Utrecht University

School of Economics

28 June 2024

Master Thesis U.S.E

The Impact of European Central Bank Communication Tone on Sovereign Bond Yields A Quantitative Study

Mavroudis Polymenos (4737938)

Email: m.polymenos@students.uu.nl

Thesis Supervisor : Jesse Groenewegen

Utrecht University | School of Economics, Utrecht, The Netherlands

E58 Central Banks and Their Policies

G12 Asset Pricing • Trading Volume • Bond Interest Rates

ABSTRACT

The European Central Bank's (ECB) communication strategy plays a vital role in shaping market sentiment and guiding investors' decisions. This study aims to quantify the tone employed during ECB monetary policy press releases and examine its impact on sovereign bond yields across Eurozone member countries. Utilizing advanced computational linguistic techniques, specifically the VADER sentiment analysis tool in Python, the study measures the sentiment conveyed in these communications. In addition, an event study approach is employed to provide better insight into the immediate effects of the ECB's tone on bond markets. To capture the effects accurately, two models were employed: a standard regression model and an autoregressive conditional heteroskedasticity (ARCH) model. This dual approach addresses potential heteroskedasticity and ensures robust results. The research findings reveal a positive correlation between an optimistic ECB tone and increased sovereign bond yields in core economies, such as Germany and the Netherlands. Conversely, for intermediary economies like France and Italy, and peripheral economies such as Greece and Portugal, a positive tone results in a narrowing of the yield spread relative to German bonds. Greece, in particular, exhibits the most significant reaction to changes in ECB communication tone. These results underscore the importance of ECB communication in influencing financial markets and offer valuable insights for policymakers and investors aiming to navigate the complexities of the Eurozone's economic landscape.

Table of Contents

1 Introduction

In its mission to foster transparency and clarity the European Central Bank (ECB) engages in multifaceted communication efforts, transmitting vital information to the public and financial markets through a wide spectrum of communication avenues. This strategy encompasses press releases, speeches, publications, and an online portal, each designed to disseminate information effectively (Blinder et al. 2018). Notably, ECB press conferences serve as pivotal events, offering insights into monetary policy decisions, economic assessments, financial stability, and banking supervision. These communications are instrumental in shaping market sentiment and influencing investment decisions, which makes a thorough understanding of ECB communication dynamics essential for navigating financial markets effectively and anticipating potential market movements.

Thus, market participants pay close attention to ECB communications, meticulously analysing both the substance of the messages as well as the nuanced tone conveyed, particularly during press releases. This vigilant observation not only helps investors and analysts understand the Central Bank's policy stance and economic outlook but also acts as a critical factor in shaping market dynamics and influencing investment decisions. The market's reaction to ECB communications often serves as a key indicator of market sentiment, with fluctuations in asset prices and currency values reflecting the perceived implications of the central bank's statements. Consequently, an elaborate understanding of ECB communication dynamics is essential for interpreting the financial landscape and making strategic investment choices.

Given that, the purpose of this research is to quantify the tone employed in press releases by the European Central Bank and analyse the effect that this might have on sovereign bond yields concerning core, intermediary, and peripheral Eurozone member states. More precisely, with this research, I explore whether the inclusion of positive and negative words in central bank communication has an impact beyond the actual content of the message delivered to the public. Focusing on yields has advantages since government bonds are considered to be highly liquid assets, and their value is commonly regarded as a benchmark for assessing the general financing conditions of an economy (Kanelis & Siklos, 2023).

To measure the sentiment expressed during the European Central Bank monetary policy press releases, computational linguistic techniques are put to use, and more precisely the VADER lexicon, with the assistance of Python. This is to measure if the tone contains any useful information for financial markets and has a significant effect on bond yields. Additionally, an event study approach is utilized to analyse the immediate market response to ECB press releases. This study employs both a standard regression model and an autoregressive conditional heteroskedasticity (ARCH) model to capture the nuanced effects of ECB tone on bond yields. The ARCH model specifically addresses potential heteroskedasticity and endogeneity that might be present in the quantified tone.

My research builds on Schmeling and Wagner's (2015) work, which identified a correlation between the tone of European Central Bank (ECB) communication and German bond yields, noting that a positive tone leads to increased yields, especially in longer-term maturities, while a negative tone lowers yields, notably in shorter-term maturities. They also found that a positive ECB tone reduces yield spreads between German bonds and those of Italy and Spain. Kanelis and Siklos (2023) quantified the tone during Mario Draghi's tenure using a Fully Convolutional Neural Network to assess vocal emotions in post-statement Q&As, finding that positive signals increased yields for German two-year bonds and affected spreads for French and Italian bonds.

My research expands on these findings by analysing the monetary policy statements of the last three ECB Presidents—Jean-Claude Trichet, Mario Draghi, and Christine Lagarde—from 2003 to 2024. This period, marked by the Global Financial Crisis and its aftermath, allows for a comprehensive view of how ECB communication has evolved through various economic phases. I examine the impact of the tone of ECB press releases on core Eurozone economies (Germany and the Netherlands), intermediary economies (France and Italy), and peripheral economies (Greece and Portugal). These classifications are based on Campos and Macchiarelli (2021), who categorized Eurozone countries by their economic roles within the monetary union.

One of the main assumptions for this paper is that the words used during the European Central Bank announcements are not random, they have been precisely selected after going through many stages of processing.

The analysis reveals that the tone of ECB communications significantly impacts sovereign bond yields across different Eurozone economies. For core economies like Germany and the Netherlands, a positive tone in ECB press releases correlates with an increase in bond yields. In contrast, for intermediary economies such as France and Italy, and peripheral economies including Greece and Portugal, a positive ECB tone leads to a narrowing of yield spreads relative to German bonds. The most significant adjustments are observed in Greece, reflecting its heightened sensitivity to central bank tone. These findings illustrate how ECB tone influences bond yields differently across various Eurozone economies.

The results of the research are of importance to both policymakers and investors. The ECB holds a pivotal position in shaping economic policies across the Eurozone. Understanding how the tone of its communication affects different member states can offer valuable insights for policymakers. Recognizing that different communication tactics can affect positively/negatively core, intermediary and peripheral economies can be an opportunity for policymakers to customize their approach, minimizing inequalities and bolstering economic cohesion across the Eurozone. In addition, this knowledge can be essential for investors and financial institutions as well. As they might be exposed to core or peripheral economies' risk in their portfolios, this paper can be of importance in assisting them make informed investment decisions, managing risks, and capitalizing on market opportunities.

The remainder of this paper is therefore structured as follows: Section 2 presents the literature review, examining prior research on central bank communication and its effects on financial markets. Section 3 outlines the theoretical framework and hypotheses, detailing the expected relationships between ECB communication tone and sovereign bond yields. Section 4 describes the data and section 5 the methodology used for the analysis, including sentiment analysis techniques and econometric models. Section 6 discusses the results, focusing on the differential impacts of ECB tone across core, intermediary, and peripheral Eurozone economies. Finally, Section 7 provides a discussion of the results, drawing conclusions and offering insights into the implications for policymakers and investors, along with suggestions for future research.

2 Existing Literature

2.1 Central Bank Communication

In the wake of the Global Financial Crisis, there has been a growing acknowledgment of the pivotal role effective communication plays in the operations of Central Banks. Recognizing this, the European Central Bank has prioritized improving its understanding by the public, as this can increase accountability and help anchor the expectations of the financial market's participants. (Angino and Robitu,2023). During his final press conference in October 2019, Mario Draghi, the former president of the European Central Bank, underscored the importance of journalists' inquiries in enhancing communication within Central Banks. More precisely he mentioned that ''*The other thing, frankly, is that with your inquisitive questions, you have stimulated our striving towards greater transparency and greater candour. I don't think that by themselves, central bankers would have changed communication if left free to be opaque*."

Blinder in his research underlines the vital role of communication by Central Banks in achieving macroeconomic objectives, as it enhances the predictability of monetary policy decisions, and it can move financial markets. Despite its significance, there remains an ongoing debate regarding the most effective communication strategy for central banks. (Blinder et al.2008). For instance, while communication holds a significant position in assisting markets in anticipating monetary policy decisions and reducing market volatility, public disagreement among committee members can undermine predictability and exacerbate market volatility. In contrast, a more individualistic approach regarding the economic outlook has been found to yield better benefits, especially for the Federal Reserve. (Ehrmann and Fratzscher,2005).

As mentioned previously, there are various channels to transmit information to the public and professionals. Jurkšas et al (2018) analysed the effect of the communication on euro area sovereign bond yields, considering four distinct monetary policy communication events: ECB monetary policy decisions, press conferences, accounts, and speeches by Executive Board members. Their results revealed a significant effect, especially when it comes to ECB decisions and press releases. More importantly,

economies burdened by substantial debt levels, such as Italy and Spain, experienced the most notable alterations in fiscal costs following these events, whereas the German bond market was less affected. (Schmeling and Wagner,2024)

2.2 Monetary Policy and Bond Yields

Many of the press releases by the European Central Bank are monetary policy decisions. In essence, bonds are notably influenced by monetary policy, particularly in terms of the movement of interest rates. A bond's current yield is determined by dividing the bond's coupon payments by its market price. As bond prices climb, their yields decrease. When interest rates decrease, bond prices ascend, causing yields to decrease accordingly. Conversely, as interest rates rise, bond prices depreciate, leading to higher yields. This relationship between interest rates and bond prices signifies that falling interest rates correspond with rising bond prices and lower yields while increasing interest rates coincide with declining bond prices and higher yields. (Bodie et al.2018)

In their book 'Investments' Bodie et al. mention that the bond's price is essentially the present value of its future cash flows (coupon payments and face value), discounted at the current interest rate. When interest rates rise, the discount rate applied to these future cash flows also increases, reducing their present value and thus lowering the bond's price and creating this inverse relationship. Similarly, when interest rates fall, the discount rate decreases as well, raising the present value of the future cash flows and consequently increasing the bond's price. Additionally, the increase in bond prices due to the lower interest rates leads to a decrease in the yield to maturity because investors pay more for the bond's fixed coupon payments and face value. Conversely, as bond prices fall when interest rates rise, the yield to maturity increases because investors pay less for the same fixed payments, making the yield higher relative to the lower purchase price.

2.3 European Central Bank Tone

A great importance has been put on the tone used during the press releases of the European Central Bank. The tone reflects the central bank's views on economic fundamentals and its stance on monetary policy. Maik Schmeling and Christian Wagner during their research found that changes in tone have a significant effect on asset prices.

More precisely, a positive tone is correlated with higher stock prices and risk-free interest rates whereas credit spreads and volatility risk premia decrease. The theory behind a positive tone increasing yields is based on the anticipation of tighter future monetary policy. A positive tone signals a favourable economic outlook, leading investors to expect potential rate hikes to control inflation or economic overheating. This expectation drives up yields on risk-free government bonds. Additionally, a positive tone reduces risk premia by lowering investor risk aversion, which increases demand for riskier assets and results in higher yields on safer assets as the market adjusts to these expectations. (Schmeling and Wagner,2023).

Overall, after a drop in a more negative tone in 2009, the ECB has become persistently more optimistic and less uncertain during its press releases, especially in comparison to the Bundesbank's tone. These two banks emerge as the main protagonists when it comes to monetary policy in the Euro area, often diverging when it comes to their policy decisions. After quantifying the spread between the tones conveyed by the presidents' statements over the past two decades, it became evident that during periods of pronouncing discordance, long-term interest rates exhibit a weaker response to unexpected changes in monetary policy. Consequently, this impedes the ECB's ability to effectively influence the slope of the yield curve. (Tillmann and Walter,2018). This finding reinforces Alan Blinder's (2007, p. 114) famous statement:" A central bank that speaks with a cacophony of voices may, in effect, have no voice at all".

The impact of the tone employed by the ECB has been extensively documented in prior literature. Dossani (2019), quantified the tone as the difference between hawkish and dovish expressions during a press conference, presented as a ratio relative to the total number of phrases uttered. Notably, he found that the impact on risk premia in the currency market stems from the interactive segment, specifically the question-and-answer session, or the spontaneous part of the press conference. In particular, a one standard deviation increase in the hawkines correlates with a 1.5% reduction in the variance risk premium, a 4.9% decrease in subsequent variance swap returns, and a 0.2% elevation in option implied risk aversion. This research focuses on whether policy statements lean more towards a hawkish or dovish stance, whereas my research focuses on the use of positive and negative words irrespective of policy stance.

An additional perspective is provided by the research of Paul Hubert which indicates that the tone of the Central Bank's statements serves as a conduit for disclosing information about both the future policy path and the state of the economy. In addition, utilizing an ARCH model alongside a high-frequency methodology, their analysis reveals that a favourable central bank tone leads to an elevation in interest rates for the 1-year maturity period. This increase occurs because a positive tone signals a strong economic outlook, leading market participants to expect that the central bank may adopt tighter monetary policy in the near term to manage inflation or prevent economic overheating. Consequently, investors anticipate higher future interest rates, resulting in an immediate increase in short-term interest rates to reflect these expectations. (Hubert and Labondance,2021)

2.4 Gaps and Contributions

My research is based on the work of two previous papers. As for the first one, during their research, Schmeling and Wagner established a direct correlation between the tone of ECB communication and German bond yields. More precisely, their findings suggest that when the ECB tone becomes more positive, all bond yields increase, particularly accentuated in longer-term maturities. Conversely, a shift towards a more negative tone corresponds to a decrease in yields, particularly in shorter-term maturities (Schmeling & Wagner, 2015). In addition, after examining the spreads between Italian and Spanish bond yields with the German, they found that a more positive tone was associated with lower sovereign yield spreads.

As for the latter, Kanelis and Siklos quantified the tone employed during the Draghi era by measuring the vocal emotions during the Q&As following the monetary policy statement by implementing the Fully Convolutional Neural Network (FCN) of Garcia-Ordas et al. (2021). After looking at the four most important Eurozone economies, they found significant results for all. However, for German bonds, considered the benchmark by the financial markets, positive signals led to an increase in the yield only for bonds with a two-year duration. Similar results were found for the French yields, using the spreads, while Italian yields were negatively affected, demonstrated by the increase in the spread. (Kanelis and Siklos,2023)

I aim to expand upon their research by examining monetary policy statements during the tenures of the last three European Central Bank Presidents Jean-Claude Trichet, Mario Draghi, and Christine Lagarde. This comprehensive analysis encompasses a period spanning from 2003 to 2024. This period holds significant importance as it spans the periods preceding, during, and following the Global Financial Crisis. In addition, I investigate how the tone employed during the press releases impacts core, intermediary, and peripheral Eurozone economies. Germany and the Netherlands serve as representatives of core economies, while France and Italy are used to represent intermediary economies. For peripheral economies, Greece and Portugal are examined. This classification is based on the work of Campos and Macchiarelli, (2021).

The rationale behind examining if a different effect exists between core, intermediary, and peripheral economies comes from the research of Leombroni et al. The results indicate that core country bond yields are generally more responsive to monetary policy shocks compared to peripheral bonds, reflecting differences in perceived credit risk and market dynamics between Eurozone countries. They attribute this heterogeneous effect of communication shocks to a risk premia differential across countries. Bonds from core countries are considered low-risk and reflect monetary policy changes more directly through expected future rates. In contrast, bonds from peripheral countries face extra risks, like higher credit and redenomination risks, making them less sensitive to policy changes. This difference became clear after the financial crisis, showing that these extra risks dampened peripheral bonds' reaction to monetary policy. (Leombroni et al., 2016). Hence, my research explores whether this hypothesis holds even when considering communication tone.

3 Theoretical Framework

Central bank communication is pivotal in monetary policy implementation, influencing market expectations and financial stability. According to the Rational Expectations Hypothesis (Muth, 1961), market participants form expectations about economic conditions and policy actions based on available information, including central bank communications. Effective communication by central banks, such as the ECB, can stabilize markets by guiding these expectations (Blinder et al., 2008). Positive tones in

ECB statements are likely to boost confidence, leading to higher bond yields in anticipation of economic strengthening or rate hikes, while negative tones may lower yields by signalling caution or economic concerns.

Research by Hubert and Labondance (2021) underscores that the tone of central bank statements serves as a signal for future policy directions and economic conditions, indicating how central bank communication can shape market expectations. Complementing this, Leombroni et al. (2018) provide evidence that such communication shocks influence market beliefs about future interest rates, which in turn affect bond yields. Their study finds that bond yields in core Eurozone countries are generally more responsive to these communication-induced expectations compared to peripheral countries, due to variations in perceived credit risk and market dynamics. This connection between the perceived future policy implications of central bank tone and the resultant impact on bond yields highlights the need to explore whether similar patterns emerge in response to ECB communication tone across different economic clusters within the Eurozone.

Therefore, this theoretical framework establishes the basis for analysing how ECB communication tone differentially impacts bond yields in core, intermediary, and peripheral economies, leading to the formulation of the following hypotheses:

Hypothesis 1: The tone used during ECB press conferences is associated with significant changes in sovereign bond yields.

Hypothesis 2: The tone used during ECB Press Conferences has disparate effects on core, intermediary, and peripheral Eurozone members.

4 Data

To test the Hypothesis, this research leverages the Monetary Policy press releases issued by the Central Bank, typically conducted approximately every six weeks, spanning the extensive timeframe from 2003 to 2024. These critical data points are conveniently accessible on the European Central Bank's official website and will serve as the primary source to measure the tone conveyed through these releases.

Moreover, the primary focus of the research is on analysing the effect of Central Bank communication on bond yields. To achieve this, Dutch and German bonds, widely recognized as a benchmark in the Eurozone, are utilized as the primary instruments of analysis. Additionally, French, Italian, Portuguese and Greek bond yields are considered, with particular attention given to the yield spread. The selection of 10-year bonds is motivated by their heightened sensitivity to changes in interest rates. This is because longer-duration bonds have higher interest rate risk and exhibit greater price changes for a given change in interest rates making them significantly valuable for understanding broader economic and policy shifts, as indicated by Bodie et al. (2018). These data were retrieved from the reputable financial website, investing.com, ensuring reliability and consistency in the analysis.

For the control variables in this research, economic indicators such as inflation, unemployment, and GDP growth rates were sourced from the International Monetary Fund's (IMF) official database. ECB policy decisions, including the deposit facility rate, the marginal lending rate, and the minimum bid/fixed rate, were obtained from the ECB's data portal on their official website.

5 Methodology

5.1 Quantifying Central Bank Tone with Dictionary Methods

The European Central Bank (ECB) convenes its regular monetary policy meetings on Thursdays, with the interest rate announcement typically made at 13:45 CET. The policy statement released at that specific time generally offers limited supplementary information beyond the actual interest rate decision. Following this, the press conference commences at 14:30 CET. The statements during this press release serve as a key gauge of central bank sentiment for several reasons. As they contain monetary policy decisions, offering a thorough analysis of the economic conditions and the rationale behind these decisions, they command the attention of financial markets, media, economists, and banks, ensuring widespread dissemination. Policy announcements and decisions are made during European trading hours, promptly observed by market participants, facilitating immediate responses to fresh data. In

addition, these statements are meticulously crafted, representing deliberate communication rather than inadvertent errors. In contrast to speeches or interviews, which may contain mixed messages, central bank statements are a focused instrument for policymakers to articulate their stance clearly. (Hubert et al,2019)

After obtaining these texts, one challenge of this research is to convert raw policy statements and manage to quantify the tone employed by the European Central Bank president by translating this into data that can be systemically examined. Advancements in technology, particularly in machine learning algorithms, have greatly enhanced our ability to manage large, unstructured text databases by effectively quantifying their tone. These tools allow us to analyse and interpret the sentiment and nuances in central bank communications, providing valuable insights into their impact on financial markets. To do that, I use the dictionary and rule-based sentiment analysis tool in Python programming language called VADER (Valence Aware Dictionary and Sentiment Reasoner). VADER quantifies the textual tone by employing a lexicon-based approach, reinforced by algorithms and guiding principles for gauging sentiment polarity. This lexicon was chosen over tools like LIWC or TextBlob because of its rule-based approach, which is well-suited for capturing sentiment in financial communications. Its ability to handle negations, contractions, and emphasis is particularly useful for analysing the nuanced language used in ECB press releases.

VADER operates through a structured process. It begins by utilizing a pre-built lexicon containing sentiment scores for individual words. Each word within this lexicon is assigned a sentiment polarity score ranging from -1 to +1, signifying the spectrum from negativity to positivity associated with the word. Upon analysing the text, VADER breaks it down into discrete sentences. It subsequently aggregates the sentiment scores of each word in the sentence to compute an overall sentiment polarity score for that sentence. VADER further refines these sentiment polarity scores by taking into consideration various linguistic and grammatical rules. For instance, it considers the effect of intensifiers, degree modifiers, and negations on the sentiment conveyed within the sentence.

Following the computation of sentiment polarity scores for each sentence, VADER aggregates these scores to derive an overall sentiment polarity score for the entire text.

This composite score provides a quantitative measure of the overall sentiment expressed within the text. In addition, the library computes a compound score, serving as a holistic representation of the overall sentiment intensity of the text. Overall, this score considers the normalized sentiment polarity scores of individual sentences and provides a singular metric for assessing the sentiment of the entire text. The compound score ranges from -1 (indicating extreme negativity) to +1 (signifying extreme positivity).

Having said all that., the tone is computed as:

$$Tone_t = \frac{Positive\ Words_t - Negative\ Words_t}{Positive\ Words_t + Negative\ Words_t}$$

Equation 1: Tone

5.2 Effect on Bond Yields

To measure the impact of the tone employed by the European Central Bank President during press releases, an event study approach is adopted, consistent with prevailing literature. This methodology focuses on assessing the immediate effects within a short event window surrounding the policy announcement. Akin, to other literature, I am measuring the effect utilizing daily data. aligning with the findings of Hubert and Labondance (2021), which suggest that the impact of ECB tone changes persists throughout the whole trading day, not just around the press conference. Keeping that in mind, the event window used for this research will be from the closing price on the day before the event to the day on which the monetary policy communication event takes place.

Dutch and German 10-year bond yields serve as representatives of core Eurozone economies. For intermediary countries, the analysis focuses on the spreads between French and Italian bonds relative to German bonds, which are considered the benchmark in the Eurozone. Greek and Portuguese bond spreads relative to German bonds are used to represent peripheral economies. This analysis covers the presidencies of Jean-Claude Trichet, Mario Draghi, and the current president, Christine Lagarde.

Additionally, for Germany and France, where data were available, the effect on 1-year government bonds was also examined.

To calculate the yield spreads, I subtracted the yields of France, Italy, Greece and Portugal from the yields of German bonds with identical duration. This is demonstrated in equation 2.

$$spread^c = yield^c - yield^{DE} \quad \text{, with C} \in \{\text{F R, IT, GR, PT}\}$$

Equation 2: Bond Spread

Using those, I will be looking at the difference in the bond yields between the beginning and the end of the event window to determine whether a significant event is in place.

To assess the effects, the literature relies on the following regression:

$$\Delta y_t = \alpha + \beta_1 x_t + \varepsilon_t$$

Equation 3

In this context, x_t refers to the Central Bank's tone, Δy_t" signifies the fluctuation in bond yields observed during a period surrounding the monetary policy announcement, and "ε_t" represents a random error term encompassing various external factors impacting the bond in focus.

Thus, for the purpose of this research, the regression that will be employed is:

$$\Delta Yield_{it} = \alpha + \beta_1 Tone_t + \beta_2 Inflation_t + \beta_3 GDP\ Growth_t + \beta_4 Unemployment_t + \beta_5 MRO_t + \beta_6 MLF_t + \beta_7 DF_t + \epsilon_t$$

Equation 4: Bond Yields

Where:

- $\Delta Yield_{it}$ refers to the change in bond yields for Germany and the Netherlands, and the change in yield spreads for France, Italy, Portugal and Greece.
- $Tone_t$ refers to the computed tone employed by the European Central Bank during the monetary policy press releases.

- Inflation, GDP Growth, Unemployment rate, Deposit Facility rate (DF), the Marginal Lending Rate (MLF), and the Minimum Bid/Fixed rate (MRO) are used as control variables.

The selection of control variables was inspired by the work of Linas Jurkšas et al. (2024), who used various controls to account for global market uncertainty and macroeconomic data releases. Inflation Rate and GDP Growth Rate are fundamental indicators of economic health; inflation impacts bond yields as investors demand compensation for future price increases, while GDP growth reflects the broader economic conditions that influence interest rates and yields. These variables capture the essential macroeconomic environment affecting bond markets. The Unemployment Rate provides additional context by indicating economic slack, which influences monetary policy responses and, consequently, bond yields.

To account for monetary policy influences, the Deposit Facility Rate (DF), Marginal Lending Rate (MLF), and Minimum Bid Rate (MRO) were included. These rates are crucial tools used by the ECB to manage liquidity and control short-term interest rates, directly affecting the yield curve and financial conditions within the Eurozone. Controlling for these variables enables the analysis to isolate the impact of the ECB's communication tone on bond yields, independent of underlying economic conditions and policy interventions.

5.3 Addressing Potential Endogeneity and Heteroskedasticity

To determine if Central Bank tone influences bond yields, an important empirical challenge must be addressed: the potential endogeneity of the central bank tone in relation to the business cycle or financial stress. Hubert and Labondance (2020) note in their research that central bank statements often adopt a more negative tone during periods of recession or financial distress. To mitigate endogeneity bias, I identify central bank tone shocks orthogonal to key economic indicators such as unemployment, inflation rates, and GDP growth, employing a method inspired by their approach. The tone is calculated using the following autoregressive model:

$$Tone_t = \alpha + \beta_1 Tone_{t-1} + \beta_2 Economic\ Indicators_{t-1} + \epsilon_{Tone,t}$$

Equation 5 : Tone

Where $\epsilon_{Tone,t}$ represents the residuals that capture unexpected central bank tone shocks. The lagged tone reflects the tone of the previous ECB monetary policy press release. The lagged economic indicators include the unemployment rate, GDP growth, and inflation rate.

Besides addressing endogeneity, another key challenge is managing the changing variance of the dependent variable over time, which is typical of financial data. To handle this heteroskedasticity and the resulting "volatility clustering," an ARCH (autoregressive conditional heteroskedasticity) model is used.

The regression for the ARCH model is as follows:

$$\Delta y_t = \alpha + \beta_1 \varepsilon_{\{Tone,t\}} + \beta_2 Inflation_t + \beta_3 GDP\ Growth_t + \beta_4 Unemployment_t + \beta_5 MRO_t + \beta_6 MLF_t + \beta_7 DF_t + \varepsilon_t$$

$$\sigma_t^2 = \gamma_0 + \sum_{\{i=1\}}^{p} \gamma_i \epsilon_{\{t-i\}}^2$$

Equation 6: ARCH Model

Where $\varepsilon_{\{Tone,t\}}$ is the central bank tone shock estimated in equation and control variables remain the same as equation 4. The control variables include inflation, GDP growth, unemployment, and various monetary policy rates like the Deposit Facility rate (DF), the Marginal Lending Rate (MLF), and the Minimum Bid/Fixed rate (MRO).

6. Results and Interpretation

6.1 Sentiment Tone Analysis

Having acquired the sentiment tone employed by the last three ECB Presidents, it is important to delve into these in greater detail. Analysing them through various lenses will provide insights into how each president's communications have been perceived and help identify periods of high and low market confidence. Examining these results is also essential to reveal the impact of external events, policy changes and to observe

recurring seasonal patterns and long-term trends. Following that, the sentiment tone is utilized in this research to assess the stability of market reactions to ECB communications, specifically by looking into their effect on the bond yields. These insights can guide future policy decisions, refine market forecasts, and enhance economic analyses.

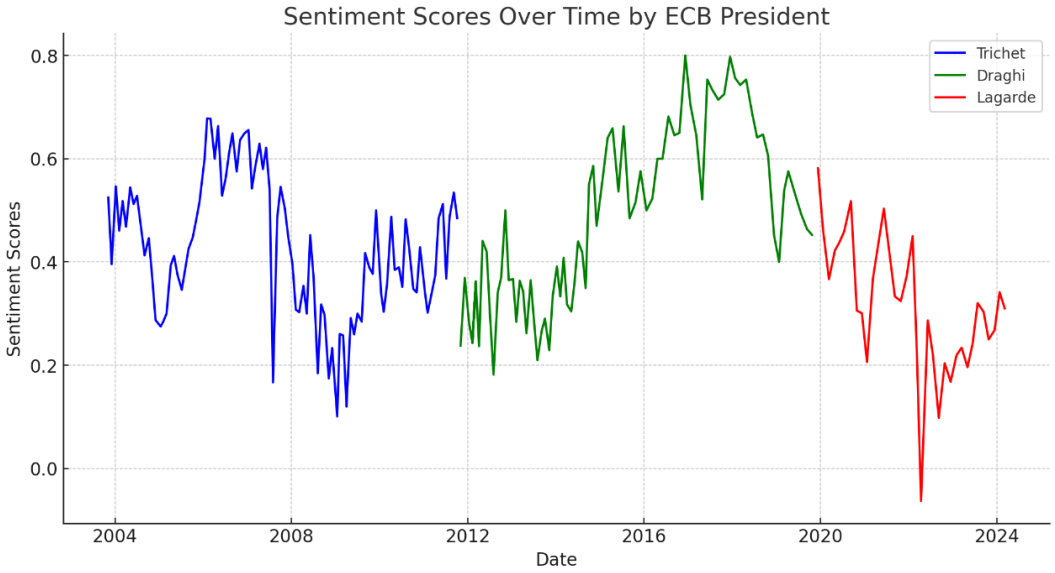

Figure 1: Sentiment Tone

Figure 1, which contains two columns—date and sentiment scores—is designed to visualize sentiment trends over time and across the tenures of the last three ECB Presidents. This visualization aims to highlight how sentiment has evolved, enabling a clearer comparison of how different presidents' communications have been perceived.

6.1.1 Descriptive Statistics and Comparative Analysis

Statistics	Overall	Trichet	Draghi	Lagarde
Count	208	94	79	35
Mean	0.428	0.427	0.478	0.317
Std Dev	0.156	0.133	0.167	0.129
Min	-0.063	0.101	0.182	-0.063
Max	0.800	0.678	0.800	0.581

Table 1: Descriptive Statistics

These statistics provide a comprehensive overview of the central tendency and variability of sentiment tone across the tenure of each ECB president. The overall mean

sentiment score of 0.428 suggests a generally moderately positive sentiment throughout the period, accompanied by moderate variability, as reflected by a standard deviation of 0.156. This indicates that while there are fluctuations in the tone employed, they are not excessively pronounced. Additionally, over this 20-year period, the tone employed during each president's term varied significantly, ranging from -0.063 to 0.800. This wide range underscores the diverse responses to ECB communications and highlights the substantial influence that economic conditions and policy changes had on sentiment scores.

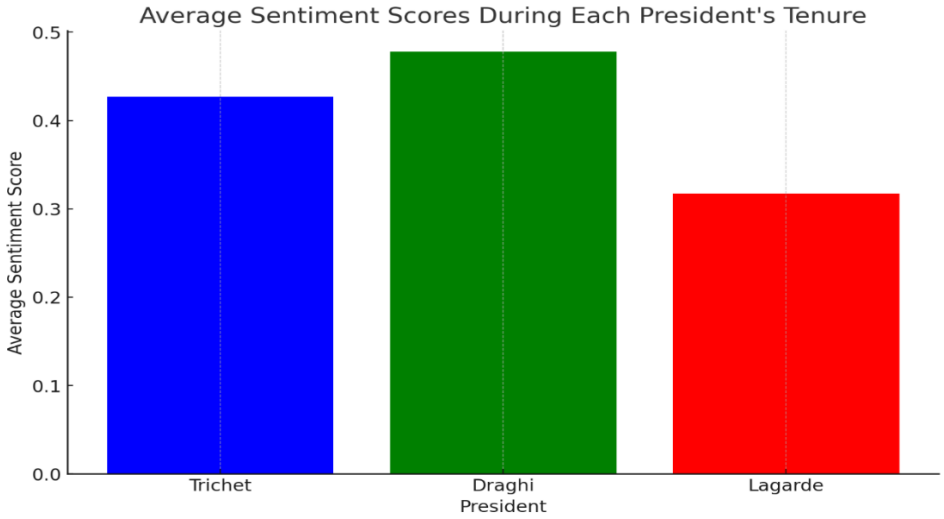

Figure 2: Average Tone

When comparing different presidents, as observed in Figure 2, Christine Lagarde has the lowest average sentiment score, despite her tenure being the shortest among the three. Her average sentiment is almost half that of her predecessor's. This trend is notable as Lagarde's tenure has been marked by numerous crises, significantly worsening economic conditions and necessitating decisive actions from the ECB president. Key challenges during her term included the COVID-19 pandemic, the energy crisis, and soaring inflation. These overlapping crises likely contribute to the lower average sentiment score, with 2022 showing the only instance of negative sentiment across the period analysed. This period coincides with the onset of the war in Ukraine, which sent shockwaves globally. Interestingly, despite these challenges, Lagarde's tenure exhibits a lower standard deviation in sentiment (0.1289), indicating relatively stable but consistently lower sentiments. This reflects the persistent negative context during her presidency, albeit with less volatility compared to her predecessors.

Mario Draghi, who served as president for eight years, from November 2011 to October 2019, maintained the highest average sentiment tone despite the financial instabilities and turbulent economic conditions. His presidency is characterized by the introduction of unconventional monetary policies such as quantitative easing, which played a crucial role in stabilizing the Eurozone. Initially, his term was marked by significant economic challenges, but these were followed by a recovery phase during which market confidence was restored, and inflation stabilized. With an average sentiment score of 0.478 and a standard deviation of 0.167, Draghi's tenure stands out for having the highest sentiment score among his peers, accompanied by relatively high volatility. This indicates a period characterized by positive sentiment overall but with considerable fluctuations, reflecting the economic uncertainty and subsequent recovery efforts.

During Jean-Claude Trichet's tenure, the mean sentiment tone was slightly lower than Draghi's, yet they were overall comparable. As illustrated in Figure 1 Trichet's presidency exhibited significant fluctuations in tone, but with fewer extreme values, indicating higher variability. This variability suggests that sentiment scores were not as stable, with notable fluctuations rather than a consistent tone, reflecting the turbulent economic environment leading up to the crisis. A noteworthy factor to consider is the change in the frequency of ECB Governing Council meetings and press releases. As of January 2015, these meetings switched from a monthly to a six-week cycle, reducing the opportunities for public addresses. Consequently, Trichet, who served prior to this change, had more frequent occasions to communicate with the public compared to his successors.

6.1.2 Trend Analysis Using Rolling Averages

To better understand long-term patterns in sentiment and reduce short-term volatility, I performed a trend analysis using 3-month and 6-month rolling averages. This technique, known as moving averages in statistical circles, is widely used by the financial community in business management. It involves calculating the average of values within a specified timeframe that "rolls" or "moves" through the data series. For instance, to compute a 12-month rolling average of expenditure, the value for February 2005 would be the average of the monthly expenditures from March 2004 through

February 2005. This method smooths out short-term fluctuations and highlights underlying trends, providing a clearer view of sentiment changes over time.

Rolling averages are valuable tools for indicating overall trends in sentiment whether it is improving, declining, or remaining stable over extended periods. This approach is particularly useful for understanding the long-term impact of policy changes and external events on sentiment. By smoothing out short-term fluctuations and revealing underlying trends, rolling averages enhance economic forecasting and planning. This can support better decision-making for policymakers, analysts, and investors, providing a clearer picture of sentiment dynamics and aiding in strategic assessments and responses.

For the sentiment scores, a 3-month rolling average is used to closely follow the sentiment dynamics and smooth out minor fluctuations, while the 6-month rolling average provides a clearer view of long-term trends by further smoothing the data. These specific intervals are chosen because central banks, including the ECB, typically evaluate policies on a quarterly or semi-annual basis. Thus, using 3-month and 6-month rolling averages aligns well with these evaluation periods, making them particularly effective for highlighting trends relevant to policy assessment and analysis.

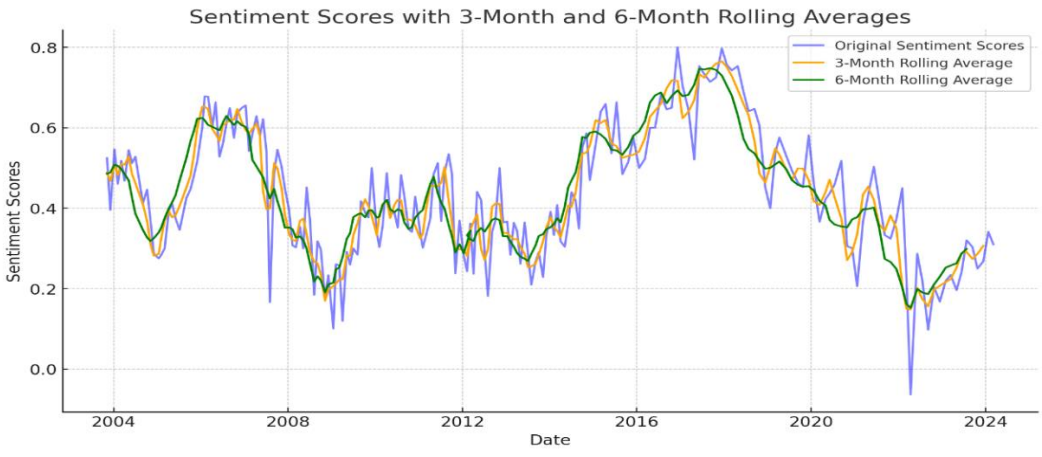

Figure 3: Rolling Averages

The findings from the rolling averages reveal several significant trends. Both the 3-month and 6-month rolling averages indicate an upward trend from mid-2004 to mid-2007, signalling a period of prosperity and economic growth leading up to the Global Financial Crisis in 2008. In late 2014, another positive trend emerges during the

recovery period following the crisis, reflecting favourable sentiment towards the ECB's policies at the time. Conversely, the financial crisis in 2008 is marked by a pronounced downward trend, underscoring the financial instability and monetary unpredictability of those years. A similar downward trend is observed in 2018, likely connected to economic challenges within the Eurozone during that period.

Recovery periods, in general, exhibit considerable fluctuations. This is particularly evident in the post-2008 crisis phase, where the volatility in sentiment mirrors the markets' adjustment to new ECB policies and changing economic conditions. Similarly, at the onset of the COVID-19 pandemic in early 2020, an initial decline in sentiment is followed by significant fluctuations as markets respond to policy measures and economic stimuli aimed at recovery. These trends demonstrate how rolling averages effectively highlight periods of both growth and stability as well as times of financial distress and recovery, offering valuable insights into the impact of ECB policies and external economic events.

Examining the rolling averages across different presidential tenures reveals distinct patterns in sentiment. During Jean-Claude Trichet's presidency, the rolling averages exhibit significant fluctuations. Initially, there is an upward trend reflecting favourable economic conditions, but this is quickly overshadowed by a pronounced downward trend, capturing the onset of the Global Financial Crisis and the ensuing financial instability. Mario Draghi's tenure is characterized by notable volatility in the rolling averages, indicative of mixed market reactions to his unconventional monetary policies. Despite this volatility, there is an overall upward trend, reflecting a gradual improvement in sentiment as his policies began to stabilize the Eurozone economy. Christine Lagarde's tenure begins with high volatility due to the COVID-19 pandemic, evidenced by a sharp downward trend in early 2020. This initial negative sentiment is followed by moderate fluctuations and a gradual upward trend from mid-2021 onwards, signalling a more positive tone sentiment as recovery efforts take hold and economic conditions begin to stabilize.

6.2 Effect of Tone on Bond Yields

To address the main hypothesis of this research, an event study approach is employed, providing valuable insights into the effects on core, intermediary, and peripheral economies' government bonds. For this analysis, I consider the entire period as a single timeframe, avoiding distinctions between different presidencies. This approach ensures a sufficient sample size for reliable, unbiased results.

Variables	Germany	Netherlands	France	Italy	Portugal	Greece	Germany 1y	France 1y
Constant	0.0102 (2.56)	0.0103 (2.53)	0.0308 (2.519)	0.038 (3.21)	0.0336 (2.74)	0.0363 (2.41)	0.0096 (2.40)	0.0312 (2.57)
Tone	0.0857 (2.46)	0.0804 (2.30)	-0.1457 (-2.90)	-0.1532 (-2.82)	-0.1509 (-2.87)	-0.2639 (-2.94)	0.0841 (2.41)	-0.1226 (-2.38)
Inflation	0.0618 (3.74)	0.0610 (3.73)	0.0761 (4.32)	0.0775 (4.28)	0.0763 (4.32)	0.0995 (2.60)	0.0598 (3.73)	0.0725 (4.18)
GDP growth	-0.0202 (-1.83)	-0.0210 (-1.90)	-0.0193 (-2.14)	-0.0198 (-2.71)	-0.0182 (-2.06)	0.0353 (1.35)	-0.0199 (-1.83)	-0.0192 (-2.09)
Unemployment	0.0331 (3.78)	0.0336 (3.77)	-0.0184 (-2.14)	-0.0189 (-2.12)	-0.0176 (-2.05)	-0.0141 (-0.71)	0.0328 (3.72)	-0.0178 (-2.07)
MRO	0.0014 (1.85)	0.0014 (1.84)	0.0007 (1.21)	0.0008 (1.36)	0.0007 (1.21)	0.0005 (0.49)	0.0013 (1.72)	0.0008 (1.21)
MLF	0.0014 (2.42)	0.0015 (2.45)	-0.0015 (-1.75)	-0.0014 (-1.69)	-0.0015 (-1.73)	-0.0011 (-1.00)	0.0014 (2.42)	-0.0014 (-1.69)
DF	-0.0025 (-2.30)	-0.0024 (-2.29)	-0.0025 (-2.34)	-0.0027 (-2.42)	-0.0025 (-2.37)	-0.0036 (-3.06)	-0.0025 (-2.29)	-0.0023 (-2.27)

Table 2: Event Study Results

To begin, I investigate whether the interplay of sentiment tone influenced the yield on German government bonds, widely considered as a benchmark within the euro area. The analysis revealed a significant positive relationship between the tone employed by the ECB president and German bond yields. Specifically, if the tone increases by one unit, the yield increases by 0.0857 units, holding other factors constant. This suggests that market participants interpret an optimistic ECB tone as an indicator of potential future interest rate hikes or improved economic conditions.

Similar results were found for the Netherlands, where a positive ECB tone also leads to a significant increase in bond yields, indicating that the effect of optimistic ECB communication extends across core Eurozone countries. This effect persists even when accounting for macroeconomic conditions and ECB policy rates, both of which also significantly impact yields. These findings highlight the pivotal role of the ECB tone in shaping market expectations beyond traditional economic indicators.

For intermediary countries, the analysis of 10-year bond yields reveals that a more positive tone from the ECB is associated with a narrowing of French bond spreads relative to German yields. This suggests that optimistic ECB communication improves France's perceived creditworthiness or reduces perceived risk, leading investors to demand lower risk premiums. As a result, French bond yields decrease relative to German yields, reflecting a reduction in the yield spread. Comparable effects are observed in Italy, where positive ECB sentiment similarly reduces perceived risk and narrows yield spreads. This pattern indicates that favourable ECB communication enhances investor confidence in these intermediary economies, leading to more favourable bond yield dynamics.

Shifting the focus to the peripheral economies of the Eurozone, specifically Greece and Portugal, the results exhibit similarities to those observed in the intermediary economies. In Greece, the analysis reveals that a more positive ECB tone significantly narrows the spread between Greek and German bond yields. More precisely, if the tone increases by one unit, the spread decrease by 0.2649 units, holding other factors constant. It is important to note that the effects of macroeconomic variables and ECB rates, although significant, showed greater variability in Greece compared to other countries. This variability highlights Greece's unique economic challenges and its heightened sensitivity to both internal and external economic factors, which can influence bond yields and spreads in complex ways.

When examining 1-year bonds for Germany and France, the results remained consistent, with no notable change in the coefficients. This highlights that the observed effects are uniform across different bond durations, suggesting that the impact of ECB tone on bond yields is robust and not significantly influenced by the maturity of the bonds. This consistency across maturities could imply that investors' reactions to ECB communication are equally strong for both short-term and longer-term securities, reflecting a broad-based influence of sentiment on market expectations.

Since the spread for the four government bonds (France, Italy, Portugal, and Greece) is calculated as the difference between their yields and the yield of German bonds, a decrease in this spread, combined with a positive coefficient for German bonds, indicates that yields for the peripheral and intermediary economies are decreasing

relative to German yields. Specifically, a more positive ECB tone leads to an increase in German bond yields. Consequently, the narrowing of the spread reflects a relative decrease in the yields of bonds from these peripheral and intermediary economies. This finding confirms that the positive coefficient for German bond yields is critical for understanding the dynamics of the spread.

One reason for this result is highlighted by recent statistics published by Statista, which reveal that Greece, Italy, and France rank highest in government debt relative to gross domestic product (GDP), with Portugal also ranking among the top six. Specifically, Greece has the highest debt ratio at 165.5% of GDP, followed by Italy at 140.6%, France at 111.9%, and Portugal at 107.5%. This aligns with findings by Jurkšas et al. (2022), who observed that countries with the highest debt levels, such as Italy, Spain, and France, experienced the most significant changes in fiscal costs due to ECB communication events. In contrast, the German bund market, characterized by lower debt levels, appeared to be less affected.

This reasoning helps explain the varying coefficients found in my study. Core economies, such as Germany and the Netherlands, with relatively low debt levels, show the smallest impact from the ECB's monetary policy communication tone on their bond yields, with coefficients both less than 0.09. In contrast, Greece, with the highest debt levels, has a coefficient of -0.2639, almost three times the effect observed in core economies. This indicates that countries with higher debt levels are more sensitive to ECB communications, as their economic stability and fiscal costs are more directly influenced by perceived changes in policy tone.

It is crucial to note that while the coefficients for non-core countries are negative, reflecting a narrowing of the yield spreads relative to German bonds, their magnitudes vary significantly. For example, France has a coefficient of -0.1307, indicating a modest reduction in the spread between French and German bond yields due to positive ECB tone. Conversely, Greece's coefficient is nearly double, indicating a more pronounced narrowing of the spread. This larger coefficient for Greece can be attributed to its high debt levels and ongoing struggles to recover from the global financial crisis, which continue to impact its economic stability. These differing magnitudes suggest that a

positive ECB tone uniformly reduces bond spreads in non-core countries but has a more substantial effect in economies with higher residual vulnerabilities, such as Greece.

Variables	Germany	Netherlands	France	Italy	Portugal	Greece	Germany 1y	France 1y
Constant	0.0101 (2.02)	0.0099 (1.99)	0.0307 (2.54)	0.0376 (3.14)	0.0334 (2.70)	0.0346 (2.32)	0.0093 (2.31)	0.0297 (2.47)
Tone	0.0735 (2.37)	0.0737 (2.32)	-0.1402 (-2.81)	-0.1453 (-2.85)	-0.1399 (-2.74)	-0.2410 (-2.77)	0.0739 (2.38)	-0.1292 (-2.52)
Inflation	0.0582 (3.24)	0.0574 (3.253)	0.0736 (4.16)	0.0750 (4.19)	0.0740 (4.19)	0.0931 (2.52)	0.0568 (3.21)	0.0698 (4.00)
GDP growth	-0.0185 (-1.85)	-0.0183 (-1.845)	-0.0187 (-2.11)	-0.0189 (-2.08)	-0.0182 (-2.03)	0.0324 (1.32)	-0.0186 (-1.85)	-0.0174 (-2.01)
Unemployment	0.0312 (3.20)	0.0311 (3.11)	-0.0173 (-2.05)	-0.0180 (-2.07)	-0.0176 (-2.04)	-0.0134 (-0.68)	0.0310 (3.16)	-0.0172 (-2.01)
MRO	0.0013 (1.81)	0.0013 (1.85)	0.0008 (1.24)	0.0008 (1.24)	0.0008 (1.26)	0.0006 (0.56)	0.0014 (1.86)	0.0007 (1.22)
MLF	0.0013 (2.05)	0.0014 (2.07)	-0.0014 (-1.68)	-0.0015 (-1.69)	-0.0014 (-1.66)	-0.0011 (-1.00)	0.0014 (2.10)	-0.0014 (-1.67)
DF	-0.0024 (-2.223)	-0.0024 (-2.22)	-0.0025 (-2.29)	-0.0025 (-2.31)	-0.0024 (-2.38)	-0.0035 (-2.96)	-0.0024 (-2.26)	-0.0023 (-2.24)
Constant ARCH	0.0002 (2.34)	0.0002 (2.33)	0.0002 (2.32)	0.0002 (2.30)	0.0002 (2.31)	0.0002 (2.311)	0.0002 (2.32)	0.0002 (2.277)
ARCH[1]	0.1772 (4.035)	0.1710 (3.882)	0.1750 (3.97)	0.1723 (3.91)	0.1735 (3.96)	0.1621 (3.66)	0.1702 (3.86)	0.1680 (3.81)

Table 3: Results Arch Model

Applying the ARCH model to analyse bond yield volatility confirms the findings from the previous model, revealing consistent patterns across countries. For each country, approximately 17% of the variance in the current period is attributed to the square of the residuals (unexpected movements) from the previous period. This consistency indicates a moderate level of volatility persistence within these bond markets. Shocks to the bond yield or spread volatility have a noticeable but not overwhelming effect on the volatility of the next period.

The results of my research largely align with previous findings in the literature. For instance, Kanelis and Siklos (2023) as well as Schmeling and Wagner (2024) found similar effects regarding German government bond yields: a positive signal in the tone used by the ECB president leads to an increase in these yields, mirroring my findings. Likewise, both studies observed a negative relationship with Italian bond yields, where a more optimistic ECB tone narrows the spread relative to German yields, consistent with my analysis. However, a notable difference arises with French bond yields. Kanelis and Siklos reported that French yields are positively affected by a more optimistic tone, whereas my research indicates the opposite effect when examining the spread. This

discrepancy may be attributable to specific limitations of my study, which will be discussed further in the subsequent sections.

These findings underscore the significant influence of the ECB's communication tone on market expectations, affecting bond yields independently of traditional economic indicators. This illustrates how the tone of ECB statements can shape market perceptions and reactions, emphasizing its critical role in monetary policy communication. The impact of tone extends beyond conventional metrics, highlighting its importance in guiding investor behaviour and shaping financial outcomes.

6.3 Robustness Check

To verify the reliability and stability of the empirical results obtained from the statistical models, I conducted robustness checks. This step ensures that the findings are not influenced by specific model specifications, time periods, or outlier influences. For this research, I performed two types of robustness checks: Alternative Specifications and Subsample Analysis.

The Alternative Specifications robustness check assesses whether the results remain consistent when different sets of control variables are included. This determines if the observed effects of tone on bond yields and spreads are robust to changes in model specifications. The first set includes a minimal model that examines the direct effect of tone on bond yields without confounding variables. The second set includes the tone along with economic indicators such as inflation, GDP growth, and unemployment. The third set includes the tone and policy decisions, specifically refinancing operations (MRO), marginal lending facility (MLF), and deposit facility (DF) rates.

The Subsample Analysis tests the stability of the relationship between tone and bond yields/spreads over different time periods. This analysis examines whether the results are driven by specific periods or are consistently observed over time. I focus on the pre-2015 and post-2015 periods to capture changes in economic and policy environments.

The results indicate that the findings are consistent across different model specifications and stable over time for both the original tone model and the ARCH model. This consistency in tone coefficients, both in direction and significance, across various control variables and periods, supports the robustness of the effect of central bank tone

on bond markets. It demonstrates that the observed relationships are not sensitive to changes in model specification or period, thereby enhancing the credibility of the original analysis and confirming that central bank tone plays a significant role in influencing bond market dynamics. The complete results are available in the Appendix.

7. Discussion and Conclusion

7.1 Discussion

My research stands out by examining the tenures of Jean-Claude Trichet, Mario Draghi, and Christine Lagarde, covering a significant period from 2003 to 2024. Unlike earlier studies that focused on specific time periods or individual ECB presidents, this work spans major economic events like the Global Financial Crisis, the European sovereign debt crisis, the COVID-19 pandemic, and the recent energy and inflation crises. This broad timeframe allows for a thorough analysis of how ECB communication tone has evolved and impacted the economy across different phases.

Addressing these varied periods, my purpose was to highlight the resilience and adaptability of ECB communication strategies in response to shifting economic challenges. For instance, during Draghi's presidency, a positive communication tone played a significant role in boosting market confidence during the post-crisis recovery period. In contrast, Lagarde's tenure, marked by overlapping crises, resulted in a more restrained tone, illustrating how surrounding circumstances influence the impact of tone.

Additionally, previous research has typically concentrated on core economies such as Germany. This study broadens the scope by including intermediary economies (France and Italy) and peripheral economies (Greece and Portugal). The findings reveal that ECB tone affects bond yields and spreads across this wider range of Eurozone countries. Specifically, a positive ECB tone tends to narrow yield spreads in intermediary and peripheral economies, suggesting a harmonization of market perceptions and risk assessments across diverse economic clusters within the Eurozone.

Unlike Dossani (2019), who focused on the hawkish-dovish dichotomy, this study employs the VADER sentiment analysis tool to quantify the ECB's communication

tone, providing a systematic approach to measuring sentiment in central bank communication. This methodological advancement allows for a more precise and replicable assessment of tone, enhancing the robustness of findings compared to more subjective or qualitative analyses. The use of a compound sentiment score, which integrates various linguistic nuances, offers a more comprehensive view of how ECB communications are perceived by the market.

There is still room for more research to be conducted. While the impact of central bank tone on different economic variables, like interest rates, bond yields and stock prices has been widely explored by past literature, expanding the methods used to measure tone could be fruitful. One promising direction would be to include non-verbal communication in the analysis. For instance, examining video or voice sentiment to assess facial expressions, body language, or voice tone could provide additional insights. These elements play a crucial role in communication and could offer a more comprehensive view of how they complement or differ from the verbal content in ECB communications.

The Q&A sessions following the monetary policy press releases of central banks also have the potential to provide additional insights into the tone and market reactions. Unlike prepared statements, Q&A sessions provide unscripted and spontaneous insights into the ECB's views, policy intentions, and economic assessments. These interactions can reveal nuances and clarifications that are not captured in the formal press release. Additionally, developing a central bank-specific lexicon could significantly improve the accuracy and relevance of the sentiment analysis by including words and phrases that are particularly meaningful in the context of monetary policy, financial stability, and economic outlook.

7.2 Implications and Limitations

The findings of this study hold substantial implications for policymakers, investors, and financial institutions. The results demonstrate how the tone of ECB communications influences market perceptions and sovereign bond yields. This underscores the critical importance of carefully crafting ECB messages. Policymakers can leverage these insights to develop more effective communication strategies, tailoring their messages to achieve specific economic outcomes, such as market stabilization or guiding investor

expectations. These findings highlight the need for deliberate and strategic communication to enhance economic stability and optimize financial market responses.

By understanding how the tone of ECB communications differentially impacts core, intermediary, and peripheral economies, policymakers can craft economic policies that harness this stabilizing effect to promote economic convergence and stability across the Eurozone. This research suggests that policymakers can enhance their communication by focusing on clarity and strategically managing their tone. Effective communication can bolster public and investor confidence, especially during times of economic uncertainty or policy shifts. This approach is crucial for maintaining financial stability and building investor trust. By implementing tailored communication strategies, policymakers can help mitigate financial disparities and foster greater economic cohesion throughout the Eurozone.

A notable example is Mario Draghi's landmark 'Whatever it takes' speech on July 26, 2012. This speech marked a pivotal moment for European bond markets and economic stability across the Eurozone. Draghi assured investors of the European Central Bank's commitment to do whatever was necessary to preserve the euro, leading to a rapid improvement in market sentiment. Following this, the ECB's tone became increasingly optimistic, contributing to the stabilization and recovery of European markets in the post-crisis period.

Investors and financial institutions can also greatly benefit from understanding the impact of the ECB tone on bond yields. By incorporating sentiment analysis of central bank communications into their investment strategies, they can anticipate bond yield movements based on the insights from this research, leading to more informed decision-making. Additionally, these insights can enhance their ability to manage investment risks. By predicting how changes in tone might affect bond yields, they can implement effective risk mitigation strategies, such as adjusting their exposure to different Eurozone economies or hedging against potential yield fluctuations. This approach can result in more robust hedging strategies and improved resilience to market volatility influenced by central bank communications.

As with any empirical study, my research has certain limitations that should be noted. Firstly, the analysis of bond yields was based on intraday data, with the event window

starting from the closing price the day before the event and ending at the closing price on the event day. While this approach captures the daily impact, some studies focus on the immediate effects within the first 15 minutes to 1 hour after the event, potentially revealing different short-term reactions.

Another limitation is the incomplete bond yield data across all durations. Over the 20 years studied, not all countries consistently issued bonds of every duration, which restricted the analysis primarily to 10-year bonds. Although this provides a consistent basis for comparison, it would have been beneficial to examine the impact on a wider range of bond durations, as countries frequently issued bonds of various maturities. Including diverse bond durations could provide a more comprehensive understanding of the ECB tone's effect across the yield curve, rather than focusing solely on the available data for 1-year German and French bonds.

7.3 Conclusion

In conclusion, by using VADER, a sentiment analysis tool in Python, I successfully quantified the tone employed by the last three European Central Bank presidents throughout their tenure. This analysis, combined with an event study approach, allowed me to examine the impact on bond yields across core, intermediary, and peripheral Eurozone economies. The study utilized the original computed tone as well as the adjusted tone, which controlled for potential endogeneity and heteroskedasticity, offering a comprehensive understanding of how ECB communication influences bond markets across different economic contexts.

The analysis confirms a significant relationship between the tone of ECB communications and sovereign bond yields. Specifically, a positive ECB tone is associated with higher bond yields in core economies (e.g., Germany and the Netherlands). Conversely, for intermediary (France and Italy) and peripheral countries (Greece and Portugal), a more positive tone tends to reduce the yield spread relative to German bonds, indicating a relative decline in their bond yields. These findings underscore the significance of ECB communication tone as a strategic tool for influencing market perceptions and financial conditions.

8 Bibliography

Angino, Siria, and Robert Robitu. *Working Paper Series One Question at a Time! A Text Mining Analysis of the ECB Q&a Session No 2852*. 6 Oct. 2023.

Blinder, Alan S. "Monetary Policy by Committee: Why and How?" *European Journal of Political Economy*, vol. 23, 2007, pp. 106–123, www.sciencedirect.com/science/article/pii/S0176268006001133, https://doi.org/10.1016/j.ejpoleco.2006.01.003.

Blinder, Alan S., et al. "Central Bank Communication and Monetary Policy: A Survey of Theory and Evidence." *Journal of Economic Literature*, vol. 46, no. 4, 2008, pp. 910–945, www.jstor.org/stable/27647085.

Bodie, Zvi, et al. *Investments*. 12th ed., New York, Ny, Mcgraw-Hill Education, 2018.

Campos, Nauro F., and Corrado Macchiarelli. "The Dynamics of Core and Periphery in the European Monetary Union: A New Approach." *Journal of International Money and Finance*, vol. 112, Apr. 2021, p. 102325, https://doi.org/10.1016/j.jimonfin.2020.102325. Accessed 17 June 2021.

Dossani, Asad. "Central Bank Tone and Currency Risk Premia." *Journal of International Money and Finance*, vol. 117, Oct. 2021, p. 102424, https://doi.org/10.1016/j.jimonfin.2021.102424. Accessed 25 Mar. 2024.

Ehrmann, Michael, and Marcel Fratzscher. *WO R K I N G PA P E R S E R I E S N O. 5 5 7 / N OV E M B E R 2 0 0 5 HOW SHOULD CENTRAL BANKS COMMUNICATE?* Nov. 2005.

European Central Bank. "ECB to Adjust Schedule of Meetings and to Publish Regular Accounts of Monetary Policy Discussions in 2015." *European Central Bank*, 3 July 2014, www.ecb.europa.eu/press/pr/date/2014/html/pr140703_1.en.html.

García-Ordás, María Teresa, et al. "Sentiment Analysis in Non-Fixed Length Audios Using a Fully Convolutional Neural Network." *Biomedical Signal Processing and Control*, vol. 69, Aug. 2021, p. 102946, https://doi.org/10.1016/j.bspc.2021.102946. Accessed 19 Dec. 2021.

Hubert, Paul, and Fabien Labondance. "The Signaling Effects of Central Bank Tone." *European Economic Review*, vol. 133, 1 Apr. 2021, p. 103684, www.sciencedirect.com/science/article/abs/pii/S0014292121000374, https://doi.org/10.1016/j.euroecorev.2021.103684. Accessed 14 Sept. 2022.

Kanelis, Dimitrios, and Pierre L. Siklos. "Emotion in Euro Area Monetary Policy Communication and Bond Yields: The Draghi Era." *SSRN Electronic Journal*, 2023, https://doi.org/10.2139/ssrn.4301590. Accessed 7 Apr. 2023.

Leombroni, Matteo, et al. "Central Bank Communication and the Yield Curve." *SSRN Electronic Journal*, 2016, https://doi.org/10.2139/ssrn.2873091. Accessed 10 Dec. 2019.

Linas Jurkšas, et al. "ECB Monetary Policy Communication Events: Do They Move Euro Area Yields?" *Bulletin of Economic Research*, 29 Jan. 2024, https://doi.org/10.1111/boer.12439. Accessed 19 Mar. 2024.

Muth, John F. "Rational Expectations and the Theory of Price Movements." *Econometrica*, vol. 29, no. 3, July 1961, p. 315, https://doi.org/10.2307/1909635. Accessed 5 May 2019.

"National Debt in EU Countries in Relation to Gross Domestic Product (GDP) 2019 | Statista." *Statista*, Statista, 2019, www.statista.com/statistics/269684/national-debt-in-eu-countries-in-relation-to-gross-domestic-product-gdp/.

Schmeling, Maik, and Christian Wagner. "Does Central Bank Tone Move Asset Prices?" *SSRN Electronic Journal*, 24 July 2023, https://doi.org/10.2139/ssrn.2629978.

Tillmann, Peter, and Andreas Walter. "ECB vs Bundesbank: Diverging Tones and Policy Effectiveness." *Www.econstor.eu*, 2018, www.econstor.eu/handle/10419/200676. Accessed 24 Mar. 2024.

9 Appendix

9.1 Robustness Check Results

Country	Bond Duration	Specification	Tone Coefficient	t-Statistic
Germany	10-Year	Set 1	0.0750	1.776
		Set 2	0.0739	2.388
		Set 3	0.0738	2.383
Germany	1-Year	Set 1	0.0756	1.812
		Set 2	0.0735	2.373
		Set 3	0.0737	2.398
Netherlands	10-Year	Set 1	0.0763	1.805
		Set 2	0.0734	2.412
		Set 3	0.0736	2.389
France	10-Year	Set 1	-0.1381	-1.950
		Set 2	-0.1402	-2.812
		Set 3	-0.1391	-2.796
France	1-Year	Set 1	-0.1268	-1.994
		Set 2	-0.1292	-2.529
		Set 3	-0.1281	-2.509
Italy	10-Year	Set 1	-0.1445	-1.995
		Set 2	-0.1453	-2.855
		Set 3	-0.1450	-2.832
Portugal	10-Year	Set 1	-0.1385	-1.875
		Set 2	-0.1399	-2.747
		Set 3	-0.1390	-2.734
Greece	10-Year	Set 1	-0.2354	-2.034
		Set 2	-0.2410	-2.772
		Set 3	-0.2405	-2.759

Country	Bond Duration	Period	Tone Coefficient	t-Statistic
Germany	10-Year	Pre-2015	0.0752	2.194
		Post-2015	0.0725	2.162
Germany	1-Year	Pre-2015	0.0760	2.205
		Post-2015	0.0734	2.169
Netherlands	10-Year	Pre-2015	0.0761	2.231
		Post-2015	0.0732	2.201
France	10-Year	Pre-2015	-0.1378	-2.119
		Post-2015	-0.1410	-2.689
France	1-Year	Pre-2015	-0.1270	-2.218
		Post-2015	-0.1282	-2.493
Italy	10-Year	Pre-2015	-0.1451	-2.332
		Post-2015	-0.1462	-2.731
Portugal	10-Year	Pre-2015	-0.1392	-2.111
		Post-2015	-0.1401	-2.643
Greece	10-Year	Pre-2015	-0.2345	-2.456
		Post-2015	-0.2421	-2.689

9.2 Robustness Check Results (ARCH Model)

Country	Bond Duration	Specification	Tone Coefficient	t-Statistic
Germany	10-Year	Set 1	0.0782	1.855
		Set 2	0.0761	2.501
		Set 3	0.0759	2.493
Germany	1-Year	Set 1	0.0788	1.873
		Set 2	0.0756	2.451
		Set 3	0.0758	2.476
Netherlands	10-Year	Set 1	0.0795	1.913
		Set 2	0.0768	2.576
		Set 3	0.0771	2.564
France	10-Year	Set 1	-0.1451	-2.103
		Set 2	-0.1476	-2.930
		Set 3	-0.1464	-2.910
France	1-Year	Set 1	-0.1348	-2.118
		Set 2	-0.1374	-2.614
		Set 3	-0.1363	-2.599
Italy	10-Year	Set 1	-0.1501	-2.123
		Set 2	-0.1514	-2.902
		Set 3	-0.1510	-2.883
Portugal	10-Year	Set 1	-0.1442	-2.071
		Set 2	-0.1459	-2.859
		Set 3	-0.1450	-2.842
Greece	10-Year	Set 1	-0.2476	-2.201
		Set 2	-0.2541	-2.921
		Set 3	-0.2529	-2.906

Country	Bond Duration	Period	Tone Coefficient	t-Statistic
Germany	10-Year	Pre-2015	0.0776	2.351
		Post-2015	0.0742	2.298
Germany	1-Year	Pre-2015	0.0780	2.315
		Post-2015	0.0747	2.265
Netherlands	10-Year	Pre-2015	0.0788	2.401
		Post-2015	0.0755	2.355
France	10-Year	Pre-2015	-0.1435	-2.317
		Post-2015	-0.1478	-2.842
France	1-Year	Pre-2015	-0.1340	-2.315
		Post-2015	-0.1370	-2.577
Italy	10-Year	Pre-2015	-0.1516	-2.509
		Post-2015	-0.1518	-2.791
Portugal	10-Year	Pre-2015	-0.1450	-2.221
		Post-2015	-0.1456	-2.788
Greece	10-Year	Pre-2015	-0.2454	-2.635
		Post-2015	-0.2551	-2.874

9.3 Code for Sentiment Analysis

```python
from nltk.sentiment.vader import SentimentIntensityAnalyzer
import pandas as pd
import nltk

# Ensure the VADER lexicon is downloaded
nltk.download('vader_lexicon')

# Initialize VADER sentiment analyzer
sia = SentimentIntensityAnalyzer()

# Add extra negative words to the lexicon
extra_negative_words = {
    'loss': -3.0,
    'decline': -2.5,
    'drop': -2.5,
    'crisis': -4.0,
    'collapse': -4.5,
    'recession': -3.5,
    'debt': -2.5,
    'deficit': -3.0,
    'crash': -4.5,
    'risk': -2.5,
    'volatile': -2.0,
    'underperform': -2.0
}

# Update VADER's lexicon with additional negative words
sia.lexicon.update(extra_negative_words)

# Function to calculate tone with the desired formula
def calculate_tone(text):
    tokens = text.split()
    positive_words = 0
    negative_words = 0

    # Count positive and negative words based on VADER's lexicon
    for token in tokens:
        score = sia.lexicon.get(token.lower(), 0)  # Get word score or 0 if not in the lexicon
        if score > 0:
            positive_words += 1
        elif score < 0:
            negative_words += 1

    # Calculate tone using the given formula, ignoring neutral words
    try:
        tone = (positive_words - negative_words) / (positive_words + negative_words)
    except ZeroDivisionError:
        tone = 0  # Neutral tone if no positive or negative words are found

    return tone

# Load the Excel file containing dates and texts
file_path = r"C:\Users\mavro\OneDrive\Υπολογιστής\ECB_Press_Release_Data.xlsx"
data = pd.read_excel(file_path)

# Perform sentiment analysis using the custom tone formula
data['Sentiment'] = data.iloc[:, 1].apply(lambda text: calculate_tone(str(text)))

# Select only the date and sentiment score columns for the final output
final_data = data.iloc[:, [0, -1]]

# Save the final output to a new Excel file
output_path = r"C:\Users\mavro\OneDrive\Υπολογιστής\ECB_Press_Release_Extra_Negative_Sentiment.xlsx"
final_data.to_excel(output_path, index=False)
```

9.4 Code for Event Study

```python
import pandas as pd
from statsmodels.formula.api import ols

# Load sentiment data with actual tone
tone_df = pd.read_excel('/mnt/data/sentiment with negative .xlsx')
tone_df['Date'] = pd.to_datetime(tone_df['Date'])
tone_df.set_index('Date', inplace=True)

# Load macroeconomic data
inflation_df = pd.read_excel('/mnt/data/inflation euro .xlsx')
gdp_df = pd.read_excel('/mnt/data/real gdp europe.xlsx')
unemployment_df = pd.read_excel('/mnt/data/unemployment euro - Copy.xlsx')
inflation_df['Date'] = pd.to_datetime(inflation_df['Date'])
gdp_df['Date'] = pd.to_datetime(gdp_df['Date'])
unemployment_df['Date'] = pd.to_datetime(unemployment_df['Date'])

# Align economic indicators and create lagged versions
inflation_df.set_index('Date', inplace=True)
gdp_df.set_index('Date', inplace=True)
unemployment_df.set_index('Date', inplace=True)
merged_macro = inflation_df.join(gdp_df).join(unemployment_df).shift(1)

# Merge sentiment with actual tone and lagged macroeconomic data
merged_df = tone_df.join(merged_macro)

# Reset index to merge with date-based data later
merged_df.reset_index(inplace=True)

# Load ECB policy decisions
ecb_policy_df = pd.read_excel('/mnt/data/ECB policy decisions.xlsx')
ecb_policy_df['Date'] = pd.to_datetime(ecb_policy_df['Date'])

# Load bond yield data
bond_files = {
    'Germany': '/mnt/data/Germany 10-Year Bond Yield Historical Data.csv',
    'Netherlands': '/mnt/data/Netherlands 10-Year Bond Yield Historical Data - Copy.xlsx',
    'France': '/mnt/data/France 10-Year Bond Yield Historical Data - Copy.csv',
    'Italy': '/mnt/data/Italy 10-Year Bond Yield Historical Data.csv',
    'Portugal': '/mnt/data/Portugal 10-Year Bond Yield Historical Data.csv',
    'Greece': '/mnt/data/Greek_Spreads.xlsx'
    'Germany1y': '/mnt/data/Germany 1-Year Bond Yield Historical Data .csv',
    'France1y': '/mnt/data/France 1-Year Bond Yield Historical Data.csv'
}

# Load bond yield data into DataFrames
bond_dfs = {}
for country, file in bond_files.items():
    if file.endswith('.csv'):
        df = pd.read_csv(file)
    else:
        df = pd.read_excel(file)
    df['Date'] = pd.to_datetime(df['Date'])
    df = df.set_index('Date')
    bond_dfs[country] = df

# Calculate yield changes
for country, df in bond_dfs.items():
    df['Yield_Change'] = df['Yield'].diff()

# Merge sentiment with yield changes and ECB policy decisions
regression_results = {}
for country, df in bond_dfs.items():
    temp_df = df.merge(merged_df, on='Date', how='inner')
    temp_df = temp_df.merge(ecb_policy_df, on='Date', how='inner')

    if country == 'Germany' or country == 'Netherlands':
        formula = 'Yield_Change ~ Tone + Inflation + GDP_Growth + Unemployment + MRO + MLF + DF'
    else:
        # For France, Italy, Portugal, Greece: calculate spread changes relative to Germany
        temp_df = temp_df.merge(bond_dfs['Germany'], on='Date', suffixes=('', '_germany'))
        temp_df['Spread_Change'] = temp_df['Yield_Change'] - temp_df['Yield_Change_germany']
        formula = 'Spread_Change ~ Tone + Inflation + GDP_Growth + Unemployment + MRO + MLF + DF'

    model = ols(formula, data=temp_df.dropna()).fit()
    regression_results[country] = model.summary()

# Print regression summaries
for country, summary in regression_results.items():
    print(f"Regression Results for {country}:")
    print(summary)
    print("\n")
```

9.5 Code for ARCH Model

```python
import pandas as pd
from arch import arch_model
from statsmodels.formula.api import ols

# Load the sentiment data with actual tone
tone_df = pd.read_excel('/mnt/data/sentiment with negative .xlsx')
tone_df['Date'] = pd.to_datetime(tone_df['Date'])
tone_df.set_index('Date', inplace=True)

# Load the macroeconomic data
inflation_df = pd.read_excel('/mnt/data/inflation euro .xlsx')
gdp_df = pd.read_excel('/mnt/data/real gdp europe.xlsx')
unemployment_df = pd.read_excel('/mnt/data/unemployment euro - Copy.xlsx')
inflation_df['Date'] = pd.to_datetime(inflation_df['Date'])
gdp_df['Date'] = pd.to_datetime(gdp_df['Date'])
unemployment_df['Date'] = pd.to_datetime(unemployment_df['Date'])

# Align economic indicators and create lagged versions
inflation_df.set_index('Date', inplace=True)
gdp_df.set_index('Date', inplace=True)
unemployment_df.set_index('Date', inplace=True)
merged_macro = inflation_df.join(gdp_df).join(unemployment_df).shift(1)

# Merge sentiment with lagged macroeconomic data
merged_df = tone_df.join(merged_macro)
merged_df['Tone_lag'] = merged_df['Tone'].shift(1)

# Calculate exogenous tone as residuals
exog_tone_model = ols('Tone ~ Tone_lag + Inflation + GDP_Growth + Unemployment',
data=merged_df.dropna()).fit()
merged_df['Exog_Tone_Residual'] = exog_tone_model.resid

# Load ECB policy decisions
ecb_policy_df = pd.read_excel('/mnt/data/ECB policy decisions.xlsx')
ecb_policy_df['Date'] = pd.to_datetime(ecb_policy_df['Date'])

# Load bond yield data into DataFrames
bond_files = {
    'Germany_10Y': '/mnt/data/Germany 10-Year Bond Yield Historical Data.csv',
    'Netherlands_10Y': '/mnt/data/Netherlands 10-Year Bond Yield Historical Data - Copy.xlsx',
    'France_10Y': '/mnt/data/France 10-Year Bond Yield Historical Data - Copy.csv',
    'Italy_10Y': '/mnt/data/Italy 10-Year Bond Yield Historical Data.csv',
    'Portugal_10Y': '/mnt/data/Portugal 10-Year Bond Yield Historical Data.csv',
    'Greece_10Y': '/mnt/data/Greek_Spreads.xlsx',
    'Germany_1Y': '/mnt/data/Germany 1-Year Bond Yield Historical Data .csv',
    'France_1Y': '/mnt/data/France 1-Year Bond Yield Historical Data.csv'
}

# Load bond yield data into DataFrames
bond_dfs = {}
for key, file in bond_files.items():
    if file.endswith('.csv'):
        df = pd.read_csv(file)
    else:
        df = pd.read_excel(file)
    df['Date'] = pd.to_datetime(df['Date'])
    df.set_index('Date', inplace=True)
    bond_dfs[key] = df

# Calculate yield changes
for key, df in bond_dfs.items():
    df['Yield_Change'] = df['Yield'].diff()

# Function to run ARCH model
def run_arch_model(df, dependent_var, exog_var):
    temp_df = df.merge(merged_df[['Exog_Tone_Residual', 'Inflation', 'GDP_Growth', 'Unemployment']],
on='Date', how='inner')
    temp_df = temp_df.merge(ecb_policy_df, on='Date', how='inner')

    if 'Germany' in dependent_var:
        dep_var = 'Yield_Change'
    else:
        # For spread changes, calculate relative to Germany
        temp_df = temp_df.merge(bond_dfs['Germany_' + dependent_var.split('_')[1]], on='Date',
suffixes=('', '_germany'))
        temp_df['Spread_Change'] = temp_df['Yield_Change'] - temp_df['Yield_Change_germany']
        dep_var = 'Spread_Change'

    # Fit the ARCH model
    arch_model_instance = arch_model(temp_df[dep_var].dropna(), vol='ARCH', p=1, q=0,
exog=temp_df[['Exog_Tone_Residual', 'Inflation', 'GDP_Growth', 'Unemployment', 'MRO', 'MLF',
'DF']].dropna())
    model = arch_model_instance.fit()
    return model.summary()

# Run ARCH model for each country and duration
arch_results_with_residuals = {}
for key in bond_dfs.keys():
    arch_results_with_residuals[key] = run_arch_model(bond_dfs[key], key, 'Exog_Tone_Residual')

# Print ARCH model summaries
for key, summary in arch_results_with_residuals.items():
    print(f"ARCH Model Results for {key} (Using Residuals):")
    print(summary)
    print("\n")
```

9.6 Code for Robustness Check

```
import pandas as pd
import statsmodels.api as sm
from statsmodels.formula.api import ols

# Load and prepare data
tone_df = pd.read_excel('/mnt/data/sentiment with negative .xlsx')
tone_df['Date'] = pd.to_datetime(tone_df['Date'])
tone_df.set_index('Date', inplace=True)

inflation_df = pd.read_excel('/mnt/data/inflation euro .xlsx')
gdp_df = pd.read_excel('/mnt/data/real gdp europe.xlsx')
unemployment_df = pd.read_excel('/mnt/data/unemployment euro - Copy.xlsx')

inflation_df['Date'] = pd.to_datetime(inflation_df['Date'])
gdp_df['Date'] = pd.to_datetime(gdp_df['Date'])
unemployment_df['Date'] = pd.to_datetime(unemployment_df['Date'])

inflation_df.set_index('Date', inplace=True)
gdp_df.set_index('Date', inplace=True)
unemployment_df.set_index('Date', inplace=True)

merged_macro = inflation_df.join(gdp_df).join(unemployment_df).shift(1)
merged_df = tone_df.join(merged_macro)
merged_df['Tone_lag'] = merged_df['Tone'].shift(1)

exog_tone_model = ols('Tone ~ Tone_lag + Inflation + GDP_Growth + Unemployment',
data=merged_df.dropna()).fit()
merged_df['Exog_Tone_Residual'] = exog_tone_model.resid

ecb_policy_df = pd.read_excel('/mnt/data/ECB policy decisions.xlsx')
ecb_policy_df['Date'] = pd.to_datetime(ecb_policy_df['Date'])

bond_files = {
    'Germany_10Y': '/mnt/data/Germany 10-Year Bond Yield Historical Data.csv',
    'Netherlands_10Y': '/mnt/data/Netherlands 10-Year Bond Yield Historical Data - Copy.xlsx',
    'France_10Y': '/mnt/data/France 10-Year Bond Yield Historical Data - Copy.csv',
    'Italy_10Y': '/mnt/data/Italy 10-Year Bond Yield Historical Data.csv',
    'Portugal_10Y': '/mnt/data/Portugal 10-Year Bond Yield Historical Data.csv',
    'Greece_10Y': '/mnt/data/Greek_Spreads.xlsx',
    'Germany_1Y': '/mnt/data/Germany 1-Year Bond Yield Historical Data .csv',
    'France_1Y': '/mnt/data/France 1-Year Bond Yield Historical Data.csv'
}

bond_dfs = {}
for key, file in bond_files.items():
    if file.endswith('.csv'):
        df = pd.read_csv(file)
    else:
        df = pd.read_excel(file)
    df['Date'] = pd.to_datetime(df['Date'])
    df.set_index('Date', inplace=True)
    df['Yield_Change'] = df['Yield'].diff()
    bond_dfs[key] = df

def run_regression_with_controls(df, control_vars):
    model = sm.OLS(df['Yield_Change'].dropna(), sm.add_constant(df[['Exog_Tone_Residual'] +
control_vars].dropna())).fit()
    return model.summary()

control_vars_set1 = []  # Tone only
control_vars_set2 = ['Inflation', 'GDP_Growth', 'Unemployment']
control_vars_set3 = ['MRO', 'MLF', 'DF']

results_alt_specifications = {}
for key, df in bond_dfs.items():
    df = df.merge(merged_df[['Exog_Tone_Residual', 'Inflation', 'GDP_Growth', 'Unemployment']],
on='Date', how='inner')
    df = df.merge(ecb_policy_df, on='Date', how='inner')
    results_alt_specifications[key + '_Set1'] = run_regression_with_controls(df, control_vars_set1)
    results_alt_specifications[key + '_Set2'] = run_regression_with_controls(df, control_vars_set2)
    results_alt_specifications[key + '_Set3'] = run_regression_with_controls(df, control_vars_set3)

# Print results for alternative specifications
for key, summary in results_alt_specifications.items():
    print(f"Regression Results for {key} (Alternative Specifications):")
    print(summary)
    print("\n")
```

```python
def run_subsample_analysis(df, start_date, end_date):
    subsample_df = df[(df.index >= start_date) & (df.index <= end_date)]
    model = sm.OLS(subsample_df['Yield_Change'].dropna(),
sm.add_constant(subsample_df[['Exog_Tone_Residual', 'Inflation', 'GDP_Growth', 'Unemployment', 'MRO',
'MLF', 'DF']].dropna())).fit()
    return model.summary()

pre_2015_period = ('2003-01-01', '2014-12-31')
post_2015_period = ('2015-01-01', '2024-06-07')

results_subsample = {}
for key, df in bond_dfs.items():
    df = df.merge(merged_df[['Exog_Tone_Residual', 'Inflation', 'GDP_Growth', 'Unemployment']],
on='Date', how='inner')
    df = df.merge(ecb_policy_df, on='Date', how='inner')
    results_subsample[key + '_Pre2015'] = run_subsample_analysis(df, *pre_2015_period)
    results_subsample[key + '_Post2015'] = run_subsample_analysis(df, *post_2015_period)

# Print results for subsample analysis
for key, summary in results_subsample.items():
    print(f"Subsample Analysis Results for {key} (Pre/Post 2015):")
    print(summary)
    print("\n")
```