreak of the pandemics due to the strong action on the financial markets made by the ECB with the Pandemic Emergency Purchase Programme (PEPP).

3.3.3. Investigating Regional Differences

Sovereign bond spreads in the Eurozone are shaped by a combination of macroeconomic, fiscal, and financial factors, but their impact is not uniform across all member states. A key distinction exists between core countries, such as Germany, the Netherlands, and Finland, which benefit from greater fiscal stability and investor confidence, and peripheral economies, including Italy, Spain, Portugal, and Ireland, which are more vulnerable to market sentiment shifts and financial stress. Given these differences, this chapter extends the empirical analysis by exploring whether the fundamental drivers of sovereign spreads operate differently in core and peripheral economies. To capture these regional variations, interaction terms between key explanatory variables and a regional dummy variable are introduced, allowing for a differentiated estimation of effects across the two groups. This approach provides deeper insight into whether financial markets apply distinct risk-pricing mechanisms based on regional classification.

A key component of this analysis is the introduction of a regional dummy variable to distinguish between core and peripheral economies. This dummy takes a value of 1 for peripheral economies (Italy, Spain, Portugal, and Ireland) and 0 for core economies (Austria, Belgium, Finland, France, and the Netherlands). This classification, widely used in the literature on sovereign spreads, reflects well-established differences in fiscal capacity, economic resilience, and investor confidence. To examine whether the effects of key macroeconomic and fiscal variables vary systematically between core and peripheral countries, the regional dummy is interacted with critical explanatory variables individuated in model 2. The model now is modified as follows:

$$Spread_{it} = \alpha_i + \beta_k X_{it} \times REGION + \delta_t + u_{it}$$

These interaction terms allow the estimation of whether financial markets penalize fiscal imbalances, external competitiveness, and liquidity conditions differently in core and peripheral economies. The other terms of the equation follow the previous specification about country and time fixed effects.

Empirical Findings and Regional Variations

The estimation results provide valuable insights into how fiscal and financial variables influence sovereign spreads across different regions. The model explains approximately 53.47% of the variation in spreads, as reflected in the R-squared value of 0.5347, indicating strong explanatory power. The Wald test statistic of 740.26 (p-value = 0.0000) further confirms the significance of the estimated relationships.

Table 6 - Estimation results Model 3, regional differences

Spread	Core Countries	Peripheral countries
region # Debt-to-GDP	-0.006 (0.007)	0.019 *** (0.005)
region # Deficit-to-GDP	0.066 *** (0.019)	0.077 *** (0.016)
region # REER	0.079 *** (0.023)	0.061 *** (0.020)
region # Liq	0.130 (0.083)	-0.180 *** (0.049)
region # ecb%	-0.035 ** (0.015)	-0.041 *** (0.015)
Intercept	-7.661 *** (2.309)	
Number of observations	726	
R-squared	0.53	
Country FE	YES	YES
Time FE	YES	YES

*** p<.01, ** p<.05, * p<.1

One of the most striking findings is the disparity in the effect of the debt-to-GDP ratio between core and peripheral economies (Table 6). In core countries, the impact of debt on spreads is insignificant (coefficient: -0.0063, $p = 0.374$), suggesting that debt levels do not interfere in the spread's determination in these economies. In contrast, in peripheral countries, the relationship is positive and highly significant (coefficient: 0.0186, $p = 0.001$), indicating that rising debt levels substantially increase borrowing costs. This suggests that investors are far more sensitive to fiscal sustainability concerns in peripheral economies, where high debt burdens may be perceived as a greater risk factor.

A similar pattern emerges for the liquidity proxy, which is particularly important in peripheral economies, but it results to be not a significant variable for the core countries. The results show that improved liquidity significantly reduces spreads in these countries (coefficient: -0.1797 , $p < 0.001$), reflecting the greater vulnerability of peripheral bond markets to funding constraints. In contrast, in core economies, the coefficient is positive but statistically insignificant (0.1301 , $p = 0.117$), suggesting that liquidity is less of a concern in countries with stronger financial and fiscal fundamentals. This finding highlights the importance of liquidity support mechanisms, particularly for weaker economies that experience greater sensitivity to market access conditions.

On the contrary, the estimation results show a consistent impact of the deficit-to-GDP ratio in both regions, with a more accentuated role in peripheral countries. Indeed, while the coefficient for core economies is 0.0658 ($p = 0.001$), in peripheral economies it is slightly larger at 0.0769 ($p < 0.001$), highlighting that even if fiscal deficits influence spreads across all Eurozone countries, markets impose greater fiscal discipline on riskier economies. These results reinforce the asymmetric nature of market scrutiny within the Eurozone, where countries with weaker fiscal positions face greater borrowing costs in response to fiscal imbalances.

The Real Effective Exchange Rate (REER) also exhibits a regionally differentiated impact on sovereign spreads. In core economies, an appreciation of the REER is associated with a significant increase in spreads (coefficient: 0.0790 , $p = 0.001$), suggesting that a loss of external competitiveness raises concerns about macroeconomic stability. The effect remains positive and significant in peripheral economies but with a lower magnitude (coefficient: 0.0605 , $p = 0.003$), indicating that while external competitiveness matters for sovereign risk pricing, its impact is more pronounced in core economies.

Finally, ECB interventions are found to be effective in reducing sovereign spreads across both core and peripheral countries, reinforcing the stabilizing role of monetary policy. The coefficient for ECB interventions is negative and significant for both subgroups, with a stronger effect in peripheral economies (-0.0407 , $p = 0.007$) compared to core countries (-0.0349 , $p = 0.016$). This suggests that ECB policies, such as bond purchases and liquidity injections, play a crucial role in mitigating sovereign risk, particularly for economies that are more susceptible to financial stress.

The findings from this analysis provide strong evidence that sovereign spread determinants function differently in core and peripheral Eurozone economies. Fiscal factors, particularly debt and deficit levels, are more heavily penalized in peripheral countries, reflecting heightened market concerns over fiscal sustainability. Similarly, liquidity constraints significantly amplify borrowing costs in these economies, whereas core countries are less affected by such factors.

At the same time, ECB interventions emerge as a key stabilizing force, effectively reducing sovereign risk across the board, but with a greater impact in peripheral economies where market pressures are stronger.

By deepening the understanding of these regional disparities, this study contributes to the broader discussion on financial integration and risk-sharing mechanisms within the Eurozone. The results highlight the need for differentiated policy responses, particularly in times of financial distress, where peripheral economies require stronger liquidity support and fiscal stabilization measures to maintain market confidence. Future research could explore whether these effects vary across different crisis periods, offering further insights into the evolving nature of sovereign risk pricing and investor behaviour in the Eurozone. However, the analysis of the time dummies, capturing the time fixed effects, help to explore how general market risk perception affected sovereign spreads in the time period considered, inducing deviations from the fundamental variables individuated.

3.3.4. Time Effect Analysis

The analysis of the estimated coefficients of the time dummies provides remarkable insights about how time effects hit the Eurozone spreads behaviours across the 20-year period taken into consideration (Table 7). The time effects reflect an additional element influencing sovereign spreads in the specific quarter period, thus representing a sort of deviation from the fundamental variables individuated that reflect the risks associated to the fiscal situation of the country, the liquidity of its sovereign debt market and the impact of the ECB monetary policy. These time dummies can therefore incorporate the market and investors sentiment in pricing sovereign bonds in different times. Interestingly, in our analysis, time effects show significant influence on the spread in the most critical moments of the euro area like between 2010 and 2012 during the sovereign debt crisis period, but also in the first years after the creation of the common currency having in this case a positive impact reducing spreads with respect to the role of the macro-fundamentals. This evidence reinforces the mispricing considerations made by several authors as De Santis (2012), De Grauwe and Ji (2012), Di Cesare (2012).

Indeed, the estimated coefficients for the early 2000s affirm a steady reduction in spreads, with significantly negative values in the first few years. For example, the time dummy for 2002-Q2 is -0.221 ($p < 0.10$), while for 2004q4, it falls to -0.859 ($p < 0.01$). These results suggest that in the first years of the currency union, market perception of sovereign risk was very low, maybe also over-confident with respect to the macro-fundamentals indicators. This downward trend continued through 2005 and 2006, supported by fiscal discipline and adherence to the Stability

and Growth Pact (SGP). Many Eurozone governments reduced their debt burdens, while inflation remained low, reinforcing investor optimism. The negative coefficients in this period reflect a market consensus that the Eurozone was a cohesive and stable economic area, with minimal default risk.

The global financial crisis marked a turning point for sovereign spreads, as the initial market optimism began to wane. In 2007, the estimated coefficients remain negative but start converging toward zero, suggesting that investors were beginning to reassess risk. By late 2008, spreads began rising, reflecting growing uncertainty following the collapse of Lehman Brothers, even if the coefficients are not statistically significant and cannot reveal a clear impact of the time effects in addition to the other variables. Interestingly, the coefficients in early 2009 remain negative, such as -0.610 ($p < 0.10$) in 2009q2, before turning positive later that year. This could suggest that in the immediate aftermath of the crisis, markets initially perceived the shock as a general liquidity event rather than a fundamental credit risk issue. However, as the economic downturn deepened, investors increasingly differentiated between stronger and weaker Eurozone economies, laying the groundwork for the sovereign debt crisis that followed. The most significant and strong impact in negative terms of the time effects on sovereign spreads it is registered in the years between 2010 and 2012, sovereign spreads rose sharply as investor concerns about sovereign default in euro area. Indeed, the estimated coefficients turn positive, with spreads increasing significantly from 2010-Q3 (0.493 , $p < 0.10$) and peaking in 2011-Q3 (2.495 , $p < 0.01$). This period marks the height of the Eurozone sovereign debt crisis, during which Greece, Ireland, and Portugal were forced to seek financial assistance due to unsustainable fiscal deficits and soaring borrowing costs. The highly positive and significant coefficients confirm a fragmentation of Eurozone sovereign bond markets, as investors demanded significantly higher risk premiums for peripheral countries compared to core economies. Time effects remained elevated in 2012, but started substantially declining after the ECB's announcement of the Outright Monetary Transactions (OMT) program, which induced markets believing that the European central bank would act as a lender of last resort in case of necessity.

Indeed, in confirmation of the effect of the ECB's announcements, by mid-2012 sovereign spreads had begun to normalize, reflecting increased investor confidence in the policy response, approaching zero and becoming not statistically significant from 2013. Indeed, following the debt crisis, sovereign spreads stabilized, with most time dummy coefficients becoming statistically insignificant between 2014 and 2015. This period coincides with the ECB's aggressive monetary policy stance, including historically low interest rates and the launch of

quantitative easing (QE) in 2015. These policies helped restore market stability by reducing borrowing costs across the Eurozone.

Only from 2016 we can notice new significant impacts of the time effects, but at a lower extent with respect to the pre-OMT announcement. This increase is noticeable around 2016-Q3 (0.776, $p < 0.05$) and 2018-Q3 (0.913, $p < 0.05$). Several factors likely contributed to this rise, including political uncertainty (e.g., Brexit), slower economic growth, and concerns over the eventual tapering of ECB stimulus programs. The announcement of QE tapering in 2017 and 2018 may have led to mild spread widening, as markets adjusted to the prospect of reduced central bank support.

Finally, the time effects remain not significant in the last quarters considered from onset of the COVID-19 pandemic in early 2020, probably also as a response to the strong response of the ECB in terms of expansive monetary policy. Indeed, unlike the debt crisis the COVID-19 shock was met with a rapid and coordinated policy response, including the ECB's Pandemic Emergency Purchase Programme (PEPP) and substantial fiscal support from national governments.

The evolution of sovereign spreads over time reflects the Eurozone's economic and financial history, highlighting how market sentiment and policy responses shape sovereign risk perception. The time dummy coefficients provide compelling evidence of the cyclical nature of sovereign risk, with significant increases during crisis periods and declines following major policy interventions.

The Eurozone debt crisis stands out as the most severe episode, with spreads reaching their highest levels between 2010 and 2012. This confirms that markets react sharply to fiscal sustainability concerns, particularly when coupled with uncertainty over policy responses. In contrast, the ECB's interventions—such as the OMT program, QE, and PEPP—consistently played a stabilizing role, reducing risk premiums and restoring investor confidence.

Looking ahead, sovereign risk in the Eurozone will likely remain closely tied to monetary policy expectations, fiscal coordination, and external shocks. Understanding these time variations is essential for policymakers aiming to maintain financial stability and prevent future episodes of market fragmentation. The findings of this chapter reinforce the importance of credible fiscal policies and a proactive central bank in ensuring sustainable borrowing costs for Eurozone governments.

Table 7 – Quarter time dummies (Model 3)

2002q1	-0.097 (0.088)	2007q1	-0.581 * (0.304)	2012q1	2.445 *** (0.280)	2017q1	0.872 ** (0.350)
2002q2	-0.221 * (0.130)	2007q2	-0.527 * (0.307)	2012q2	2.013 *** (0.276)	2017q2	0.645 * (0.362)
2002q3	-0.310 ** (0.157)	2007q3	-0.522 (0.326)	2012q3	1.320 *** (0.279)	2017q3	0.576 (0.372)
2002q4	-0.526 *** (0.196)	2007q4	-0.524 (0.339)	2012q4	0.834 *** (0.289)	2017q4	0.492 (0.374)
2003q1	-0.662 *** (0.234)	2008q1	-0.574 (0.355)	2013q1	0.785 *** (0.289)	2018q1	0.633 * (0.373)
2003q2	-0.681 *** (0.239)	2008q2	-0.468 (0.337)	2013q2	0.712 ** (0.297)	2018q2	0.746 ** (0.376)
2003q3	-0.745 *** (0.261)	2008q3	-0.105 (0.318)	2013q3	0.440 (0.301)	2018q3	0.913 ** (0.374)
2003q4	-0.785 *** (0.279)	2008q4	0.139 (0.340)	2013q4	0.183 (0.308)	2018q4	0.913 ** (0.367)
2004q1	-0.654 ** (0.263)	2009q1	-0.268 (0.343)	2014q1	0.007 (0.305)	2019q1	0.844 ** (0.363)
2004q2	-0.690 ** (0.273)	2009q2	-0.610 * (0.351)	2014q2	-0.010 (0.291)	2019q2	0.659 * (0.359)
2004q3	-0.812 *** (0.301)	2009q3	-0.793 ** (0.361)	2014q3	0.001 (0.286)	2019q3	0.669 * (0.356)
2004q4	-0.859 *** (0.299)	2009q4	-0.635 * (0.326)	2014q4	0.093 (0.282)	2019q4	0.673 * (0.354)
2005q1	-0.719 ** (0.283)	2010q1	0.005 (0.296)	2015q1	0.305 (0.287)	2020q1	0.575 (0.390)
2005q2	-0.646 ** (0.273)	2010q2	0.246 (0.293)	2015q2	0.326 (0.288)	2020q2	0.208 (0.422)
2005q3	-0.577 ** (0.267)	2010q3	0.493 * (0.297)	2015q3	0.337 (0.293)	2020q3	0.029 (0.450)
2005q4	-0.532 ** (0.266)	2010q4	0.723 ** (0.289)	2015q4	0.474 (0.303)	2020q4	-0.039 (0.465)
2006q1	-0.587 ** (0.281)	2011q1	1.123 *** (0.297)	2016q1	0.614 * (0.314)	2021q1	0.216 (0.469)
2006q2	-0.605 ** (0.291)	2011q2	1.957 *** (0.293)	2016q2	0.586 * (0.324)	2021q2	0.404 (0.477)
2006q3	-0.566 * (0.293)	2011q3	2.495 *** (0.292)	2016q3	0.776 ** (0.335)	2021q3	0.608 (0.484)
2006q4	-0.575 * (0.297)	2011q4	2.381 *** (0.282)	2016q4	1.001 *** (0.344)	2021q4	0.713 (0.476)

3.3.5. Policy implications, limits and further research perspectives

The empirical results of this study offer key insights into the determinants of sovereign bond spreads in the Eurozone, underscoring the role of fiscal sustainability, liquidity conditions, global risk sentiment, and monetary policy interventions. These findings highlight the need for a policy framework that prioritizes economic stability, productive investments, and a proactive central bank response rather than a rigid adherence to austerity-driven fiscal rules.

The strong relationship between debt-to-GDP ratios and sovereign spreads in peripheral economies suggests that markets impose stricter borrowing conditions on countries with weaker fiscal positions. However, as the findings from De Grauwe and Ji (2012) suggest, the sharp rise in spreads during the Eurozone debt crisis was partly driven by market overreaction rather than actual fiscal fundamentals. This implies that strict austerity measures, imposed in 2011 by the European Commission to the countries asking financial support in response to rising spreads, may have exacerbated economic downturns rather than restoring fiscal stability, or at least were not able “per-se” to tackle the financial turmoil on the markets as evidenced by the investor sentiment captured by the time effects.

An effective policy response should move beyond an excessive focus on fiscal consolidation and instead advocate for countercyclical fiscal policies accompanied by an adequate monetary policy intervention. Fiscal policies focused solely on deficit reduction—rather than stimulating economic recovery—may be misguided. Indeed, during economic downturns increased investment policies aimed to increase potential productivity of a country can restore country competitiveness, which has also a relevant role in spreads determination as demonstrated by the impact of the Real Effective Exchange Rate in our analysis.

To mitigate market overreaction, European institutions should strengthen common debt issuance mechanisms, such as expanding the role of Eurobonds. The issuance of joint debt instruments, as temporarily introduced with the EU’s Recovery Fund, could help reduce asymmetric pressures on peripheral economies, ensuring that borrowing costs reflect economic fundamentals rather than speculative market behavior.

Moreover, the study finds that liquidity conditions play a significant role in driving sovereign spreads, particularly in peripheral countries. A lack of liquidity in sovereign bond markets results in higher borrowing costs, making it essential for policymakers to develop market stabilization mechanisms. The European Central Bank (ECB) has played a crucial role in stabilizing financial markets through interventions such as the Outright Monetary Transactions (OMT) program and Quantitative Easing (QE) policies. The findings confirm that ECB interventions have had a stabilizing effect on spreads, particularly for vulnerable economies.

This underscores the importance of maintaining an active central bank capable of intervening in sovereign debt markets to prevent liquidity crises and financial fragmentation. However, recent policy shifts toward monetary tightening driven by inflation concerns, accompanied by the end of PEPP and PSPP, raises concerns about the ECB's ability to contain fragmentation while pursuing price stability.

For these reasons the actual ECB mandate, with the only focus on inflation targeting, put some shadows on its ability of intervention, even if in the last 13 years we assisted to a noticeable enlargement of its sphere of action. In order to overcome these limits, the ECB could adopt a dual mandate approach, similar to the Federal Reserve, balancing inflation control with employment and financial stability objectives. This would allow for a more nuanced response to economic downturns, preventing premature tightening that could trigger renewed sovereign debt pressures.

Concluding, the results of this study confirm that sovereign spreads are not only a function of fiscal fundamentals but also of liquidity conditions, investor sentiment, and ECB policy actions. An adequate policy response should emphasize economic stabilization, social investment, and proactive central bank interventions rather than relying on simple austerity-driven fiscal consolidation.

Limits and Future Research Directions

While this study provides a comprehensive analysis of the determinants of sovereign bond spreads in the Eurozone, it is important to acknowledge certain limitations that could impact the interpretation of the results. These limitations stem from both the nature of the dataset and the econometric methodology, as well as from broader structural factors that shape sovereign risk in financial markets. Recognizing these constraints not only allows for a more cautious interpretation of the findings but also opens the door for future research to address these gaps and extend the analysis in new directions.

The dataset covers a period from 2002 to 2022 and includes a wide range of fiscal, macroeconomic, financial, and monetary indicators. However, sovereign spreads can be influenced by other factors beyond those explicitly considered in this work such as political and institutional stability, maturity of public debt, structure of the banking system, that in this study are captured by fixed effects but could also be investigated in a detailed way.

Another important limitation concerns the assumption of linear relationships between variables. The econometric model used in this study assumes that sovereign spreads respond in a linear fashion to changes in fiscal, liquidity, and monetary policy variables. However, financial markets often exhibit nonlinear dynamics, especially during periods of crisis. It is possible that

the relationship between debt levels and sovereign spreads is not constant over time, but rather contingent on certain threshold effects. For instance, markets may react moderately to rising debt levels up to a certain point, but once a critical threshold is breached, spreads could escalate rapidly due to fears of default or unsustainable borrowing costs.

The methodology employed in this research Prais-Winsten regression with Panel-Corrected Standard Errors (PCSE) was chosen to address common econometric concerns such as heteroskedasticity and serial correlation. However, dynamic panel data models could be useful in accounting for potential endogeneity issues, particularly regarding the influence of past sovereign spreads on current market expectations. Sovereign spreads are often persistent over time, meaning that past values may have explanatory power for current movements.

Beyond methodological improvements, there are several promising avenues for future research. One particularly relevant extension could be to deepen the impact of possible Eurozone institutional reforms on sovereign bond spreads. Over the past two decades, the Eurozone has undergone significant changes, including the establishment of the European Stability Mechanism (ESM), the creation of the Banking Union, and the introduction of fiscal governance frameworks such as the Next Generation EU (NGEU) recovery fund, but further reforms of the Stability and Growth Pact (SGP) are now one of the primary topic of the agenda of the European Institutions.

Additionally, a comparative study between the Eurozone and other countries not belonging to the currency union could yield interesting insights into the unique challenges faced by a currency area with a centralized monetary policy but decentralized fiscal policies.

In conclusion, while this thesis has provided a thorough investigation into the determinants of sovereign spreads in the Eurozone, several avenues for further research remain open. Addressing the limitations discussed here and incorporating new methodological approaches, broader economic considerations, and forward-looking risk factors could enhance our understanding of sovereign risk pricing. As economic conditions evolve and financial markets continue to adapt to new challenges, continuous research in this field will be essential to inform policymakers, investors, and academics alike.

Conclusions

This thesis has conducted an in-depth examination of the long-term determinants of sovereign bond spreads in the Eurozone, utilizing a rigorous econometric analysis applied to a panel dataset covering nine Eurozone countries from 2002 to 2022. By integrating fiscal, macroeconomic, financial, and monetary policy factors, this study offers a comprehensive perspective on how bond markets price sovereign risk across various economic conditions and policy responses.

Chapter 1 established the historical background of sovereign spreads within the Eurozone, detailing their evolution following the adoption of the common currency. Initially, sovereign yields converged, reflecting the market's confidence in the economic and fiscal integration of Eurozone members. However, the Global Financial Crisis of 2007-2008 and the subsequent European Sovereign Debt Crisis of 2010-2012 highlighted structural fiscal weaknesses, leading to a sharp divergence in sovereign spreads, especially in peripheral economies. The role of the European Central Bank (ECB) became crucial in restabilizing trust for weaker countries in the markets in 2012 with OMT announcement, as its interventions through unconventional monetary policy instruments helped mitigate spreads and ensure financial stability.

Chapter 2 provides a comprehensive review of the existing literature on the determinants of sovereign bond spreads, highlighting the key theoretical and empirical contributions in this field. The chapter categorizes the main drivers of sovereign spreads into three primary sources of risk: credit risk, liquidity risk, and global risk aversion (Attinasi et al., 2009; Bernoth et al., 2012; Caggiano and Greco, 2012). The literature review also underscores the increasing role of ECB monetary policy interventions in influencing sovereign spreads, particularly in the post-crisis period mitigating the effects of market fragmentation within the Eurozone (De Grauwe et al., 2017; Afonso et al., 2018). Furthermore, the chapter discusses the regional heterogeneity in sovereign risk pricing, emphasizing the distinction between core and peripheral Eurozone countries. While core economies generally benefit from lower risk premia due to stronger fiscal positions and higher market liquidity, peripheral countries are subject to greater market scrutiny and higher borrowing costs, particularly during periods of financial instability (Costantini et al., 2014; Afonso et al., 2015; Afonso and Jalles, 2019).

Chapter 3 provided a detailed exploration of the dataset, the econometric methodology employed, and the key empirical findings related to the determinants of sovereign bond spreads in the Eurozone. The analysis relied on a comprehensive panel dataset covering nine Eurozone countries over two decades, incorporating fiscal, macroeconomic, financial, and monetary policy variables. The methodology was designed to address econometric issues of this typology

of panel data such as heteroskedasticity, serial correlation, and cross-sectional dependence, ensuring robust and reliable estimation results. A key aspect of this study was the application of the Prais-Winsten regression model with Panel-Corrected Standard Errors (PCSE), which was chosen due to its ability to handle heteroskedasticity and serial correlation while accounting for the interdependencies between countries.

The empirical results confirmed several well-established theories in the literature, providing evidence of their validity over the 20-period time span taken into account. Model 1 exhibits the first regression results with only country fixed effects. The general-to-specific approach employed reject the significance of some macro-economic variables such as GDP Growth, Current Account Balance and Real Effective Exchange Rate. On the contrary, it finds robust evidence of the impact of Debt and Deficit-to-GDP ratio in increasing the spreads, and by a lower extent also of VSTOXX as a proxy for international risk aversion, while it reveals a positive effect of the liquidity variable on the spreads, meaning that more liquid bonds markets induce lower spreads. Interestingly the model shows also a significant impact of the stabilization effect of the ECB monetary policy, implying that the purchases programs of sovereign bonds on the markets have an important role in lowering spreads.

In the second model, time fixed effects are introduced in the form of quarterly time dummies and macro-period dummies, reflecting the major structural breaks individuated in the literature and by the evidence of the data analysis. The results are mostly coherent with the first model and show that the quarterly time dummies approach perform better. Differently from what happens in the macro-time period dummies model, in quarterly dummies approach the VSTOXX coefficient loses completely significance, clearly indicating that as the only time variant and country invariant regressor it incorporates a specific time effect which is absorbed more precisely by the quarterly dummies. On the contrary, the Real Effecting Exchange Rate estimator gains significance reflecting the impact of external competitiveness on sovereign risk perception.

To account also for the regional differences between core and peripheral countries a third model has been introduced with the employment of two regional dummies for the two groups. Noticeably, the estimation results demonstrate a different impact of debt-to-GDP in the two groups, with a not significant impact for the core countries, compensated by a strong and significant impact for the peripheries. This evidence could suggest that debt-to-GDP is not a per-se significant variable that influence spreads, but it can trigger yield differential only beyond certain thresholds becoming relevant in the countries where the debt burden is quite consistent. On the contrary the model indicates a significant impact of the deficit-to-GDP in both groups, even if by a larger extent for the peripheral countries, suggesting a role of primary

fiscal driver of the sovereign spreads. Like debt-to-GDP, also the liquidity proxy has different outcomes in the two groups, demonstrating that a more liquid sovereign debt market has a positive effect in reducing spread in the case of peripheral countries.

In all the models, the European Central Bank's interventions, captured through the monetary policy variable, were found to be highly effective in compressing spreads. This result aligns with previous research highlighting the stabilizing role of the ECB through its asset purchase programs and unconventional monetary policies (Afonso et al., 2018; Eijffinger and Pieterse-Blom, 2022). The empirical results confirm the pivotal role of the ECB in stabilizing sovereign debt markets, particularly during crises. The effectiveness of intervention programs such as the Securities Market Programme (SMP), Outright Monetary Transactions (OMT), Public Sector Purchase Programme (PSPP), and the Pandemic Emergency Purchase Programme (PEPP) underscores the importance of a proactive and adaptable monetary policy framework in preserving market stability.

The time effects included in the model provided further insights into the evolution of sovereign spreads over different economic cycles. The analysis confirmed that spreads were subject to particular time effects during financial crises, especially during from 2010 to 2012 during European Sovereign Debt Crisis. But time effects revealed to be significant also in the pre-crisis period with a negative effect, representing the different degree of market sentiment in the different times and how it had diverse impact before and after the beginning of the debt crisis. The final picture that emerges from this analysis confirms the considerations made by those authors that highlighted the "mispricing" phenomena (De Santis, 2012; De Grauwe and Ji, 2012; Di Cesare 2012) that incurred in the Eurozone before the intervention of the European Central Bank with non-conventional policies. This interpretation is sustained by the evidence caught both by the time effect dummies and by interactions of the variable with the regional dummies, which demonstrate an asymmetric effect of several determinants in the two groups. These considerations suggest that lot of the economic distress that Eurozone countries suffered during the debt crisis could have been prevented by a sooner intervention of the ECB as a lender of last resort, rather than posing the attention only on the fiscal discipline of the peripheral countries, which in fact was representing only a limited part of sovereign spreads determination. The different behaviour adopted by the Eurozone both in terms of fiscal and monetary policy during the COVID-19 pandemic crisis demonstrate that a different way-out to the debt-crisis that prevented the sovereign spread deflagration was possible. On the other hand, the relevance that also this study attributes to the fiscal fundamentals like public deficit and debt should not induce to ignore that macro-variables to the policy decisions of the euro area, but the ideal outcome should include the adoption of sound fiscal targets within the framework of a more

integrated fiscal and monetary union which can smooth the impact of sentimental or speculative behaviours of the markets.

As the ECB shifts towards a monetary tightening cycle in response to inflationary concerns, the challenge of managing sovereign spread divergence will become more pronounced. The phasing out of asset purchase programs may leave highly indebted economies vulnerable to renewed market pressures. In this context, the ECB may need to deploy new instruments to prevent excessive fragmentation and ensure financial cohesion within the Eurozone.

This thesis contributes to the growing body of literature on sovereign bond spreads in the Eurozone by providing strong empirical evidence on the interplay between fiscal, financial, and monetary determinants on a long run perspective of 20 years, followed in quarterly observations. The results highlight the asymmetric nature of market discipline, the crucial role of liquidity conditions, and the effectiveness of ECB interventions in mitigating spread divergence.

From a policy perspective, the findings reinforce the importance of credible fiscal frameworks, proactive monetary interventions, and deeper financial integration to sustain the stability of sovereign debt markets. As the Eurozone navigates new challenges—including inflationary pressures, geopolitical risks, and fiscal policy coordination—ensuring a well-balanced interaction between monetary and fiscal policies will be vital.

By the individuation the key drivers of sovereign spreads, this study provides valuable insights for policymakers, investors, and researchers alike. Future advancements in fiscal governance, enhanced financial stability mechanisms, and adaptive monetary policy tools will be crucial in maintaining the resilience and cohesion of the Eurozone's sovereign debt markets.

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Appendix A - Stata implementation

The `xtpcse` command in Stata is a powerful alternative to feasible generalized least squares (FGLS) for estimating linear cross-sectional time-series models when disturbances are not assumed to be independent and identically distributed (i.i.d.). Unlike FGLS, `xtpcse` can handle cases where disturbances exhibit heteroskedasticity—variance that differs across panels—or where they show both heteroskedasticity and contemporaneous correlation across panels, meaning the errors may be related across entities at the same time point.

Additionally, `xtpcse` is flexible enough to account for autocorrelation within each panel, where the residuals for one observation in a panel are correlated with residuals for prior observations within that same panel. This autocorrelation parameter can be consistent across all panels or allowed to vary for each individual panel, providing greater adaptability in modeling complex error structures.

Indeed, the `xtpcse` command in Stata implements Ordinary Least Squares (OLS) with panel-corrected standard errors (PCSE), as developed by Beck and Katz (1995). This methodology was designed primarily for panel data where the number of time periods (T) exceeds the number of cross-sectional units (N), i.e., $N < T$, which is common in political science and macroeconomic research. Beck and Katz criticized the use of Feasible Generalized Least Squares (FGLS) in such contexts, arguing that it tends to underestimate standard errors, leading to overconfident statistical inferences. They maintained that in small- N , large- T panels, OLS remains the best estimator for the coefficients, but its standard errors need correction to account for panel-specific heteroskedasticity and contemporaneous correlation across units. To address this issue, they introduced panel-corrected standard errors (PCSE), which provide more robust and reliable inference in such datasets. Unlike FGLS, PCSE does not impose strong assumptions on the error structure, making it a preferred approach when dealing with panel data where error variances and correlations may vary over time or across units. A key advantage of PCSE is its ability to handle both heteroskedasticity and cross-sectional correlation in the error terms, which are commonly observed in macroeconomic and financial panel datasets.

Both estimators—`xtpcse` and FGLS—are consistent as long as the conditional mean is correctly specified. However, if the assumed covariance structure is correct, the FGLS estimates from `xtgls` are more efficient. Nonetheless, research by Beck and Katz (1995) has shown that full FGLS variance-covariance estimates tend to be overly optimistic (anticonservative) when applied to typical datasets used in social sciences—often with 10–20 panels and 10–40 periods per panel. Their findings suggest that Ordinary Least Squares (OLS) or Prais-Winsten estimates

with Panel-Corrected Standard Errors (PCSE) provide coverage probabilities that are closer to nominal, making them more reliable for inference in such contexts (Stata.com).

xtgls provides more efficient FGLS estimates of model parameters, but with the drawback that its standard error estimates are conditional on the estimated disturbance covariance. Beck and Katz (1995) argue that the gain in statistical power from using FGLS with such data is minimal and that the standard errors from FGLS are often overly optimistic (anticonservative). This means that FGLS can lead to underestimating the true variability in the estimates, which may result in misleadingly narrow confidence intervals and an increased risk of Type I errors.

When specifying autocorrelation with panel-specific coefficients (using the `correlation(psar1)` option in Stata's `xtpcse` command), each panel's autocorrelation coefficient (ρ_i) is estimated individually. This is done by running an OLS regression across all panels, and then calculating the residuals specific to each panel. This approach allows each panel to have its own autocorrelation structure, rather than assuming a uniform autocorrelation parameter across all panels, which can be particularly useful when the persistence of the error term varies by panel (e.g., by country in a cross-national study). This flexibility improves model accuracy by accounting for unique time dependencies within each panel.

Treatment of individual effects

Unlike a fixed effects model, `xtpcse` does not automatically control for time-invariant, panel-specific characteristics (such as country-specific traits). In a fixed effects framework, individual effects are removed by demeaning or differencing, isolating within-panel variation and removing unobserved, stable heterogeneity. However, `xtpcse` retains all observed data without demeaning or differencing, so it does not inherently account for these unique, panel-specific effects.

Because `xtpcse` does not control for unobserved, time-invariant heterogeneity, its results align more closely with a random effects model. In this setup, individual (panel-specific) effects are assumed to be uncorrelated with the regressors, similar to random effects assumptions, making it unsuitable for situations where unobserved heterogeneity is suspected to correlate with the explanatory variables.

In order to approximate a fixed effects model, we manually add dummy variables for each panel (e.g., country) to capture these unobserved characteristics. This can help control for individual-specific effects.

The main advantage of `xtpcse` lies in its ability to provide Panel-Corrected Standard Errors (PCSE), which adjust for heteroskedasticity and cross-sectional dependence across panels. `xtpcse` is particularly valuable when dealing with heteroskedastic and serially correlated panels,

but it doesn't directly address fixed effects. Its strength lies in managing complex error structures rather than controlling for individual-specific effects.

The Core Estimation Command

The primary estimation command used in Stata is:

```
xtpcse Spread Debt def GDPGrowth CA REER Liq ecb region i.country i.time, correlation(psar1)  
hetonly rhotype(tscorr)
```

which follows the methodology outlined in Chapter 3.

The terms “i.country” and “i.time” introduce fixed effects for each country and each quarter, respectively.

The second part of the Stata command consists of options that correct for key statistical problems commonly encountered in macroeconomic panel data.

The option “correlation(psar1)” specifies that the error terms in the regression follow a panel-specific autoregressive process of order 1 (AR1). This means that each country's residuals are allowed to be correlated over time independently from those of other countries. Without correcting for this, estimates could suffer from bias due to serial correlation, while the panel-specific is preferred since a common AR1 process for all countries would impose a restrictive assumption, potentially leading to inefficient estimates.

The “hetonly” option corrects for heteroskedasticity, allowing for the variance of the error term to differ across countries.

Finally, the “rhotype(tscorr)” option specifies that the estimator should account for time-series correlations in the residuals when computing the covariance matrix. This is particularly important in macro-financial datasets, where economic conditions tend to evolve over time in a correlated pattern.

In summary, the Stata command used for estimating the determinants of sovereign bond spreads combines an econometrically robust estimation strategy with careful attention to panel data issues. By implementing the estimation in this way, the model ensures that results are economically meaningful and econometrically robust, allowing for a nuanced analysis of the drivers of sovereign spreads in the Eurozone.