Uncertainty in Communication and Sovereign Debt Risk: Evidence From an Event Study and Fixed Effects Estimation Model of 16 EMU Countries

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Abstract

This study investigates the impact of uncertainty in the European Central Bank's (ECB) monetary policy accounts on the sovereign debt risk of Eurozone countries, and whether this effect is amplified during periods of systemic stress like the Covid-19 pandemic and the Ukraine invasion. Using event study analysis and fixed effects regression models with country fixed effects, we analyze cumulative abnormal returns (CARs) of 10-year government bond yield spreads across 16 Eurozone countries from 2015 to 2024. Uncertainty in ECB communications is quantified by classifying sentences as certain or uncertain using large language models (LLMs) fine-tuned with expert and LLM-generated annotations. The findings indicate that the proportion of uncertain sentences in the ECB's policy accounts does not have a statistically significant impact on sovereign yield spreads, even during periods of heightened systemic stress. Instead, macroeconomic variables and global financial conditions play a more substantial role in influencing bond yields. These results suggest that investors may not heavily factor in the linguistic uncertainty of the ECB's policy accounts when assessing sovereign debt risk, highlighting the predominance of fundamental economic indicators over communication uncertainty in sovereign debt markets.

Table of Contents

1 Introduction

Central bank communication has become an indispensable instrument in the conduct of monetary policy, exerting significant influence on financial markets and economic stability (Blinder et al., 2008). In the Eurozone, the European Central Bank (ECB) employs various communication channels, notably the monetary policy accounts, to convey its policy intentions and assessments of economic conditions. These communications play a crucial role in shaping investor expectations and market behavior, particularly in sovereign debt markets where government bond yield spreads serve as proxies for perceived sovereign risk (Afonso et al., 2015).

Uncertainty in central bank communication can have profound effects on financial markets. When communications are ambiguous or convey uncertainty, they can lead to increased risk premiums and asset price volatility (Hansen & McMahon, 2016). Investors may demand higher yields on sovereign bonds to compensate for the perceived increase in risk, potentially affecting a country's borrowing costs and fiscal sustainability (Reinhart & Rogoff, 2010). This study investigates the impact of uncertainty in the ECB's monetary policy accounts on soveraign default risk. Specifically, it addresses the research question: *Does uncertainty in ECB monetary policy accounts increase risk of sovereign default for EMU countries?*

To explore this question, we conduct an event study analysis and employ fixed effects regression models with country fixed effects. The event study examines the immediate market reactions to the release of the ECB's monetary policy accounts by analyzing cumulative abnormal returns (CARs) of 10-year government bond yield spreads across 16 Eurozone countries. Sovereign bond yield spreads are used as proxies for default risk as they reflect the markets perception of the riskiness of the asset. The fixed effects regression assesses the relationship between the quantified uncertainty in the ECB's communications and the observed CARs, controlling for macroeconomic and global financial variables.

A novel aspect of this study is the use of advanced textual analysis methods to quantify uncertainty in the ECB's communications. We utilize language models (LMs) for text classfication and fine-tune them with both expert-labeled and large language model(LLM)-generated annotations to create a measure of the proportion of uncertain sentences in the monetary policy accounts. This approach allows for a more nuanced analysis of how linguistic uncertainty affects investor perceptions and sovereign debt risk.

Our findings indicate that the uncertainty in the ECB's monetary policy accounts does not have a statistically significant impact on sovereign yield spreads, and hence sovereign default risk. This result holds across different event windows and during periods of heightened systemic stress, such as the Covid-19 pandemic and the Ukraine invasion. Instead, macroeconomic factors and global financial conditions, such as unemployment rates, industrial production growth, and global market volatility indices, play a more substantial role in influencing sovereign bond yields.

The remainder of the paper is structured as follows: Section 2 reviews the relevant literature on central bank communication, uncertainty, and sovereign debt risk. Section 3 outlines the methodology, including data collection, measurement of uncertainty, and the analytical framework. Section 4 presents the findings from the event study and regression analyses. Section 5 discusses the implications of the results in the context of existing literature. Section 6 addresses the limitations of the study and potentail future reseach avenues. Finally, the Conclusion summarizes the study.

2 Literature Review

Central bank communication has emerged as a pivotal instrument in the conduct of monetary policy, with profound implications for financial markets and economic stability. The ECB utilizes various communication channels. Understanding how these communications, particularly the uncertainty they may embody, influence sovereign debt risk is crucial for policymakers and investors alike. Sovereign debt risk, often proxied by government bond yield spreads, reflects investors' perceptions of a country's creditworthiness and fiscal sustainability. This literature review critically examines the scholarly debates on central bank communication, the role of uncertainty, and their impact on sovereign debt risk within the Eurozone.

2.1 – Central Bank Communication and Market Expectations

Central bank communication plays a vital role in shaping market expectations and influencing financial asset prices. Blinder et al. (2008) argue that effective communication enhances the transparency and credibility of monetary policy, reducing information asymmetries between the central bank and market participants. This transparency is essential for guiding investor expectations and promoting financial stability.

The Efficient Market Hypothesis (EMH), proposed by Fama (1970), posits that financial markets are informationally efficient, meaning that asset prices fully reflect all available information. Under this framework, central bank communications should be rapidly and accurately incorporated into asset prices, including sovereign bond yields. However, the degree to which markets efficiently process and respond to central bank communications remains contested. However, the EMH could also suggest that central bank communication has limited effects as markets would have already processed the information conveyed by central banks if policy expectations are accurate and if economic conditions remain predictable.

Woodford (2001, p. 12) emphasizes that successful monetary policy is about managing the "the evolution of market expectations". This perspective underscores the strategic use of communication by central banks to signal future policy actions and influence economic outcomes. Mishkin (2004) elaborates on this argument and highlights the importance of transparency, suggesting that transparent communication can enhance the effectiveness of monetary policy by aligning market expectations with policy objectives.

Contrary to the EMH, behavioral finance scholars such as Shiller (2003) highlight that cognitive biases and irrational behavior can lead to market inefficiencies. Investors may misinterpret or overreact to central bank communications, leading to asset price volatility that does not reflect underlying fundamentals. This suggests that the impact of central bank communication on market expectations and asset prices may be more complex than the EMH implies.

Shiller (2003) further argues that psychological factors and herd behavior can amplify market reactions to uncertainty. This can result in asset price volatility that deviates from fundamentals, challenging the assumptions of the EMH. Understanding these behavioral responses is essential for assessing the impact of communication uncertainty on sovereign debt risk.

Ehrmann and Fratzscher (2007) find that ECB policy announcements influence bond yields by shaping market expectations about future interest rates; clear and consistent communication from the ECB leads to more predictable market reactions and reduces uncertainty among investors. Andersson et al. (2006) demonstrate that unexpected policy signals from the ECB cause immediate adjustments in bond yields across different maturities, as market participants update their expectations regarding the central bank's monetary policy stance. Both studies highlight that ECB communications serve as a critical channel through which monetary policy decisions affect financial markets, directly impacting sovereign bond yields by altering investors' perceptions and expectations.

Overall, evidence shows that central bank communication has significant influence on economic outcomes and expectations. Investors use these communications to form expectations on future policy and economic conditions, and as a result adjust their decision making accordingly. Utilizing this evidence, we can form our first hypothesis of this study:

H1: ECB Communication has a significant effect on perceptions of default risk.

2.2 – Uncertainty in Central Bank Communication

Uncertainty in central bank communication is a critical factor influencing investor behavior and financial markets. Knight (1921) distinguishes between measurable risk and unmeasurable uncertainty, emphasizing that uncertainty can significantly affect economic decision-making. Measurable risk involves situations where the probabilities of different outcomes are known or can be accurately estimated based on historical data or statistical models, thus allowing for calculated decision-making and risk management. In contrast, unmeasurable uncertainty refers to scenarios where the probabilities of outcomes are unknown or cannot be quantified due to a lack of information or unprecedented circumstances. Here, outcomes are unpredictable, and decision-makers must rely on judgment and intuition rather than statistical calculations. When central bank communications are ambiguous or inconsistent, they introduce uncertainty, making it challenging for investors to form accurate expectations about future monetary policy and economic conditions.

Hansen and McMahon (2016) investigate the macroeconomic effects of central bank communication, focusing on the tone and language used in Federal Reserve communications. They find that increased uncertainty in central bank communications is associated with heightened asset price volatility and risk premiums. Their findings suggest that uncertainty can have tangible adverse effects on financial markets, supporting the view that clarity in communication is essential for market stability.

In the context of the Eurozone, Hayo and Neuenkirch (2015) analyze how financial market participants process ECB communications. They conclude that unclear or ambiguous statements from the ECB can lead to increased uncertainty, affecting bond yields and investor behavior. This effect is particularly pronounced during periods of economic stress, where market participants are more sensitive to central bank signals. Their study highlights the importance of not only the content but also the clarity of communication in influencing market perceptions.

Bloom (2009) demonstrates that uncertainty shocks can lead to significant declines in economic activity and increased financial market volatility. He argues that uncertainty can cause firms to postpone investment and hiring decisions, leading to economic slowdowns. In financial markets, uncertainty can exacerbate herding behavior and overreactions, as investors rely on limited information to make decisions (Shiller, 2003). This challenges the EMH by highlighting that information asymmetries and behavioral biases can prevent markets from fully and efficiently incorporating new information.

2.3 – Impact of Uncertainty on Sovereign Debt Markets

Policy Uncertainty and Financial Markets

Policy uncertainty has been shown to have significant effects on financial markets and economic activity. Baker et al. (2016) construct an Economic Policy Uncertainty (EPU) Index and find that higher levels of policy uncertainty are associated with increased bond yield spreads and decreased investment. Their research indicates that uncertainty regarding fiscal, monetary, and regulatory policies can lead investors to demand higher risk premiums.

Pastor and Veronesi (2012) model the relationship between policy uncertainty and stock prices, showing that uncertainty can increase the equity risk premium due to the additional risk perceived by investors. While their focus is on equity markets, the underlying mechanism applies to sovereign debt markets, where uncertainty about economic policies can affect bond yields.

Bloom (2009) further supports these findings by demonstrating that uncertainty shocks can lead to significant declines in economic activity and increased financial market volatility. The cumulative evidence suggests that policy uncertainty is a critical determinant of financial market conditions and investor behavior.

Uncertainty in ECB Communications

Uncertainty in ECB communications can have pronounced effects on sovereign debt markets. De Santis (2012) analyzes the euro area sovereign debt crisis and finds that uncertainty regarding the ECB's policy stance contributed to increased sovereign yield spreads. The absence of clear guidance on policy measures, such as the possibility of unconventional monetary interventions, heightened market fears and risk perceptions.

Fratzscher et al. (2016) study the impact of the ECB's unconventional monetary policies and their communication on financial markets. They conclude that clear and decisive communication regarding policy actions can effectively reduce sovereign bond yields and stabilize markets. Conversely, ambiguity or delays in communication can undermine the effectiveness of policy measures.

Evidence therefore shows that uncertainty in central bank communication has a signficant impact on investors decision making and their perception of overall risk. Given these perceptions, investors will demand higher risk premia from sovereign bonds, especially for those which are considered to be riskier, such as those of periphery and highly indebted countries in the EMU. For this reason, we construct our second hypothesis:

H2: Uncertainty in ECB Communication leads to increased perceptions of default risk, thus widening yield spreads on 10 year government bond yields.

2.4 – Determinants of Sovereign Debt Risk

Macro-Financial Determinants

Sovereign debt risk is influenced by a multitude of macroeconomic and financial factors. Afonso et al. (2015) examine the determinants of sovereign bond yield spreads in the European Monetary Union (EMU) and identify fiscal variables such as government debt levels and budget deficits as significant factors. High debt-to-GDP ratios raise concerns about a country's fiscal sustainability and ability to service its debt, leading investors to demand higher yields.

Manganelli and Wolswijk (2009) find that macroeconomic fundamentals, including GDP growth and inflation rates, significantly influence sovereign yield spreads. Strong economic growth enhances a country's debt-servicing capacity, reducing perceived risk. In contrast, high inflation can erode the real returns on bonds, prompting investors to demand higher yields as compensation.

Reinhart and Rogoff (2010) further provide a historical perspective on the relationship between high public debt and economic growth. They argue that when debt levels exceed certain thresholds, they can impede economic growth and increase the likelihood of sovereign debt crises. Their analysis underscores the importance of sound fiscal management in maintaining sovereign creditworthiness. They note that "high debt/GDP levels can be associated with significantly lower growth outcomes" (Reinhart & Rogoff, 2010, p. 577), which in turn adds pressures on countries ability to service debt and increases default. Moreover, they note that high debt levels mixed with periods of high inflation further increase default risk, as higher price levels lead to increasing interest rates which raises the costs of servicing debt (Reinhart and Rogoff, 2013)

Moreover, Woo and Kumar (2015) build on these arguing by highlighting how higher debt levels can potentially decrease private investment, as decision makers percive these countries as being vulnerable to defualt risk. They highlight how crowding out of private investment reduces a countries productive capacity and potential economic growth. These effects can further influence other jurisdictions, particularly in integrated economic and monetary unions, such as the EMU, as core countries within these unions take on the responsibility of bailing out periphery members during periods of high default risk: “mutualization could potentially result in continuing slow growth or even recession in the core countries” (Reinhart and Rogoff, 2013, pg. 10; Burriel et al., 2020).

Country-Specific and Political Factors

Country-specific factors, such as political stability and institutional quality, play a crucial role in sovereign debt risk assessment. Beetsma et al. (2013) highlight that political uncertainty, policy instability, and governance issues can increase investors' risk perceptions. While this might not specifically include uncertainty in central bank communication, the authors show how uncertainity regarding economic policies, that might arise from political events such as elections and policy shifts, influences decision makers expectations of future conditions

Moreover, Bernoth et al. (2004) argue that "markets may anticipate fiscal support for EMU countries in financial distress unless these countries had been very undisciplined before." Their arguments further underline what Reinhart and Rogoff (2010) argue, in that fiscal discipline plays a vital role in sovereign debt risk, especially in its way of shaping expectations which can lead to investors demanding higher risk premia, in other words higher yields, on sovereign bonds.

Global Financial Conditions

Global financial conditions and investor sentiment significantly influence sovereign debt risk. Longstaff et al. (2011) demonstrate that global risk factors, such as international liquidity and global risk aversion, account for a substantial portion of the variation in sovereign credit spreads. During periods of global financial stress, investors tend to engage in flight-to-quality behavior, shifting investments towards perceived safe-haven assets, which can widen yield spreads for countries deemed riskier.

Bekaert et al. (2013) emphasize that global uncertainty can amplify the effects of domestic vulnerabilities on sovereign debt risk. They argue that even countries with strong fundamentals are not immune to spillover effects from global financial markets. This interconnectedness underscores the complexity of assessing sovereign debt risk in an increasingly globalized financial system.

Overall, sovereign yield spreads can be seen as being influenced by factors related to fiscal discipline, debt sustainability, macroeconomic factors related to growth potential, and global factors leading to increased systemic stress and market uncertainty that then further exarcebate the factors outlined above. These factors imply the ability of sovereign yield spreads to proxy for perceptions of default risk as when investors deem a sovereign to be at risk, they demand higher risk premia. Therefore, we construct a list of control variables accounting for these factors. Furthermore, we can construct our third and final hypothesis:

H3: The effects of uncertainty in ECB communication on perceptions of default risk are more pronounced during periods of heightened systemic stress, such as the Covid-19 pandemic and the Ukraine invasion.

2.5 – Measuring Uncertainty in Central Bank Communication

We now discuss the advancements in textual analysis and natural language processing (NLP) that have enabled researchers to systematically quantify linguistic phenomena, such as unceratainty, in central bank communications.

Textual Analysis Methods

Loughran and McDonald (2011) develop specialized dictionaries for financial texts to assess sentiment and uncertainty. Applying such methods to central bank communications allows for the analysis of linguistic cues that may signal uncertainty. However, reliance on pre-defined word lists can be limiting, as context and syntax play significant roles in conveying meaning.

Gentzkow et al. (2019) discuss the use of text as data in economic research, highlighting the potential of machine learning techniques to analyze large volumes of textual information. They caution that context is crucial, and simplistic word counts may not capture the nuanced expressions of uncertainty. They advocate for methods that consider the semantic structure and contextual usage of words.

Use of Large Language Models

The use of large language models (LLMs), as demonstrated by Howard and Ruder (2018), represents a significant advancement in measuring uncertainty. By fine-tuning pre-trained models on specific corpora, researchers can capture complex linguistic patterns and contextual meanings. This approach allows for a more accurate classification of sentences conveying certainty or uncertainty.

Malo et al. (2014) emphasize the importance of combining automated methods with human-annotated datasets to improve accuracy and reliability. They show that machine learning models trained on gold-standard labels can outperform traditional dictionary-based methods in detecting semantic orientations in economic texts. This methodology addresses some of the limitations of previous approaches and enhances the measurement of uncertainty in central bank communications.

Despite these advancements, the application of such techniques to ECB communications remains limited. There is an opportunity to leverage these methods to gain deeper insights into how uncertainty in central bank communications affects sovereign debt markets.

2.6 – Gaps in the Literature and Relevance to Current Research

While considerable research has been conducted on central bank communication and its impact on financial markets, several gaps remain.

Firstly, there is a lack of studies specifically examining how uncertainty in ECB monetary policy accounts influences sovereign debt risk in the Eurozone. Much of the existing literature focuses on policy actions rather than the content and tone of communications. This leaves an incomplete understanding of the channels through which communication affects market perceptions and sovereign debt risk.

Secondly, the application of advanced textual analysis methods, such as LLMs combined with human annotation, is relatively novel in this context. By employing these methods, the current research can provide more nuanced measurements of uncertainty and its effects. This addresses the limitations of earlier studies that relied on simpler textual analysis techniques.

By addressing these gaps, the current research contributes to the literature by providing a detailed analysis of the impact of uncertainty in ECB communications on sovereign debt risk, utilizing advanced methodological approaches.

3 Methodology

3.1 Measurement

Source of ECB Monetary Policy Accounts

The primary source of text data for this research consists of the European Central Bank (ECB) monetary policy accounts, which are released following each Governing Council meeting (ECB, 2024). These meetings, occurring roughly every six weeks, provide detailed insights into the Council's discussions on economic, financial, and monetary developments, as well as policy options. Section 2 of the accounts, which focuses on the Governing Council's discussions and monetary policy decisions, is particularly relevant for this study.

These accounts are essential for communicating the ECB's stance on key economic issues, such as interest rates, inflation, and growth. As these communications influence investor expectations and market behavior, they provide a valuable data source for examining the impact of uncertainty on financial markets, particularly government bond yield spreads. By capturing both certainty and uncertainty in ECB communications, the study aims to assess how these elements affect perceptions of sovereign risk across Eurozone countries. The accounts are published four weeks after the meetings, ensuring the timing of public access aligns with potential market impacts rather than the meeting date itself.

Timeframe and Scope

The study examines ECB monetary policy accounts from February 19, 2015, to May 10, 2024. This timeframe captures diverse economic conditions, including periods of stability, crises, and geopolitical disruptions, such as the Covid-19 pandemic and the Ukraine invasion. Seventy-five ECB monetary policy accounts are analyzed, with the release dates used as the key events, reflecting when market participants first access the information.

The accounts were sourced from the ECB's website, and web scraping techniques were used to automate the data retrieval process. The focus was on extracting Section 2 of the accounts, which deals with policy deliberation and communicates the uncertainty of economic outlooks and monetary policy direction. After extraction, the text was cleaned and split into 10,004 individual sentences.

3.1.1 – Creation of the Uncertainty Measure

LLM Generated Labels

A key objective of this research is to quantify the level of uncertainty in ECB monetary policy accounts. To do this, all 10,004 sentences were classified as either "certain" or "uncertain." The classification process began with 500 sentences manually labeled following strict guidelines to ensure consistency and accuracy. In addition, 1,000 sentences were labeled using a large language model (LLM), forming a dataset of 1,500 sentences used to fine-tune a custom language model to classify the remaining 8,504 sentences.

The LLM chosen for automated labeling was the Mixtral-8x7B-Instruct-v0.1 model, selected for its robustness in handling domain-specific language and text classification tasks. Its open-source nature provides transparency and flexibility for optimal performance (Mistral AI, 2023). The LLM was prompted with instructions that emphasized identifying speculative language, hedging terms, and ambiguity. Sentences with terms such as "could," "might," or "appears" were labeled as uncertain, while concrete actions or consensus-driven conclusions were labeled as certain (Rubin, 2010; Malo et al., 2013). The full prompt is shown in Appendix A.

To improve accuracy, the chain-of-thought reasoning technique was employed, prompting the LLM to reason through its decision-making process. Self-consistency was also used, generating three potential labels per sentence, with the most frequent label selected for the final classification (Wei et al., 2022; Wang et al., 2023). Few-shot learning was applied by providing two labeled examples per category, allowing the LLM to better learn the data's underlying pattern (Parnami and Lee, 2022). The key generation parameters were fine-tuned for consistency: top-p was set to 0.90, ensuring the LLM sampled from the top 90% of predicted word distributions, and temperature was set to 0.4, balancing randomness while preserving accuracy (Holtzman et al., 2020; Peeperkorn et al., 2024; Gilardi, Alizadeh, and Kubli, 2023). The repetition penalty was set to 1.0 to prevent overuse of certain phrases, and max_new_tokens was capped at 512 to ensure complete responses. A list of the generation parameters and their exact values can be found in Table A.1 in Appendix A.

The gold-standard labels, created by manual annotation, followed the same criteria used for the LLM-generated labels. This consistency minimized the risk of inconsistencies and bias in the training data.

Training the Custom Language Model

After generating the initial set of labels, the remaining 8,504 sentences were classified using a custom fine-tuned language model. The base model selected for fine-tuning was DistilRoBERTa-base , a distilled version of the RoBERTa-base model. Knowledge distilliation is the process of compressing large language models into smaller and more efficient ones (Gou et al., 2020). RoBERTa, short for Robustly Optimized BERT Approach, is a transformers-based model that was pre-trained on a large corpus of English text using the masked language modeling objective (Liu et al., 2019). This training approach enables RoBERTa to learn bidirectional representations of text, making it highly effective for tasks such as sentence classification, where context from both sides of a word or phrase is essential for accurate interpretation (Malo et al., 2013).

The fine-tuning process was conducted using HuggingFace's AutoTrain platform, a no-code interface that streamlines the model training process by allowing users to upload labeled datasets and configure the training settings without needing to write complex code. For this task, the dataset was split into a training set of 1,300 sentences and a validation set of 200 sentences, ensuring that the model could be evaluated on unseen data throughout the training process.

The training process involved several key parameters, each of which had a significant impact on the model's performance. The learning rate was set to 1e-05, a low rate that ensures the model weights are updated gradually, preventing the model from converging too quickly and potentially missing the optimal solution. This learning rate is particularly suited for fine-tuning pre-trained models, as it allows for small, incremental adjustments to the model's weights based on the new training data (Liu et al., 2019). The batch size was set to 10, balancing the need for computational efficiency with the ability to process multiple examples simultaneously without overwhelming the GPU memory.

The model was trained for 3 epochs, meaning that the entire training dataset was passed through the model three times. This number of epochs strikes a balance between ensuring the model has enough exposure to the training data and avoiding overfitting, where the model becomes too specialized to the training data and performs poorly on new, unseen data. The maximum sequence length was set to 256 tokens, ensuring that each input sentence or sequence was truncated or padded to this length, allowing the model to process both short and long sentences effectively without running into memory constraints. A list of all training parameters and their respective values shown in Table A.2 Appendix A.

Different Large Language Models were fine-tuned and their performance on the text classification task was evaluated based on their accuracy and F1 Scores. Similarly, a simpler model such as the Multinomial Naïve Bayes classifier was tested as well. Accuracy measures the percentage of correct predictions out of all predictions made, providing a general sense of how often the model is right. However, it can be misleading when dealing with imbalanced datasets where some classes are much more frequent than others. The F1 Score addresses this by combining precision and recall into a single harmonic mean, offering a balanced view that accounts for both the accuracy of positive predictions and the model's ability to identify all relevant instances (Goutte and Gaussier, 2005). A summary of the model performance metrics is shown in Table 1 below.

Table 1: Text Classification Model Performance

Model	Accuracy	F1.Score
DistilRoBERTa-base	0.790	0.738
DistilBERT-base-uncased	0.767	0.720
DeBERTaV3-large	0.757	0.704
BERT-base-uncased	0.747	0.710
DistilRoberta-financial-sentiment *	0.756	0.681
FinBERT †	0.753	0.675
XLM-RoBERTa-large	0.753	0.694
Multinomial Naive Bayes Classifier	0.693	0.632

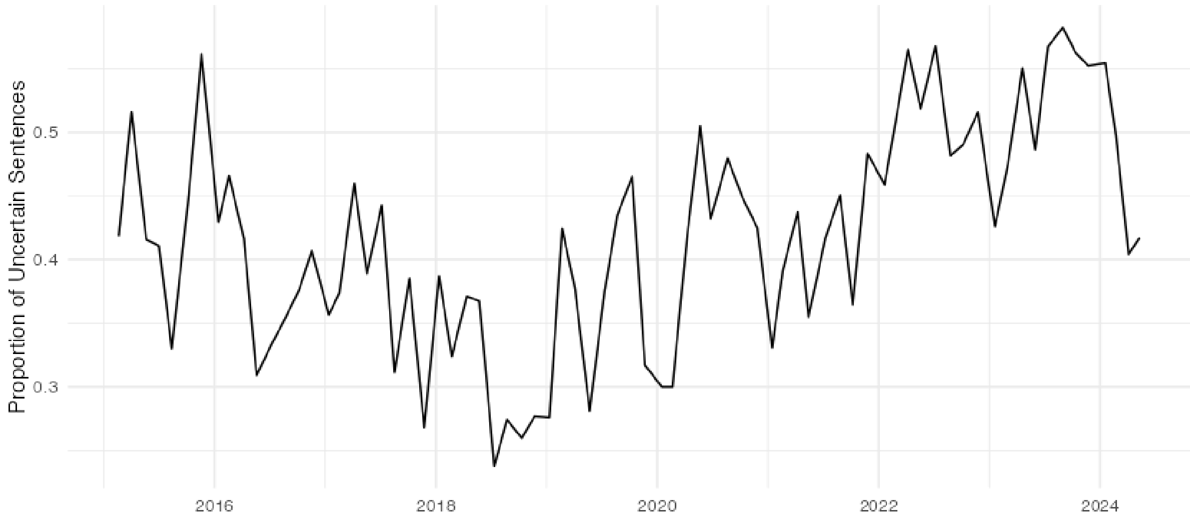
* Fine-tuned version of distilroberta-base on the financial_phrasebank dataset.
† Pre-trained on financial communication text.

Based on the performance metrics presented in Table 1, the DistilRoBERTa-base model stands out as the best performer, achieving the highest accuracy and F1 score among the compared models. It provides the best balance between correctly classifying data points and maintaining a strong balance between precision and recall. Although other models, such as DistilBERT-base-uncased and DeBERTaV3-large, exhibit competitive performance, DistilRoBERTa-base consistently outperforms them. Domain-specific models like FinBERT and DistilRoBERTa-financial-sentiment do not achieve superior results, suggesting that general models like DistilRoBERTa-base are more effective for this task. The traditional classification algorithm (Multinomial NB classifier) significantly underperforms compared to the modern transformer-based models, both in terms of accuracy and F1 score. Therefore, DistilRoBERTa-base is selected as the most reliable and effective model for deployment. Links to the individual fine-tuned LLMs are provided in Table A.3 Appendix A.

After labeling all 10,004 sentences, the uncertainty measure was calculated by aggregating the sentence-level classifications for each monetary policy account. Specifically, the proportion of uncertain sentences for each account was calculated by dividing the number of sentences labeled as uncertain by the total number of sentences in that account. This proportion represents the main independent variable in the analysis, allowing for a comparison of uncertainty levels across different monetary policy accounts.

Figure 1 below shows the result of this methodology, showing the values of the proportion of uncertain sentences in ECB monetary policy accounts over time. The graph shows a clear trend with uncertainty increasing during the Covid-19, falling after about a year, and then increasing again following the invasion of Ukraine and the inflationary pressures that followed. Furthermore, we see high proportions of uncertain sentences in 2015 and 2016, likely due to the aftermaths of the Euro Sovereign Debt Crisis and the uncertainty surrounding the ECBs policy stance (De Santis, 2012).

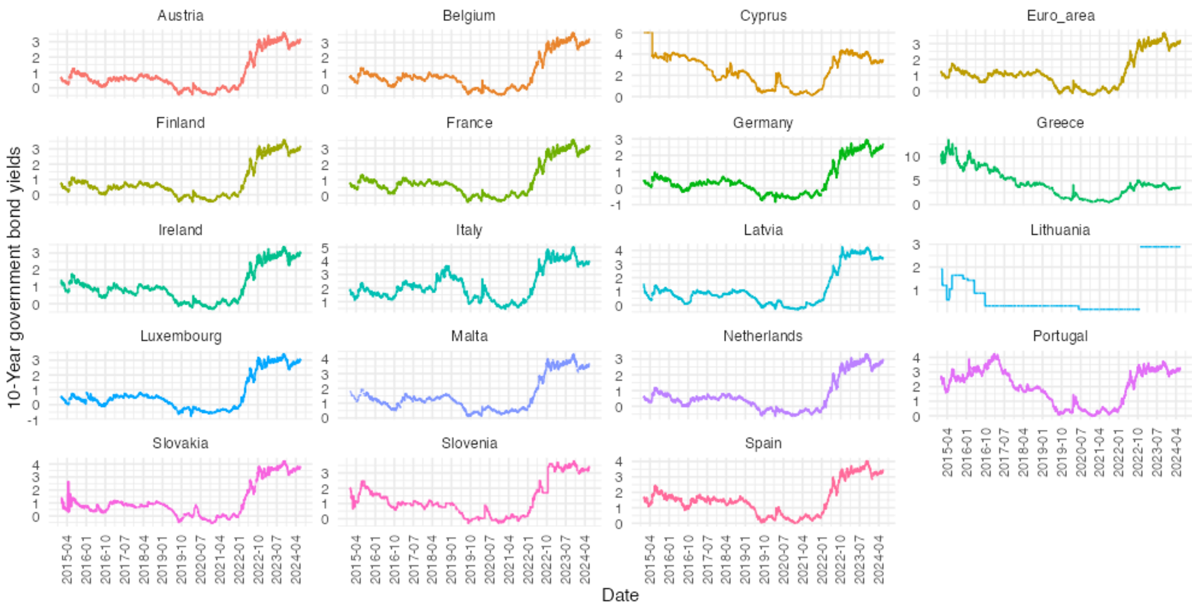
Figure 1: Uncertainty in ECB Monetary Policy Accounts



3.1.2 – Data Collection of Government Bond Yields and Economic Variables

The primary dependent variables in this study are the 10-year government bond yield spreads of 16 EMU countries, excluding Croatia and Estonia due to data availability. Additionally, Figure 2 below shows the government bond yields for the respective countries the EMU as a whole, and as we can see, the Lithuanian bond yields remain effectively static from October 2016 up to about October 2022, when they suddenly jump from just above 0% to about 3%. This lack of variation could negatively influence our analysis as we use daily yield spread changes to measure effects of events, and therefore, Lithuania would exhibit no change for much of the sample period. For this reason we decide to exclude it from the analysis. Finally, Germany is excluded as it serves as the benchmark for calculating yield spreads. The bond yields were sourced from Eurostat's Maastricht Treaty EMU convergence criterion series, which covers long-term government bonds traded in secondary markets, with maturities around ten years (Eurostat, 2024b). This harmonized data ensures comparability across Eurozone countries.

Figure 2: 10-year government bond yields



Yield spreads were calculated using German bond yields as the benchmark due to Germany's economic stability within the Eurozone. The German bund is seen as a safe asset, with lower yields reflecting investor confidence in Germany’s fiscal management (Galati and Tsatsaronis, 2003). Yield spreads act as proxies for default risk, where higher spreads indicate greater risk (Bernoth et al., 2004; Remalona et al., 2007).

Additional macroeconomic and financial variables, identified in prior literature as influencing yield spreads, are included for control purposes. These include the real effective exchange rate, which assesses a country's price competitiveness relative to its trading partners (Eurostat, 2024a), the harmonized index of consumer prices (HICP), industrial production growth, unemployment rate, government deficit, total government debt, total GDP, and debt securities issued as proxies for trading volume. Global financial conditions are represented by the VSTOXX index (measuring Euro STOXX 50 volatility) (STOXX, 2024), the VIX index (measuring S&P 500 volatility as a proxy for market uncertainty) (CBOE, 2024), the Composite Indicator of Systemic Stress (CISS), the Cboe Crude Oil ETF Volatility Index (OVX), and Brent crude oil prices for Europe. Both the VIX and CISS have been used as a proxy for international financial risk, particularly in researching the influence of international financial risk on euro area bond yields with the VIX capturing global factors whereas the CISS captures more Euro area specific factors excluded from the VIX (Afonso et. al., 2015; Mody, 2009; Beber et. al., 2008; Holló et. a., 2012). We further include US-German yield spreads. A table with all the variable, their descriptions, and where they are sourced from shown in Table B of Appendix B.

Preprocessing included cleaning the data and adjusting it to the correct frequency. Quarterly data was expanded into monthly data by assigning quarterly values to the corresponding months, and then all data in monthly frequency was lagged by one month to account for reporting delays. This ensures the data better reflects the information available to market participants at the time of decision-making. Daily data was averaged across the event window for use in the event study. Finally, all variables were merged with the uncertainty measures based on their most recent values for each event date.

3.2 Data Analysis

3.2.1 – Event Study

To measure the effects of ECB communication on country yield spreads, an event study framework is employed, treating the individual monetary policy account releases as the events. This methodology is particularly suitable for analyzing how these releases affect bond yield spreads because event studies are designed to capture the market's immediate response to new information (MacKinlay, 1997).

The selection of events in this study includes 75 ECB monetary policy account releases, spanning from February 19, 2015, to May 10, 2024. The event windows are specified to capture both immediate and short-term market reactions. Three event windows are used: [-5, +5] days, [-1, +1] days, and [-2, +2] days around each event date. The rationale for these windows is to balance the capture of immediate market reactions with the need to allow for short-term adjustments as market participants fully process the new information.

In addition to the event window, the estimation window is defined as the 20 days preceding each event. The purpose of the estimation window is to calculate normal returns (or yield spreads in this case) that are expected in the absence of the event. By using a 20-day estimation window, we ensure that the event window does not overlap with the estimation window "to prevent the event from influencing the normal performance model parameter estimates" (MacKinlay, 1997, pg. 15). While the estimation window size can be considered quite small, due to the events being roughly 30 trading days apart, a larger estimation window is impossible while preventing overlap with the event window.

Calculation of Abnormal Returns

We are interested in measuring the effects of the events on changes in yield spreads. Abnormal returns can be understood as the effect size of the events and in this study represent the difference between the observed yield spread change and the expected yield spread change based on a normal market environment. To estimate the normal returns, we employ a market model, a widely used approach in event studies. In traditional event studies on asset returns, the market model calculates expected returns by relating the return of a security to the return of a broader market portfolio (MacKinlay, 1997). This allows us to predict what the yield spread change would have been in the absence of the event, and therefore calculate the effect of the event. The regression equation used for estimating normal returns is:

$$Predicted\_Spread\_Change_{it} = \alpha_i + \beta_i \cdot MarketSpreadChange_t + \epsilon_{it} \quad (1)$$

Here, $Predicted\_Spread\_Change_{it}$ represents the yield spread change of EMU country i on day t, $MarketSpreadChange_t$ is the average yield spread change across all EMU countries (serving as a proxy for overall market performance), α_i and β_i are country-specific coefficients, and ϵ_{it} is the error term. The market spread is calculated by sourcing the Euro area aggregate of the Maastricht Treaty EMU convergence criterion series from Eurostat and then calculating the spread using the German yield as a benchmark and measuring the day to day change (Eurostat, 2024b). A similar approach to the one used in this study was applied by Afonso et al. (2012), where they calculate adjusted yield spreads by subtracting the country average yield spread (an equally weighted portfolio of the EU countries) from the sovereign yield spreads, therefore de-meaning the country specific spreads (Afonso et al., 2012, pg. 612). As the country yield spreads are highly correlated, the purpose of this is to control for any market wide movements and effectively extract the isolated effect of the event on the specific country yield spread (Afonso et al., 2012; Longstaff et al., 2011).

Once normal returns are estimated, abnormal returns are calculated as the difference between the observed change in yield spreads and the expected change in yield spreads, as predicted by the market model:

$$AR_{it} = Spread\_Change_{it} - (\alpha_i + \beta_i \cdot MarketSpreadChange_t) \quad (2)$$

As the abnormal returns isolate the effect of the event on each country's yield spread by removing the broader market movements, this method is particularly valuable in sovereign risk studies as it helps distinguish between market-wide factors influencing bond yields and country-specific factors that arise due to new information from the ECB.

Cumulative Abnormal Returns (CAR)

To assess the overall impact of an event over the entire event window, we calculate cumulative abnormal returns (CAR). The CAR aggregates abnormal returns across the event window for each country-event pair, capturing the total effect of the event on bond yield spread changes. The formula for CAR is:

$$CAR_{i,e} = \sum_{t=T_1}^{T_2} AR_{it} \tag{3}$$

Where $CAR_{i,e}$ is the cumulative abnormal return for country i during event e and T_1 and T_2 represent the start and end of the event window, respectively. For example, in the [-5, +5] window, T_1 would be five days before the event and T_2 would be five days after the event.

By summing the abnormal returns across the event window, CAR captures the full extent of the market's reaction to the event. Positive CAR values indicate that the event led to a widening of the country’s yield spread, suggesting increased sovereign risk. Conversely, negative CAR values suggest that the event led to a narrowing of the yield spread, implying a reduction in perceived risk.

Statistical Significance Testing

After calculating abnormal and cumulative abnormal returns, we assess their statistical significance using t-tests. The purpose of these tests is to determine whether the observed abnormal returns and CARs are significantly different from zero. For individual events, t-tests are conducted on the CARs across all countries to assess whether the events have a significant impact on the Eurozone as a whole.

Additionally, we conduct t-tests for each country to assess the overall effect of all events on individual countries' CARs. To account for potential correlations between countries, we use clustered standard errors, which help control for cross-sectional dependence. Clustered standard errors are necessary in this context because the same event affects multiple countries simultaneously, leading to correlated errors. Without this adjustment, standard errors could be underestimated, leading to inflated t-statistics (Cameron and Miller, 2015).

3.2.2 – Regression Analysis Using Fixed Effects Model

To further explore the relationship between uncertainty in ECB policy accounts and bond yield spreads, we employ a fixed effects regression model with country fixed effects. This model allows us to control for unobserved characteristics of each EMU country that might influence their bond yield spreads, such as institutional quality, political stability, or fiscal rules. The fixed effects model is specified as follows:

$$CAR_{it} = \beta_0 + \beta_1 \cdot UncertaintyProportion_t + \gamma_i + \ \varphi X_{it} + \epsilon_{it} \qquad (4)$$

Here $UncertaintyProportion_t$ captures our main independent variable of interest which is the proportion of uncertain sentences in the ECB policy account release corresponding to the event at time t. The term φX_{it} controls for country specific time-varying confondounders and time-varying confounders that are identical across all countries. These confounders include the control variables listed above. Finally, γ_i controls for country specific time-invariant factors for country i, and $\epsilon_{it}$is the error term.

The use of fixed effects is justified because the uncertainty measure varies across time but not across countries for a given event (since all countries are exposed to the same ECB account release). Thus, country fixed effects control for any unobserved heterogeneity across countries, allowing the analysis to focus on the impact of the time-varying uncertainty measure.

Model Diagnostics and Testing Assumptions

Heteroskedasticity, autocorrelation, and cross-sectional dependence can undermine the validity of our results by affecting the accuracy of standard errors and, consequently, hypothesis testing. Heteroskedasticity occurs when the variance of residuals is not constant across observations, leading to inconsistent standard errors (Greene, 2003). Autocorrelation arises when residuals are correlated over time, resulting in inefficient estimates and biased standard errors. Cross-sectional dependence, common in panel data, occurs when residuals are correlated across countries, potentially biasing standard errors as well. To address these issues, the Breusch-Pagan test is used to detect heteroscedasticity (Greene, 2003, pg. 224), and the Breusch-Godfrey test is applied to identify autocorrelation (Breusch, 1978). Both tests returned statistically significant p-values, with both being statistically significant at all conventional levels, therefore rejecting the null hypothesis of homoscedasticity and no autocorrelation. Pesaran’s CD test is further employed to detect cross-sectional dependence (Pesaran, 2004); however, the p-value is insignificant, therefore no issues with cross-sectional dependence is detected. To correct for heteroscedasticity and autocorrelation, cluster-robust standard errors are used (Cameron and Miller, 2015).

Subset Analysis: Covid-19 Pandemic and Ukraine Invasion Periods

To further explore the robustness of our findings, subset analyses are performed focusing on two major global events: the Covid-19 pandemic and the Ukraine invasion. The Covid-19 pandemic subset includes the period from March 1, 2020, to October 31, 2021, covering the first year a half of the Covid-19 pandemic, and includes 13 events. This period represents the initial shock and uncertainity surrounding the Covid-19 pandemic, making it a crucial test case for the relationship between ECB communication uncertainty and sovereign risk. Similarly, the Ukraine invasion subset spans from November 1, 2021, to November 1, 2023, and includes 16 events. This time period is chosen to reflect the impact of geopolitical tensions on Eurozone economies and sovereign risk perceptions due to rising energy prices and the subsequent inflation that was caused by the invasion (Checherita-Westphal and Dorrucci, 2023).

By comparing the effects of uncertainty on bond yield spreads during these critical periods with the overall sample, we assess whether the relationship between ECB communication uncertainty and market reactions is amplified or attenuated during times of heightened global uncertainty. To do so we create indicator variables for the events within the time periods defined above and create subsets of the data on which we perform country fixed effects estimation.

4 Findings

4.1 – Event Study Analysis

To assess the immediate impact of the European Central Bank's (ECB) monetary policy account releases on sovereign bond markets, we conducted an event study analyzing the average cumulative abnormal returns (CARs) for 16 Eurozone countries. Table 2 below presents the CARs for each country across three event windows: [-5, +5], [-2, +2], and [-1, +1] with the event date being t_0.

Table 2: Average CARs per Country

Country	Event Window		
	[-5,+5]	[-1,+1]	[-2,+2]
Austria	-0.0013 (0.892)	-0.005 (0.2177)	0.0002 (0.9743)
Belgium	0.0002 (0.9811)	0.0025 (0.3333)	0.0036 (0.2943)
Cyprus	0.0218 (0.4152)	0.0153 (0.2241)	0.0085 (0.6224)
Finland	-0.0013 (0.8248)	0.0006 (0.8002)	0.0016 (0.6205)
France	0.0011 (0.8971)	-0.0058 (0.1223)	0.0051 (0.3678)
Greece	-0.0344 (0.5842)	0.0153 (0.4877)	0.0053 (0.9209)
Ireland	0.0064 (0.5551)	0.0104 (0.113)	0.0103 (0.1766)
Italy	0.0039 (0.7542)	0.0068 (0.3432)	0.0031 (0.7089)
Latvia	-0.015 (0.3291)	-0.0072 (0.3958)	-0.0154 (0.1327)
Luxembourg	-0.0057 (0.5609)	-0.0043 (0.2584)	0.0064 (0.4559)
Malta	0.0055 (0.5988)	-0.0019 (0.668)	0.0053 (0.396)
Netherlands	0.0032 (0.7231)	-0.0012 (0.7317)	-0.0037 (0.4925)
Portugal	0.0045 (0.7872)	0.0142 (0.079)	0.0068 (0.5535)
Slovakia	-0.0019 (0.9359)	0.0044 (0.5093)	0.0092 (0.3103)
Slovenia	-0.0111 (0.6526)	-0.0066 (0.5102)	0.0044 (0.8368)
Spain	-0.0035 (0.7211)	-0.0034 (0.55)	-0.0064 (0.3414)

Note: CAR values are displayed with p-values in parentheses. Statistically significant values are shown in bold.

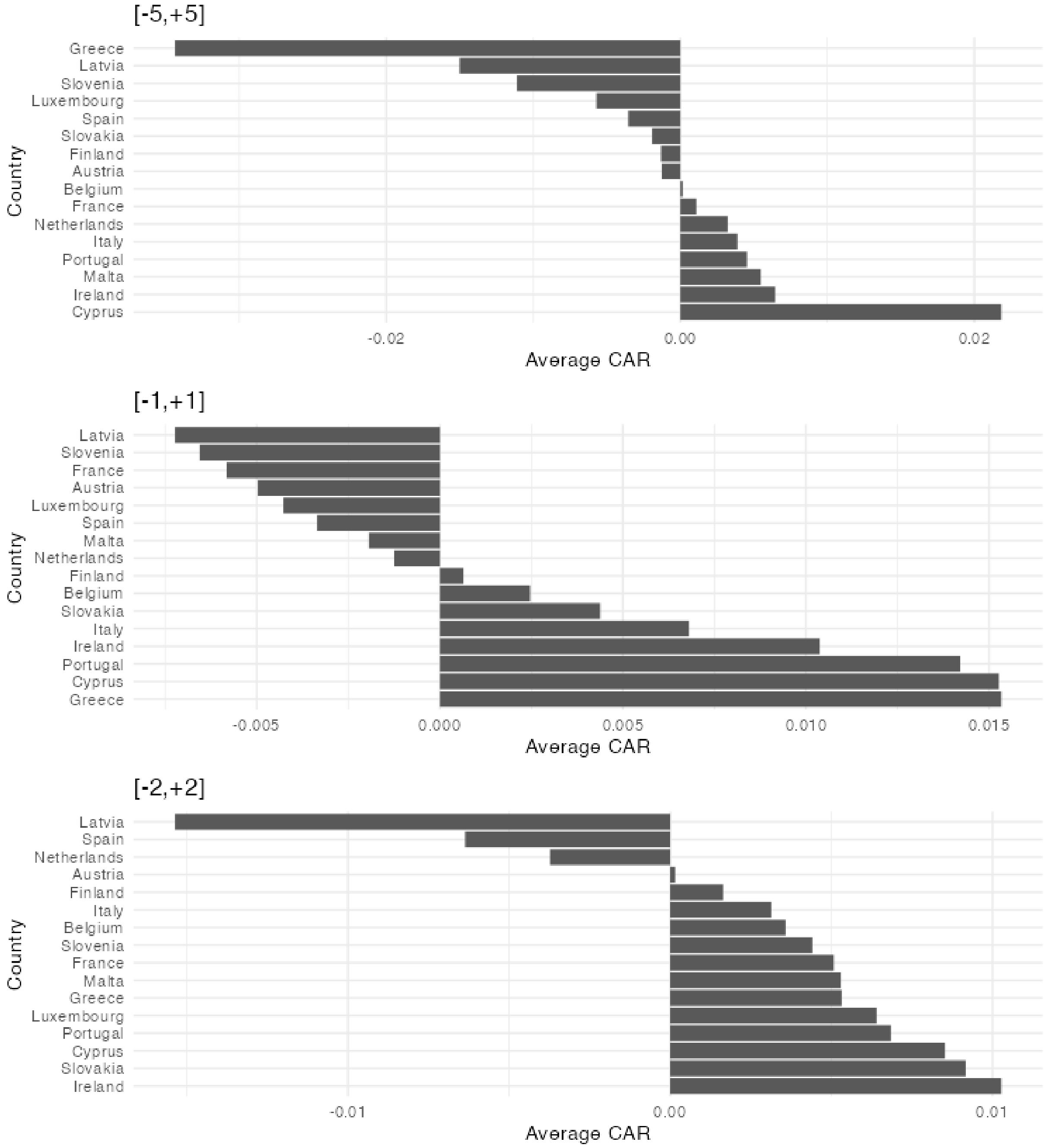
The CARs represent the cumulative effect of the ECB's policy releases on 10-year government bond yield spreads. Positive CARs indicate an increase in yields beyond expectations (implying heightened perceived risk), while negative CARs suggest a decrease or smaller-than-expected increase.

Across most countries, the CARs are close to zero and not statistically significant, indicating minimal immediate impact from the ECB's communications. For example, Austria's CARs range from -0.0050 to -0.0002 with high p-values, showing no significant effect. Similar patterns are observed for Belgium, Finland, France, and the Netherlands.

Notably, Portugal exhibits a marginally significant CAR of 0.0142 ($p = 0.079$) in the [-1, +1] window, suggesting a potential short-term increase in perceived sovereign risk following the ECB's policy releases. Ireland also shows higher CARs in shorter windows, though they are not statistically significant at conventional levels.

In summary, the event study indicates that the ECB's monetary policy account releases do not have a uniform or strong immediate effect on the sovereign bond yields of Eurozone countries. Any observed impacts are limited and may be influenced by country-specific factors rather than a broad market response. Figure 3 below further graphically shows the average event effects on the 16 countries studied.

Figure 3: Average CARs per Country



Following the country-specific analysis, we examine the impact of individual European Central Bank (ECB) monetary policy account releases on sovereign bond yields across all countries. Table 3 below presents the average CARs for these specific event dates across the relevant event windows, and only shows those which where statistically significant (p-value < 0.05). Events and event windows without statistically significant CARs are omitted from the table.

Table with all the average CARs across all countries for the individual events is shown in Table C in Appendix C.

Table 3: Significant CARs per Event

Event Date	[-5,+5]	[-1,+1]	[-2,+2]
2016-01-14		0.0579 (0.0294)	
2016-10-06		-0.0385 (0.0483)	-0.0634 (0.0272)
2019-02-21	-0.0501 (0.0146)		
2019-11-21	0.0396 (0.027)		
2020-02-20		-0.0182 (0.0059)	
2020-05-22		-0.0197 (0.0499)	
2020-08-20		0.017 (0.0395)	
2021-02-18		0.0177 (0.0458)	
2021-04-08		0.0136 (0.0076)	
2022-01-20	0.0836 (0.0154)		0.0503 (0.0219)
2022-05-19		-0.0147 (0.0492)	
2022-11-24	0.0472 (0.0493)		
2023-06-01		0.0267 (0.0392)	
2023-08-31			-0.0292 (0.0307)
2023-11-23		0.0214 (0.0301)	
2024-02-22		-0.0152 (0.0257)	

Note: Note: CAR values are displayed with p-values in parentheses. CAR values are averages across all countries per event

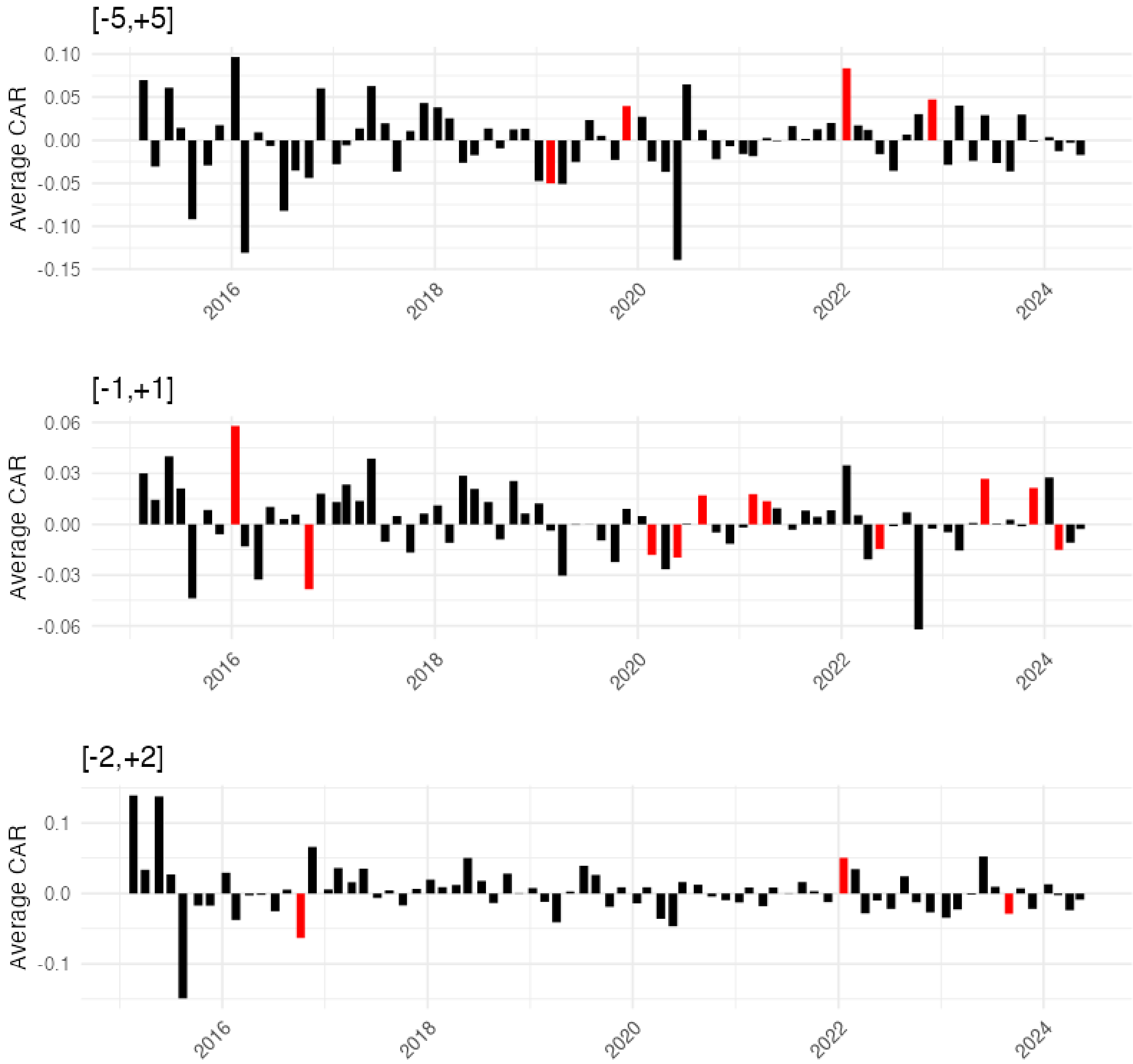
Table 3 lists 16 event dates between 2016 and 2024 where the ECB's communications significantly affected 10-year government bond yield spreads. For each event, only the event windows with significant CARs are shown.

For example, on January 14, 2016, a significant positive CAR of 0.0579 (p = 0.0294) was observed over the [-5, +5] window, suggesting that the ECB's communication led to an increase in bond yields beyond expectations, possibly reflecting heightened perceived risk. Conversely, on October 6, 2016, significant negative CARs in the [-1, +1] and [-2, +2] windows indicate a decrease in yields, potentially signaling improved investor confidence following the policy release.

The direction and magnitude of significant CARs vary across events, reflecting differing market reactions to the ECB's communications. Positive CARs, such as those on November 21, 2019, imply increased yields and perhaps elevated uncertainty or risk perception. Negative CARs, like those on February 21, 2019, suggest a reduction in yields and possibly enhanced market confidence.

These findings demonstrate that while the ECB's monetary policy account releases do not consistently impact sovereign bond yields across all events, specific communications can significantly influence market perceptions and investor behavior at certain times.
Figure 4 below shows a graphical representation of these values, with the statistically signficant events shown in red, to try to visualize any pattern across time. However, as is shown, this is not the case and there is no discernable pattern present.

Figure 4: Average CARs per Event



Overall, while some event dates show statistically significant effects, there is no statistically significant evidence of monetary policy accounts having a sizable impact on sovereign yield spread changes across the 16 EMU countries. Furthermore, there is no evidence of the events having a discernable trend of effects over time.

4.2 – Fixed Effects Analysis

Following the event study analysis, we employed a fixed effects regression model with country fixed effects to examine the relationship between the Proportion of Uncertain Sentences in the ECB's monetary policy accounts and the cumulative abnormal returns (CARs) of 10-year government bond yield spreads. Table 4 presents the results for all event dates, while Table 5 and Table 6 focus on the subsamples during the Covid-19 pandemic and the Ukraine invasion, respectively. Each table includes three models corresponding to the different event windows: [-1, +1], [-2, +2], and [-5, +5].

In Table 4, the coefficients for the Proportion of Uncertain Sentences are positive across all event windows – 0.006 for [-1, +1], 0.064 for [-2, +2], and 0.014 for [-5, +5]. However, none of these coefficients are statistically significant. This suggests that the level of uncertainty in the ECB's communications does not have a significant effect on the abnormal changes in sovereign bond yield spreads in the immediate aftermath of policy releases, however the coefficients show a movement in the predicted direction, where higher proportions of uncertainty lead to wider sovereign yield spreads.

Table 4: Fixed Effects Model with Country Fixed Effects

	Dependent variable:		
	CAR		
	[-1,+1]	[-2,+2]	[-5,+5]
Proportion of Uncertain Sentences	0.006 (0.050)	0.064 (0.113)	0.014 (0.123)
HICP	-0.0002 (0.001)	-0.002 (0.002)	-0.0005 (0.002)
Industrial Production Growth	-0.0004 (0.0003)	-0.001 (0.001)	-0.002** (0.001)
Real Effective Exchange Rate	-0.0003 (0.001)	0.001 (0.003)	-0.001 (0.003)
Unemployment Rate	0.005* (0.003)	0.005 (0.008)	0.002 (0.009)
Current Account Balance	0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)
Government Deficit (% of GDP)	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)
Total Debt (% of GDP)	0.001 (0.0004)	0.001 (0.001)	-0.0003 (0.001)
Total Debt Securities Issued	0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)
Short Term Debt Securities Issued	0.00000 (0.00000)	0.00000** (0.00000)	0.00000 (0.00000)
STOXX50 Volatility Index	-0.001 (0.001)	-0.001 (0.001)	0.001 (0.002)
VIX Index	0.002* (0.001)	0.002 (0.001)	0.002 (0.003)
Crude Oil Volatility Index	0.0003 (0.0004)	0.0005 (0.001)	-0.0001 (0.001)
Crude Oil Prices: Brent - Europe	0.0003 (0.0003)	0.001* (0.001)	0.001 (0.001)
CISS	-0.111*** (0.033)	-0.124** (0.048)	-0.167** (0.072)
US-Germany Yield Spread	0.007 (0.010)	0.015 (0.018)	0.012 (0.027)
Observations	1,237	1,237	1,237
R^2	0.033	0.020	0.013
Adjusted R^2	0.004	-0.010	-0.016
F Statistic (df = 20; 1200)	1.318	1.631**	1.193

Note: Table presents results of Country Fixed Effects Estimation using cluster robust standard errors to account for serial correlation and heteroscedasticity. Significance Levels: *p<0.1; **p<0.05; ***p<0.01

Among the control variables, the CISS (Composite Indicator of Systemic Stress), representing global financial conditions, has negative and statistically significant coefficients in all event windows: -0.111 for [-1, +1], -0.124 for [-2, +2], and -0.167 for [-5, +5]. This indicates that higher systemic stress is associated with lower CARs, however, this effect is counter intuitive as we would expect more financial stress to be associated with widening yield spreads. The Unemployment Rate, a macroeconomic factor, shows a positive and significant coefficient at the 95% confidence level in the [-1, +1] window (0.005), suggesting that higher unemployment rates are associated with higher CARs in the immediate reaction to the monetary policy account. This may reflect increased perceived sovereign risk during times of economic weakness. Industrial Production Growth, another macroeconomic indicator, has a negative and statistically significant coefficient at the 99% confidence level in the [-5, +5] window (-0.002). This implies that lower industrial production growth is associated with higher CARs over a longer horizon, indicating that declining industrial activity may elevate concerns about debt sustainability. The VIX Index, representing global market volatility, shows a positive and significant coefficient in the [-1, +1] window (0.002). This suggests that increased global market volatility is associated with higher CARs in the short term, reflecting heightened risk aversion among investors. Similarly, the Crude Oil Prices: Brent - Europe, a global economic indicator, has a positive and significant coefficient in the [-2, +2] window (0.001). This suggests that rising oil prices may contribute to higher CARs, possibly due to concerns about inflationary pressures affecting economic stability.

Other control variables, such as HICP (inflation rate), Government Deficit, and Total Debt, do not show statistically significant effects in any event window and show minimal effect sizes. This indicates that fiscal discipline and debt sustainability factors may not have an immediate impact on abnormal yield spread changes in response to ECB communications.

For model fit statistics, the R^2 values are relatively low across all event windows – 0.033 for [-1, +1], 0.020 for [-2, +2], and 0.013 for [-5, +5] – suggesting that the models explain a modest proportion of the variation in CARs. The F-statistics indicate that only the model for the [-2, +2] window is statistically significant overall (F = 1.631**), implying that the included variables jointly explain some of the variation in CARs during this event window.

In Table 5 below, focusing on the Covid-19 period, the Proportion of Uncertain Sentences has positive coefficients for the [-1,+1] and [-2,+2] event windows, with the largest in the [-2, +2] window (0.159), and a negative coefficient for the [-5,+5] event window. However, these coefficients remain statistically insignificant, suggesting that uncertainty in ECB communications did not significantly affect CARs during the pandemic. Regardless, the coefficients show that the effect of uncertainty during this time dissipates after a few days of the release of the monetary policy account.

Significant control variables include Industrial Production Growth, shows a negative and statistically significant coefficient in the [-2, +2] window (-0.001) [-5, +5] window (-0.003), however, again the effect size is minimal. This indicates that lower industrial production growth is associated with higher CARs over the longer event window, reflecting increased perceived risk during periods of economic slowdown. The Crude Oil Volatility Index and Crude Oil prices, have negative and significant coefficients in the [-1, +1] window (-0.002 and -0.001 respectively) windows, however, the effect size is again minimal and contrary to whatis expected. Similarly, the coefficient for Total Debt Securities Issued and Short Term Debt Securities are statistically significant, but effectively 0. Furthermore, the coefficient on US-Germany yield spreads is negative and statistically significant in the [-1,+1] window, showing a unit decrease in the US-Germany yield spreads leads to a 0.056 increase in the CAR values of that event window, implying an improvement in the German 10-year Bunds as a safe asset which is competitive with the US 10 year treasury yield. This implies that during periods where investors are more likely to show actions of flight-to-safety, such as during the Covid-19 pandemic with increasing global financial stress, when the 10 year German Bunds becomes more competitive with the US 10 year treasury bill, investors demand higher risk premia to hold other EMU sovereign bonds compared to the safer german bond.

Table 5: Fixed Effects Model with Country Fixed Effects for Covid-19

	Dependent variable:		
	CAR		
	[-1,+1]	[-2,+2]	[-5,+5]
Proportion of Uncertain Sentences	0.082 (0.103)	0.159 (0.103)	-0.089 (0.119)
HICP	-0.002 (0.002)	-0.0005 (0.004)	0.008 (0.007)
Industrial Production Growth	-0.001 (0.0004)	-0.001* (0.001)	-0.003* (0.002)
Real Effective Exchange Rate	-0.003 (0.003)	-0.005 (0.007)	-0.005 (0.009)
Unemployment Rate	-0.008 (0.005)	-0.005 (0.004)	0.012 (0.009)
Current Account Balance	0.00000 (0.00000)	-0.00000 (0.00000)	0.00000 (0.00000)
Government Deficit (% of GDP)	-0.0003 (0.001)	-0.002 (0.001)	-0.004 (0.003)
Total Debt (% of GDP)	-0.0004 (0.001)	0.0003 (0.001)	-0.001 (0.002)
Total Debt Securities Issued	0.00000* (0.00000)	0.00000 (0.00000)	0.00000 (0.00000)
Short Term Debt Securities Issued	-0.00000** (0.00000)	0.00000 (0.00000)	0.00000* (0.00000)
STOXX50 Volatility Index	0.007 (0.004)	0.0005 (0.006)	0.005 (0.007)
VIX Index	-0.004 (0.004)	0.004 (0.005)	0.001 (0.008)
Crude Oil Volatility Index	-0.002* (0.001)	-0.002 (0.002)	-0.001 (0.002)
Crude Oil Prices: Brent - Europe	-0.001* (0.001)	0.001 (0.001)	-0.0005 (0.002)
CISS	-0.015 (0.089)	-0.004 (0.219)	-0.291 (0.196)
US-Germany Yield Spread	-0.056* (0.030)	0.014 (0.045)	0.018 (0.062)
Observations	221	221	221
R^2	0.156	0.177	0.102
Adjusted R^2	0.012	0.037	-0.051
F Statistic (df = 16; 188)	92.370***	451.183***	98.048***

Note: Table presents results of Country Fixed Effects Estimation using cluster robust standard errors to account for serial correlation and heteroscedasticity. Significance Levels: *p<0.1; **p<0.05; ***p<0.01

In Table 6 below, during the Ukraine invasion period, the Proportion of Uncertain Sentences shows a negative coefficient in the [-1, +1] window (-0.207), and positive coefficients in the [-2, +2] (0.079) and [-5, +5] (0.042) windows. However, none of these coefficients are statistically significant. This indicates that uncertainty in ECB communications did not have a significant effect on CARs in this subsample, likely implying the stronger influence of factors related to the geopolitical conflict.

Table 6: Fixed Effects Model with Country Fixed Effects for the Ukraine Invasion

	Dependent variable:		
	CAR		
	[-1,+1]	[-2,+2]	[-5,+5]
Proportion of Uncertain Sentences	-0.207 (0.141)	0.079 (0.227)	0.042 (0.289)
HICP	-0.005* (0.003)	-0.002 (0.004)	-0.003 (0.006)
Industrial Production Growth	-0.0001 (0.0002)	0.0004 (0.0003)	0.0001 (0.001)
Real Effective Exchange Rate	0.007 (0.005)	0.009 (0.007)	0.002 (0.011)
Unemployment Rate	0.019 (0.015)	0.014 (0.022)	-0.020 (0.028)
Current Account Balance	0.00000 (0.00000)	-0.00000 (0.00000)	0.00000 (0.00000)
Government Deficit (% of GDP)	-0.002 (0.002)	-0.005** (0.002)	-0.001 (0.002)
Total Debt (% of GDP)	-0.0004 (0.002)	0.001 (0.003)	-0.002 (0.004)
Total Debt Securities Issued	-0.00000 (0.00000)	-0.00000** (0.00000)	-0.00000 (0.00000)
Short Term Debt Securities Issued	0.00000 (0.00000)	0.00000** (0.00000)	0.00000 (0.00000)
STOXX50 Volatility Index	-0.005 (0.003)	-0.004 (0.003)	0.002 (0.005)
VIX Index	-0.004 (0.003)	0.005 (0.004)	0.007 (0.007)
Crude Oil Volatility Index	0.002 (0.002)	0.003 (0.002)	-0.002 (0.004)
Crude Oil Prices: Brent - Europe	0.003** (0.001)	-0.0001 (0.001)	-0.002 (0.002)
CISS	-0.047 (0.065)	-0.108 (0.089)	-0.063 (0.167)
US-Germany Yield Spread	0.021 (0.015)	0.047 (0.040)	-0.015 (0.052)
Observations	268	268	268
R^2	0.144	0.110	0.034
Adjusted R^2	0.027	-0.011	-0.097
F Statistic (df = 16; 235)	3.733***	114.131***	243.670***

Note: Table presents results of Country Fixed Effects Estimation using cluster robust standard errors to account for serial correlation and heteroscedasticity. Significance Levels: *p<0.1; **p<0.05; ***p<0.01

This is shown in the coefficient for the Crude Oil Prices: Brent - Europe, which exhibits a positive and statistically significant coefficient in the [-1, +1] window (0.003), indicating that higher oil prices are associated with higher CARs, reflecting increased perceived risk due to inflationary pressures or supply concerns stemming from geopolitical events. Other significant control variables in this period include the Harmonized Index of Consumer Prices (HICP), which has a negative and significant coefficient in the [-1, +1] window (-0.005). This suggests that higher inflation rates are associated with lower CARs in the short term. Government deficit shows a negative and statistically significant coefficient in the [-2,+2] window (-0.005), however, again the direction of this coefficient is counter intuitive, where it shows that poorer fiscal discipline leads to lower sovereign yield spreads. This relationship could be explained by the fact that investors believed in stronger economic performance due to higher public spending. Additioanally, both Total and Short-term Debt Securities issued show statistically significant coefficients in the [-2, +2] window, however, the effect sizes are again effectively 0.

Overall, across all tables and event windows, the coefficients for the proportion of uncertain sentences are not statistically significant. This suggests that uncertainty in the ECB's monetary policy communications does not have a significant immediate impact on the sovereign bond yield spreads of Eurozone countries, and that investors place higher importance on macroeconomic and global factors in assessing sovereign debt risk.

Macroeconomic Factors, more specifically variables like the Unemployment Rate and Industrial Production Growth show significant associations with CARs. Higher unemployment rates are linked to higher CARs in the short to medium term, while lower industrial production growth is associated with higher CARs over longer windows. These findings indicate that domestic economic conditions are influential in determining sovereign debt risk.

Global indicators such as the CISS, Crude Oil Volatility Index, and Crude Oil Prices demonstrate significant effects on CARs. For instance, higher systemic stress as measured by the CISS is associated with lower CARs. Rising crude oil prices correlate with higher CARs, reflecting concerns about inflation and economic stability due to energy costs.

The Current Account Balance and Government Deficit show marginal significance in some models, indicating that fiscal health plays a role in investor perceptions of sovereign risk, although their impact is less consistent compared to macroeconomic and global factors.

5 Discussion

The objective of this study was to examine the impact of uncertainty in the European Central Bank's (ECB) monetary policy accounts on the sovereign yield spreads of Eurozone countries. By conducting an event study analysis and employing fixed effects regression models, we aimed to test three hypotheses: (H1) that monetary policy accounts have a statistically significant impact on perceptions of defualt risk, measured through sovereign yield spreads; (H2) that a higher proportion of uncertain sentences in monetary policy accounts increases sovereign yield spreads; and (H3) that the effects of uncertainty are more pronounced during periods of heightened systemic stress, such as the Covid-19 pandemic and the Ukraine invasion.

5.1 – Impact of Monetary Policy Accounts on Sovereign Yield Spreads

Our event study analysis revealed that, across most Eurozone countries, the cumulative abnormal returns (CARs) associated with the release of the ECB's monetary policy accounts were close to zero and not statistically significant. This finding suggests that the policy accounts did not have a uniform or strong immediate effect on EMU sovereign bond yields, thus failing to provide robust support for Hypothesis 1, leading us to be unable to reject the null hypothesis of no effect being present.

Notably, Portugal exhibited a marginally significant positive CAR in the [-1, +1] event window, however only at 90% confidence level, indicating a potential short-term increase in perceived sovereign risk following the ECB's policy releases. Ireland also showed higher CARs in shorter windows, though these were not statistically significant at conventional levels. These country-specific reactions imply that certain nations may be more sensitive to ECB communications due to unique economic or fiscal conditions. However, the lack of consistent and significant effects across the majority of countries suggests that the ECB's monetary policy accounts did not elicit strong market responses in terms of sovereign yield spread movements.

These findings align with the literature that questions the immediate market impact of central bank communications when they do not convey new or unexpected information. Blinder et al. (2008) argue that the effectiveness of central bank communication depends on its ability to influence market expectations. If the policy accounts largely reiterate previously known information or the market has already priced in expected policy actions, the release may not significantly affect bond yields. This further aligns with the EMH, which argues that investors' decisions fully reflect all available information (Fama, 1970).

5.2 – Influence of Uncertainty in ECB Communications

The fixed effects regression analysis focused on assessing whether the proportion of uncertain sentences in the ECB's monetary policy accounts influenced sovereign yield spreads. Across all event windows and subsamples, the coefficients for the proportion of uncertain sentences were not statistically significant. Although the coefficients were positive in most cases – indicating a direction consistent with Hypothesis 2 – the lack of statistical significance suggests that uncertainty in the ECB's communications did not increase risk of sovereign default, as the proportion of uncertain sentences does not have a meaningful impact on the abnormal changes in sovereign bond yield spreads.

This result contrasts with previous studies that have found significant effects of central bank communication uncertainty on financial markets. Hansen and McMahon (2016) demonstrated that increased uncertainty in central bank communications can elevate risk premiums and affect investor confidence. Our findings suggest that, at least in the context of the ECB's monetary policy accounts, the level of linguistic uncertainty may not be a critical factor influencing investor behavior in sovereign debt markets.

One possible explanation is that investors may differentiate between different communication channels of the ECB. The monetary policy accounts, while detailed, are released with a delay and may not contain immediate policy signals compared to press conferences or policy statements. As Ehrmann and Fratzscher (2007) note, the timeliness and clarity of communication are crucial for market impact. Investors might prioritize more immediate sources of information, thereby diminishing the influence of uncertainty within the accounts.

5.3 – Effects During Periods of Heightened Systemic Stress

In examining the subsamples for the Covid-19 pandemic and the Ukraine invasion, we aimed to test Hypothesis 3, which stated that the effects of uncertainty in the ECB's communications would be more pronounced during times of heightened systemic stress. The analysis showed that, even during these periods, the proportion of uncertain sentences did not have a statistically significant effect on sovereign yield spreads.

During the Covid-19 pandemic, although the coefficients for uncertainty were positive in the [-1, +1] and [-2, +2] event windows, they remained statistically insignificant. Similarly, during the Ukraine invasion period, the coefficients were not significant, and the direction of the effect varied across event windows. These findings suggest that, contrary to our hypothesis, uncertainty in ECB communications did not have an amplified impact on sovereign debt risk during periods of elevated systemic stress.

This result may indicate that, in times of crisis, investors focus more on tangible economic indicators and immediate policy actions rather than the nuances of central bank communication. Bloom (2009) highlights that uncertainty shocks can have significant negative effects on economic activity and increase market volatility. However, our findings imply that the uncertainty conveyed through ECB monetary policy accounts does not significantly contribute to such effects in sovereign bond markets during crises.

5.4 – Importance of Macroeconomic and Global Factors

The analysis revealed that macroeconomic and global factors played a more substantial role in influencing sovereign yield spreads. Variables such as the unemployment rate, industrial production growth, the VIX Index, and crude oil prices showed statistically significant associations with CARs in various event windows.

The unemployment rate exhibited a positive and significant effect in the [-1, +1] window, indicating that higher unemployment rates are associated with higher sovereign yield spreads. This finding aligns with the notion that deteriorating domestic economic conditions heighten perceived sovereign risk (Afonso et al., 2015, Manganelli and Wolswijk, 2009). Similarly, lower industrial production growth was associated with higher CARs over longer event windows, reflecting concerns about economic slowdown and its impact on debt sustainability.

Global financial conditions, as captured by the VIX Index and crude oil prices, also significantly influenced sovereign yield spreads. The positive association between the VIX Index and CARs suggests that increased global market volatility leads investors to demand higher risk premiums on sovereign bonds. Rising crude oil prices were associated with higher CARs, possibly due to fears of inflationary pressures and their adverse effects on economic stability (Filippidis et al., 2020).

Interestingly, the Composite Indicator of Systemic Stress (CISS) consistently showed a negative and significant relationship with CARs across all event windows. This counterintuitive result suggests that higher systemic stress is associated with lower sovereign yield spreads. One possible explanation is a flight-to-quality phenomenon, where investors, during times of systemic stress, shift investments toward sovereign bonds perceived as safer assets, thereby lowering yields. However, during times of higher financial and systemic stress, while we would expect the flight-to-quality phenomonen, we would noramlly expect it to be director towards safer assets such as the 10 year German Bunds. De Grauwe and Ji (2013) discuss how investor behavior during crises can lead to such effects, particularly within the Eurozone where core countries' bonds are viewed as safe havens.

5.5 – Implications and Contributions to the Literature

The findings of this study contribute to the ongoing discourse on the efficacy of central bank communication and its influence on financial markets. While previous literature has established that central bank communications can impact asset prices (De Santis, 2012; Hansen & McMahon, 2016), our results suggest that the uncertainty within the ECB's monetary policy accounts does not significantly affect sovereign yield spreads, highlighting the nuanced effects of linguistics on investors perceptions.

This study highlights the possibility that the market may not heavily weigh the uncertainty in policy accounts, possibly due to their delayed release or because they do not provide new information beyond what is already disseminated through other channels. It underscores the importance of the content and timing of communication, supporting the arguments of Blinder et al. (2008) regarding effective central bank communication.

Moreover, the stronger influence of macroeconomic and global factors suggests that investors prioritize fundamental economic indicators over central bank language when assessing sovereign debt risk. This aligns with the Efficient Market Hypothesis (Fama, 1970), which posits that markets are efficient in processing available information, and supports the idea that observable economic data may overshadow the effects of communication uncertainty.

6 Limitations

This study acknowledges several key limitations, particularly concerning the use of large language models (LLMs) to classify uncertainty in European Central Bank (ECB) monetary policy accounts. While LLMs are powerful tools capable of processing and labeling vast amounts of textual data, they are not free from prediction errors. Even with relatively high accuracy rates, these errors are not purely random; they can systematically correlate with variables used in subsequent analyses. Ignoring such prediction errors introduces bias into the results, leading to distorted estimates, invalid confidence intervals, and inaccurate p-values (Egami et al., 2023). This issue is especially relevant in our context, where the uncertainty in ECB communications might have been misclassified due to the limited accuracy of the model used for classifying sentences (an accuracy of 79%). This potential misclassification could have contributed to our findings of no statistically significant effects on sovereign yield spreads.

We attempted to address this limitation by combining both gold-standard expert labels and LLM-generated labels when constructing our training dataset. However, we did not implement the "bias-corrected pseudo outcomes" method as defined by Egami et al. (2023, p. 6). The Design-Based Supervised Learning (DSL) method offers a robust approach to mitigate this issue. DSL combines large-scale automated annotations from LLMs with a smaller set of expert-coded labels, employing a doubly robust procedure that corrects for bias in the automated labels. This ensures valid statistical inference even when the surrogate predictions from LLMs are imperfect. By integrating automated and expert-coded labels, DSL provides more reliable estimates and accurate confidence intervals, particularly in studies like ours that rely on text-based variables in downstream statistical analyses (Egami et al., 2023). Had DSL been applied in this study, it might have reduced the measurement error associated with our LLM-generated uncertainty classifications, enhancing the robustness of our findings.

Additionally, our study focuses on 16 Eurozone countries, which may differ in their sensitivity to ECB communications due to variations in economic conditions, fiscal policies, and levels of financial market development. These heterogeneities could lead to country-specific responses that are obscured when aggregate results are considered. While some countries, such as Portugal, showed marginally significant results in our event study, the broader findings suggest that ECB communications did not have a uniformly significant impact across the Eurozone. This aligns with Beetsma et al. (2013), who highlight that political and economic differences among Eurozone countries can lead to divergent market reactions. Future research should explore these country-specific factors more deeply, potentially focusing on individual countries to better understand how economic and fiscal conditions shape the impact of central bank communications.

The temporal scope of our study also introduces limitations. Although we accounted for significant economic disruptions like the Covid-19 pandemic and the Ukraine invasion, further analysis is needed to explore how unconventional monetary policies implemented during these periods interacted with ECB communication strategies. Such policies, including quantitative easing and emergency liquidity measures, may have influenced the effects of ECB communications in ways that were not fully captured in this study. Fratzscher et al. (2016) emphasize that the ECB's unconventional monetary policies can have significant market impacts and international spillovers. Future research could delve into the communication strategies of these unconventional monetary policies specifically, to better understand their combined effects on sovereign risk perceptions, especially given the uncertainty surrounding their effectiveness due to their relatively recent introduction (Gambetti & Musso, 2017).

Overall, while this study provides important insights into the relationship between uncertainty in ECB communications and sovereign yield spreads, the use of LLMs without bias correction introduces a significant limitation. The application of the DSL method could have improved the accuracy and reliability of our results by addressing measurement error in our text-based variables. Moreover, the varying sensitivities of different Eurozone countries to ECB communications and the complexities introduced by unconventional monetary policies during crises warrant further investigation. Future research addressing these areas would enhance the understanding of central bank communication's impact on financial markets and sovereign risk perceptions.

7 Conclusion

This study investigated the impact of uncertainty in the European Central Bank's monetary policy accounts on the sovereign yield spreads of Eurozone countries. By employing event study analysis and fixed effects regression models, we examined whether the proportion of uncertain sentences in the ECB's communications influenced perceptions of sovereign risk, particularly during periods of heightened systemic stress such as the Covid-19 pandemic and the Ukraine invasion.

Our findings indicate that uncertainty in the ECB's monetary policy accounts does not have a statistically significant effect on sovereign yield spreads. This suggests that investors may not heavily weigh the linguistic uncertainty in these communications when assessing sovereign debt risk. Instead, macroeconomic indicators and global financial conditions, such as unemployment rates, industrial production growth, and market volatility indices, play a more significant role in influencing bond yields.

These results imply that while central bank communication is essential, the uncertainty conveyed through delayed and detailed channels like the monetary policy accounts may not substantially impact market perceptions in the sovereign debt market. Investors appear to prioritize immediate economic data and more timely policy signals.
Future research could explore the impact of uncertainty in other forms of central bank communication, such as press conferences or policy statements, which may have a more immediate effect on markets. Additionally, employing advanced textual analysis methods with bias correction, such as the Design-Based Supervised Learning method, could enhance the accuracy of uncertainty measurements and provide deeper insights into how

communication affects financial markets. Excluding this aspect from this study is a major limitation.

Appendix

GitHub Repository with all code and data sets used:

https://github.com/jjonas313/MSsDSPP_DISSERTATION_GLSL3/tree/main

Appendix A – Uncertainty Measure Creation

A1 – LLM Prompt:

"""
You are a highly qualified expert trained to annotate machine learning training data.

Your task is to analyze the uncertainty in the TEXT below from an economic researcher or investor perspective and label it with only one of the two labels: uncertain or certain.

Label the TEXT as uncertain if it includes any indication of doubt, ambiguity, or speculation, such as the use of words or phrases like "could," "might," "should," "possibly," "perhaps," "seem," "likely," "unlikely," "appears," "unclear," "uncertain,"
or hedging language like "it is believed that" or "expected to." Additionally, label a sentence as uncertain if it presents mixed signals, conflicting indicators, or any suggestions where outcomes are not definitively stated. A sentence should also be
labeled uncertain if it reflects on potential scenarios or outcomes that depend on multiple variables, future events, or missing information. However, even with uncertainty-related words, if the sentence presents a clear factual base, strong consensus,
or a well-established truth that remains uncontested, it should be examined closely to ensure the overall context justifies an uncertain label.

Label the TEXT as certain if it expresses a clear, definitive conclusion, or presents information without any indication of doubt. Sentences should be labeled certain if they describe actions, events, or decisions that are presented as factual, concrete,
or based on widely accepted knowledge. Even if a sentence discusses future events, if it is rooted in strong factual statements, well-supported projections, or universal truths, and does not leave room for ambiguity, it should be considered certain.
Additionally, sentences that outline specific outcomes, results, or actions that are not contingent on unknown variables, or that reflect a consensus or widely acknowledged view, should be labeled as certain.

Consider carefully whether any hedging or speculative language is actually present before labeling as uncertain. Be attentive to the difference between discussing multiple possibilities (uncertain) and presenting a well-grounded interpretation of current data or trends (certain).

Base your label decision only on the TEXT and avoid speculation beyond what is explicitly stated.

You first reason step by step about the correct label and then return your label.

You ALWAYS respond only in the following JSON format: {{"reason": "...", "label": "..."}}
You only respond with one single JSON response.

Examples:
Text: Looking ahead, survey-based measures of inflation expectations had declined.
JSON response: {{"reason": "The text states a definitive and observed fact about the decline in survey-based measures of inflation expectations", "label": "certain"}}
Text: Ms Schnabel reviewed the latest financial market developments.
JSON response: {{"reason": "The text simply describes an action without providing any evaluative information or indicating the outcome of the review", "label": "certain"}}
Text: The latest indicators on trade gave mixed signals while pointing overall towards broad stabilisation.
JSON response: {{"reason": "The text acknowledges mixed signals from trade indicators, indicating ambiguity and a lack of definitive conclusion", "label": "uncertain"}}
Text: Moreover, it remained to be seen by how much indirect effects would contribute to a further rise in core inflation over time.
JSON response: {{"reason": "The text mentions that contribution of indirect effects on core inflation are yet to be seen and are unknown, indicating uncertainty and a lack of definitive conclusion", "label": "uncertain"}}

Your TEXT to analyse:
TEXT: {text}
JSON response: """

A2 – LLM Generation Parameters

Table A.1: Generation Parameters

Parameter	Value
top_p	0.9
top_k	None
temperature	0.4
repetition_penalty	1
do_sample	TRUE
max_new_tokens	512
return_full_text	FALSE
max_time	None
stream	FALSE
details	FALSE
use_cache	FALSE
wait_for_model	FALSE

A2 – AutoTrain LM Training Parameters:

Table A.2: Training Parameters

Parameter	Value
top_p	0.9
top_k	None
temperature	0.4
repetition_penalty	1
do_sample	TRUE
max_new_tokens	512
return_full_text	FALSE
max_time	None
stream	FALSE
details	FALSE
use_cache	FALSE
wait_for_model	FALSE

A3 – FineTuned Language Models

Table A.3: Models Finetuned

Model
DistilRoBERTa-base
DistilBERT-base-uncased
DeBERTaV3-large
BERT-base-uncased
DistilRoberta-financial-sentiment
FinBERT
XLM-RoBERTa-large

[a] Multinomial Niave Bayes Classifier specified in R.

Appendix B – Data Collection

B1 – Variable descriptions

Table B: Variable descriptions and links

Variable	Description	Source
yield_spreads	Yield spreads calculated using Eurostat's Maastricht Treaty EMU convergence criterion series. These represent bond yields for EMU countries with maturities around 10 years. German yields used as benchmark.	Eurostat
proportion_uncertain	Proportion of uncertain words in the ECB Monetary Policy Accounts	ECB
hicp	Harmonized Index of Consumer Prices (HICP) - Index 2015 = 100	Eurostat
industrial_production_growth	Industrial production growth - percentage change on previous period	Eurostat
reer	Real effective exchange rate (REER) - deflated by consumer price index (CPI)	Eurostat
unemp_rate	Unemployment rate - percentage of total labor force	Eurostat
current_account_balance_million_euro	Current account balance - in million euros	Eurostat
deficit_percent_gdp	General government deficit as a percentage of GDP	Eurostat
debt_total_percent_gdp	General government debt as a percentage of GDP	Eurostat
debt_securities	General government debt securities issued - Liabilities, transactions (flow of debt securities)	Eurostat
short_term_debt_securities	General government short-term debt securities - Liabilities, transactions (flow of debt securities)	Eurostat
v2tx	V2TX volatility index	STOXX
vix	VIX volatility index	FRED
ovx	CBOE Crude Oil volatility index	FRED
brent_price	Crude Oil Prices: Brent - Europe	FRED
ciss	Composite Indicator of Systemic Stress (CISS)	ECB Data Portal
yield_spread_US_D	Yield spread between 10-year German government bonds and 10-year US Treasury bonds	FRED/Bundesbank

Appendix C – Findings

C1 – Individual Event CARs across all Countries

Table C: Average CARs per Event across Countries

Event Date	[-5,+5]	[-1,+1]	[-2,+2]
2015-02-19	0.07 (0.3413)	0.0301 (0.2768)	0.1395 (0.2033)
2015-04-02	-0.0307 (0.7119)	0.0144 (0.4864)	0.0334 (0.0601)
2015-05-21	0.0612 (0.6662)	0.0401 (0.1145)	0.1381 (0.2328)
2015-07-02	0.0144 (0.7776)	0.0211 (0.471)	0.0269 (0.2241)
2015-08-13	-0.0919 (0.6114)	-0.0438 (0.4827)	-0.1491 (0.4442)
2015-10-08	-0.0294 (0.198)	0.0084 (0.54)	-0.017 (0.3278)
2015-11-19	0.0175 (0.6195)	-0.0061 (0.756)	-0.0171 (0.3632)
2016-01-14	0.0966 (0.4336)	0.0579 (0.0294)	0.0292 (0.3868)
2016-02-18	-0.1306 (0.124)	-0.0132 (0.6832)	-0.038 (0.5169)
2016-04-07	0.0093 (0.8644)	-0.0326 (0.0799)	-0.0027 (0.9314)
2016-05-19	-0.0064 (0.8431)	0.0102 (0.7091)	-0.002 (0.9351)
2016-07-07	-0.0823 (0.1945)	0.0031 (0.7967)	-0.0255 (0.3941)
2016-08-18	-0.0353 (0.4286)	0.0058 (0.7319)	0.0055 (0.8726)
2016-10-06	-0.0438 (0.1281)	-0.0385 (0.0483)	-0.0634 (0.0272)
2016-11-17	0.0605 (0.084)	0.018 (0.4703)	0.0663 (0.071)
2017-01-12	-0.0279 (0.3789)	0.0131 (0.4666)	0.0057 (0.7976)
2017-02-16	-0.0057 (0.9314)	0.0233 (0.3041)	0.0359 (0.3237)
2017-04-06	0.0137 (0.7354)	0.0137 (0.4044)	0.0159 (0.1888)
2017-05-18	0.0631 (0.4201)	0.0388 (0.1033)	0.035 (0.1812)
2017-07-06	0.0197 (0.414)	-0.0105 (0.6131)	-0.0063 (0.7571)
2017-08-17	-0.0364 (0.0915)	0.0049 (0.6589)	0.0044 (0.4497)
2017-10-05	0.0108 (0.6851)	-0.0168 (0.0894)	-0.0168 (0.2696)
2017-11-23	0.0431 (0.2611)	0.0063 (0.5453)	0.0065 (0.6958)
2018-01-11	0.038 (0.2961)	0.0111 (0.7056)	0.0196 (0.5092)
2018-02-22	0.0255 (0.4764)	-0.0111 (0.5033)	0.0089 (0.4209)
2018-04-12	-0.0263 (0.2358)	0.0285 (0.5323)	0.012 (0.632)
2018-05-24	-0.0176 (0.7349)	0.0208 (0.3676)	0.05 (0.3232)
2018-07-12	0.0137 (0.5719)	0.0131 (0.273)	0.0177 (0.2423)
2018-08-23	-0.0097 (0.7994)	-0.0091 (0.3278)	-0.0134 (0.4301)
2018-10-11	0.0126 (0.6019)	0.0254 (0.403)	0.028 (0.3917)
2018-11-22	0.0135 (0.4536)	0.0064 (0.5441)	0.0006 (0.9693)
2019-01-10	-0.0474 (0.1815)	0.0122 (0.3121)	0.0077 (0.6069)
2019-02-21	-0.0501 (0.0146)	-0.0039 (0.6843)	-0.0117 (0.4402)
2019-04-04	-0.0508 (0.2812)	-0.0303 (0.1087)	-0.0413 (0.1039)
2019-05-23	-0.0255 (0.5284)	-0.0003 (0.9721)	0.0029 (0.8127)
2019-07-11	0.0234 (0.5237)	0.0001 (0.9926)	0.0391 (0.1592)
2019-08-22	0.0053 (0.8988)	-0.0097 (0.3955)	0.0261 (0.064)

Note: Note: CAR values are displayed with p-values in parentheses. CAR values are averaged across all countries per event

Table C - Continued

Event Date	[-5,+5]	[-1,+1]	[-2,+2]
2019-10-10	-0.023 (0.1716)	-0.0224 (0.0535)	-0.0188 (0.0669)
2019-11-21	0.0396 (0.027)	0.0091 (0.2973)	0.0087 (0.3853)
2020-01-16	0.0272 (0.1615)	0.0049 (0.499)	-0.0139 (0.2688)
2020-02-20	-0.0246 (0.4206)	-0.0182 (0.0059)	0.0088 (0.7905)
2020-04-09	-0.0368 (0.313)	-0.0266 (0.2282)	-0.0363 (0.0706)
2020-05-22	-0.1394 (0.1128)	-0.0197 (0.0499)	-0.0468 (0.063)
2020-06-25	0.065 (0.0555)	0.0004 (0.9766)	0.0161 (0.2567)
2020-08-20	0.0121 (0.3232)	0.017 (0.0395)	0.0124 (0.2024)
2020-10-08	-0.0222 (0.0949)	-0.005 (0.488)	-0.0044 (0.5707)
2020-11-26	-0.0068 (0.6793)	-0.0116 (0.113)	-0.0094 (0.2257)
2021-01-14	-0.0162 (0.2871)	-0.0018 (0.8377)	-0.0126 (0.2666)
2021-02-18	-0.0187 (0.2066)	0.0177 (0.0458)	0.0085 (0.5483)
2021-04-08	0.0027 (0.8611)	0.0136 (0.0076)	-0.0178 (0.2695)
2021-05-14	-0.0008 (0.932)	0.0094 (0.516)	0.0084 (0.4518)
2021-07-09	0.0165 (0.2544)	-0.0034 (0.5374)	0.0005 (0.9281)
2021-08-26	0.0016 (0.9113)	0.0081 (0.3489)	0.0161 (0.1568)
2021-10-07	0.0129 (0.2508)	0.0045 (0.3561)	0.0033 (0.7337)
2021-11-25	0.0201 (0.061)	0.0083 (0.4763)	-0.0122 (0.1873)
2022-01-20	0.0836 (0.0154)	0.0349 (0.0556)	0.0503 (0.0219)
2022-03-03	0.0172 (0.6939)	0.0053 (0.6824)	0.0343 (0.1178)
2022-04-07	0.0121 (0.6341)	-0.0208 (0.1561)	-0.0287 (0.1135)
2022-05-19	-0.0164 (0.4847)	-0.0147 (0.0492)	-0.0099 (0.2906)
2022-07-07	-0.0357 (0.197)	-0.0011 (0.9293)	-0.0217 (0.6212)
2022-08-25	0.0066 (0.8434)	0.0071 (0.5519)	0.0242 (0.0825)
2022-10-06	0.0302 (0.456)	-0.0621 (0.1405)	-0.0124 (0.6539)
2022-11-24	0.0472 (0.0493)	-0.0028 (0.8295)	-0.0273 (0.1603)
2023-01-19	-0.0287 (0.3799)	-0.0049 (0.7136)	-0.0349 (0.2721)
2023-03-02	0.0402 (0.2256)	-0.0156 (0.1517)	-0.0225 (0.1782)
2023-04-20	-0.0241 (0.3185)	0.0009 (0.9388)	-0.0016 (0.9141)
2023-06-01	0.029 (0.3043)	0.0267 (0.0392)	0.0526 (0.0529)
2023-07-13	-0.0266 (0.3241)	0.0004 (0.9707)	0.0095 (0.4144)
2023-08-31	-0.0363 (0.2814)	0.0028 (0.8431)	-0.0292 (0.0307)
2023-10-12	0.0297 (0.2408)	-0.0011 (0.9147)	0.0072 (0.68)
2023-11-23	-0.0015 (0.9326)	0.0214 (0.0301)	-0.0217 (0.2188)
2024-01-18	0.0038 (0.8961)	0.0275 (0.0887)	0.0131 (0.3408)
2024-02-22	-0.0129 (0.336)	-0.0152 (0.0257)	-0.0024 (0.7564)
2024-04-04	-0.0027 (0.8931)	-0.011 (0.0932)	-0.0235 (0.1895)
2024-05-10	-0.0174 (0.1236)	-0.003 (0.6713)	-0.0087 (0.3339)

Note: Note: CAR values are displayed with p-values in parentheses. CAR values are averaged across all countries per event

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