1. Sentiment Analysis of Central Bank Monetary Policy Communication

1.1 Data

Our dataset comprises a collection of speeches from the institutional website of the most four important central banks of the world, Federal Reserve, European Central Bank (ECB), Bank of England (BoE), and Bank of Japan (BoJ). Generally, speeches can vary in their format, depending on the event at which the speech is delivered. The most original contribution of this section is the evaluation of time-varying connectedness and spillover effects and the construction of a sentiment index. For example, we find that the Federal Reserve influences the other Central Banks for the whole period of analysis, with an increasing magnitude after the Great Recession, proving its "leading role". After the European debt crisis, the ECB increased its relevance, whereas the BoE gradually reduced it. Finally, the BoJ seems to have a lower impact on other central banks' communication.

Pre-processing

After having prepared the dataset with raw data in *.txt* format, we apply a set of text mining techniques following the literature in the field of Natural Language Processing (Silge and Robinson, 2017). Such transformations are necessary to process the documents. In detail, the raw data are converted into a text-corpus. We clean the text by converting it to lowercase and then removing numbers, extra spaces, punctuation, and regular expressions. A stemming algorithm is also applied to eliminate common suffixes and prefixes. Finally, we tokenize the text, that is, the text is categorized in blocks readable by the software. After this pre-processing phase, we achieve a document-term matrix, which is used to calculate the indicator.

In Figures 2-5 we show the Central Bank Sentiment Index (hereafter CBSI) time series and highlight global, such as the Great Recession and the beginning of the Covid-19 crisis (dotted lines) and governor's time in office. In Table 2 we see the number of documents analyzed for each central bank.

Table 1. Composition of our dataset

|	Fed	ECB	BoE	BoJ
Total	237	478	123	228
Yearly average	19	30	9	16

1.2 Introduction

Central bank communication has evolved over the years as an important component of monetary policy design and execution. According to Blinder et al., (2008), central bank communication refers to the quantity and quality of information made available to the public regarding the central bank's monetary policy objectives and strategy; and its perception of the economic outlook as well as signals about future policy trajectory. Thus, the development of

appropriate communication strategies has become popular among central banks, especially as a means of shaping market expectations. As argued by Coenen et al., (2017), the increased popularity of central bank communication derives from the need for greater monetary policy transparency as a strategic requirement for inflation targeting monetary policy framework.

Naghdaliyev (2011) argued that the need to effectively manage expectations constitutes one of the key policy challenges of the post-2008 global financial crisis. He further emphasized that the provision of appropriate information to the public about central bank policy actions helps reduce rather than exacerbate economic uncertainties, thus making central bank communication a primary tool for expectations management.

Figure 1: Central bank's objectives communication
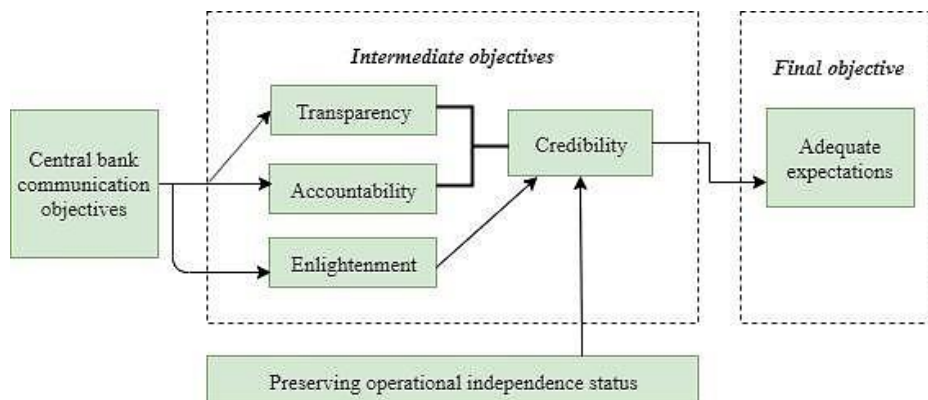

Source: Naghdaliyev (2011)

While the final objective relates to the effective management of expectations, the intermediate objectives of central bank communication should necessarily encompass transparency, accountability, and credibility (Figure 1). Of the three intermediate objectives, credibility is the most crucial, noting that the ability of the central bank to adequately shape expectations rests on its credibility. Thus, the crucial link between central bank communication and central bank credibility represents one of the reasons why communication has become an important aspect of monetary policy.

Several channels are usually adopted for communication, including but not limited to monetary policy reports, minutes of monetary policy meetings, post-meeting briefings by central bank Governors, and speeches by Monetary Policy Committee (MPC) members. Recognizing the crucial roles of central bank communication in monetary policy effectiveness, many central banks have developed communication strategies to systematically disseminate their policy objectives and decisions to the public. For instance, the Governing Council of the European Central Bank holds its monetary policy meeting every six weeks, with the ECB President conducting a press conference after each meeting to explain its monetary policy decisions from a prepared statement, similarly, the FOMC (of the Federal Reserve -FED-) holds eight regularly scheduled meetings per year. At these meetings, the Committee reviews economic and financial conditions to determine the appropriate stance of monetary policy and assesses the risks to its long-run goals of price stability and sustainable economic growth.

Here all the monetary policy documents communicated by governors and published by these central banks were analyzed using text mining tools and it was found that concerns relating to financial stability and economic uncertainties were quite high during the crisis. Studies have examined the relationship between central bank communication and macroeconomic out-turns. For instance, Shapiro and Wilson (2019) applied text mining techniques to analyze the transcripts of the FOMC meetings, the minutes of their meetings as well as speeches of FOMC members for the period 1986-2013. They extracted a measure of monetary policy sentiment from the group of documents considered and showed that FOMC's negative sentiments were inversely related to the United States' output growth.

We contribute to the empirical literature along several dimensions. Following Loughran and McDonald (2011), we construct our own Central Bank Sentiment Indexes, applying text analysis to a novel dataset that comprises releases and speeches published by the Federal Reserve, the European Central Bank, the Bank of England, and the Bank of Japan between 2008 and 2020. In addition, we create word clouds for the fifty most important words for each central bank using the Terms Frequency-Inverse Document Frequency function (Tf-IDF).

Figure 2. Governor's and MPC speeches
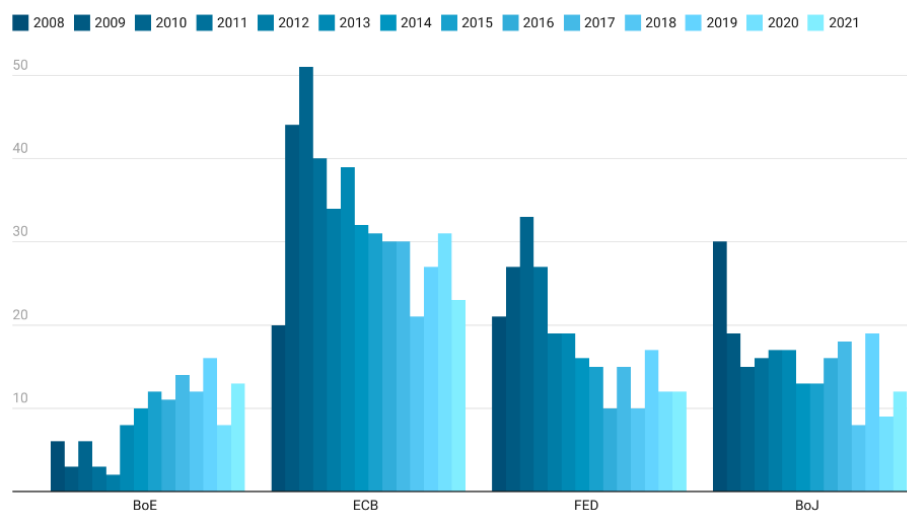
Having processed the textual data into a form suitable for analysis, we examined the readability, and sentiments of the policy documents. While the central banks' communication has decreased over the years, possibly suggesting that monetary policy transparency has not improved over the years. In addition, our results indicate that the words and terms driving the linguistic contents of the communique were influenced by the Bank's policy objectives as well as the nature of shocks hitting the global and local economies.

Analyzing Figure 2, there may be a structural break in the series caused by the Great Recession, and the relative Financial Crisis, to prove this, we consider the average of Governor's communique for each country, for example for the period 2008-2010, the BoE average communique published were 5, and increased considerably for the period 2011-2019 (9) until 11 for 2019-2020, so for the case of the BoE we can say that they increased its transparency. On the contrary, we see the cases of ECB and Fed, for 2008-2010, the ECB published an average of 38 and the Fed 27 communique respectively, for 2011-2019, both institutions decreased the number

of communique, the ECB with an average of 32 and the Fed 16, for the last period, the average decreased too, ECB with an average of 27 and, the Fed with 12. Lastly, the BoJ follows the same declining pattern, for 2008-2010 with an average of 21, for 2011-2019 with 15, and 2020-2021 with only 11.

1.3 Construction of the Sentiment index

This section aims to build and analyze a sentiment analysis model which will allow us to categorize monetary authorities based on their sentiments, that is whether they are positive, negative, and also the magnitude of their tone. This section employs text-mining techniques to analyze the communication strategy of the four world's most important central banks during the period 2008-2021. Since the policy communique released after each meeting of the monetary policy committee (MPC) represents an important tool of central banks communication, we construct a corpus based on 1,066 policy communique: Bank of England (123), Federal Reserve (237), European Central Bank (478) and Bank of Japan (228).

To see if the texts may contain some useful insight to predict the Central Banks interest rate, we use the Loughran and McDonald Sentiment Word List[1] to measure the sentiment of each statement. This dictionary contains several thousand words appearing in textual analysis in accounting and financial documents such as 10K, 10Q. It includes words in different forms, so stemming or lemmatizing should not be applied. We applied a simple technique to flip the sentiment for negation (e.g., can't, isn't, no, etc.).

The opinions and affective states of people reflected in a corpus of textual data can be based on sentiment analysis. The procedure for sentiment analysis involves categorizing the opinion expressed in a document as positive, neutral, or negative. We apply this technique to our corpus data set to study the evolution of monetary policy sentiments as expressed in the policy communique. The monetary policy sentiment score summarizes the perception of the MPC regarding the upside and downside risks to the achievement of each Central Bank's policy objectives.

Following the approach in Binette and Tchebotarev (2019), the central bank's monetary policy net sentiment score (MPSS) for each document in our corpus is derived as:

$$MPSS = \frac{(Npositive - Nnegative)}{NTotal} * 100 \qquad (1)$$

Where $Npostive$ denotes the number of words expressing positive sentiments, $Nnegative$ is the number of words expressing negative sentiments, and $NTotal$ is the total number of words in document. Any positive sentiment term used in a document takes a value superior to 1 while a negative sentiment term takes a value inferior to -1. It is implied in Eq. (1) that a value of MPSS > 0 indicates positive sentiments while MPSS < 0 signifies the expression of negative sentiments. The computed MPSS enables us to derive useful insights regarding the central bank's perception of the direction of change in economic conditions.

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[1] These Loughran and McDonald lexicon makes use of unigrams, unigrams are a type of n-gram model that consists of a sequence of 1 item, that is, a word collected from a given textual data. The Loughran and McDonald model performs an analysis of the shareholder's reports.

1.4 Results of Sentiment Analysis

In Figures 3 and 4, we show the plot of the computed monetary policy net sentiment score (MPSS) for the period 2008 – 2021. The global average MPSS for the period was 0.0496, implying that the MPC was inundated by policy uncertainties generated by various global and domestic economic shocks during the sample period.

Table 2. Sentiment score

Central Bank	Global MPSS	Governors' MPSS		
Bank of England	-0.1109	M. King: -1.323	M. Carney: 0.206	A. Bailey: 0.015
European Central Bank	0.3368	J.C. Trichet: 0.141	M. Draghi: 0.536	Ch. Lagarde: -0.001
Federal Reserve	-0.1496	B. Bernanke: -0.377	J. Yellen: 0.181	J. Powell: 0.151
Bank of Japan	0.1224	T. Fukui: 0.752	M. Shirakawa: -0.502	H. Kuroda: 0.553

Note. – The monetary policy sentiment score is the average value for each governor and central bank.

Our results show that the FED's policy statements have recorded a less optimistic tone and more certainty to the negative impact of the crisis and economic phenomenon, while the tones of the policy statements published by the ECB and Bank of Japan (BoJ) have remained unchanged and with a more optimistic tone. Being Sir. King was the least optimistic governor (although it is important to consider the number of its documents of 23), while the most optimist was Mr. Draghi.

### Sentiment analysis index and growth

As shown in Figure 3, the issues relating to the impacts of economic shocks on each economy has remained an important source of concern to the monetary authorities, for example, we can show different peaks in the sample, in the first quarter of 2009 the FED, reached the most negative sentiment peak, while the BoE recorded its negative peaks in the second semester of 2016 during the economic recession; while the BoJ recorded its most negative peak during the last quarter of 2008, and finally, the ECB showed its one during the second quarter of 2009.

Our sentiment indicators mimic the general path of economic performance for each country's economy. The lowest points of the sentiment index also coincide with the deteriorating economic outlook during the main economic recessions of the past two decades. For instance, the dip in the MPSS reflects the great recession (hat occurred between 2007 and 2009). For example, the lowest BoE's MPSS, which was recorded in July 2016 reflects the MPC's perception regarding the potential risks to the attainment of its policy objectives concerning interest rates, and economic growth, which was 0.44%.

On the other hand, the BoE's MPSS record two peaks in the first quarter of 2016, and the second quarter of 2019 with the MPC expressing its satisfaction with the performance of the economy, especially with regards to economic growth (of 0.54%). While the BoJ peaked in the

third quarter of 2016, the Fed show its peak in the last quarter of 2016, last, the ECB recorded its peak one year later, at the end of 2017.

Figure 3. Economic growth and the sentiment index
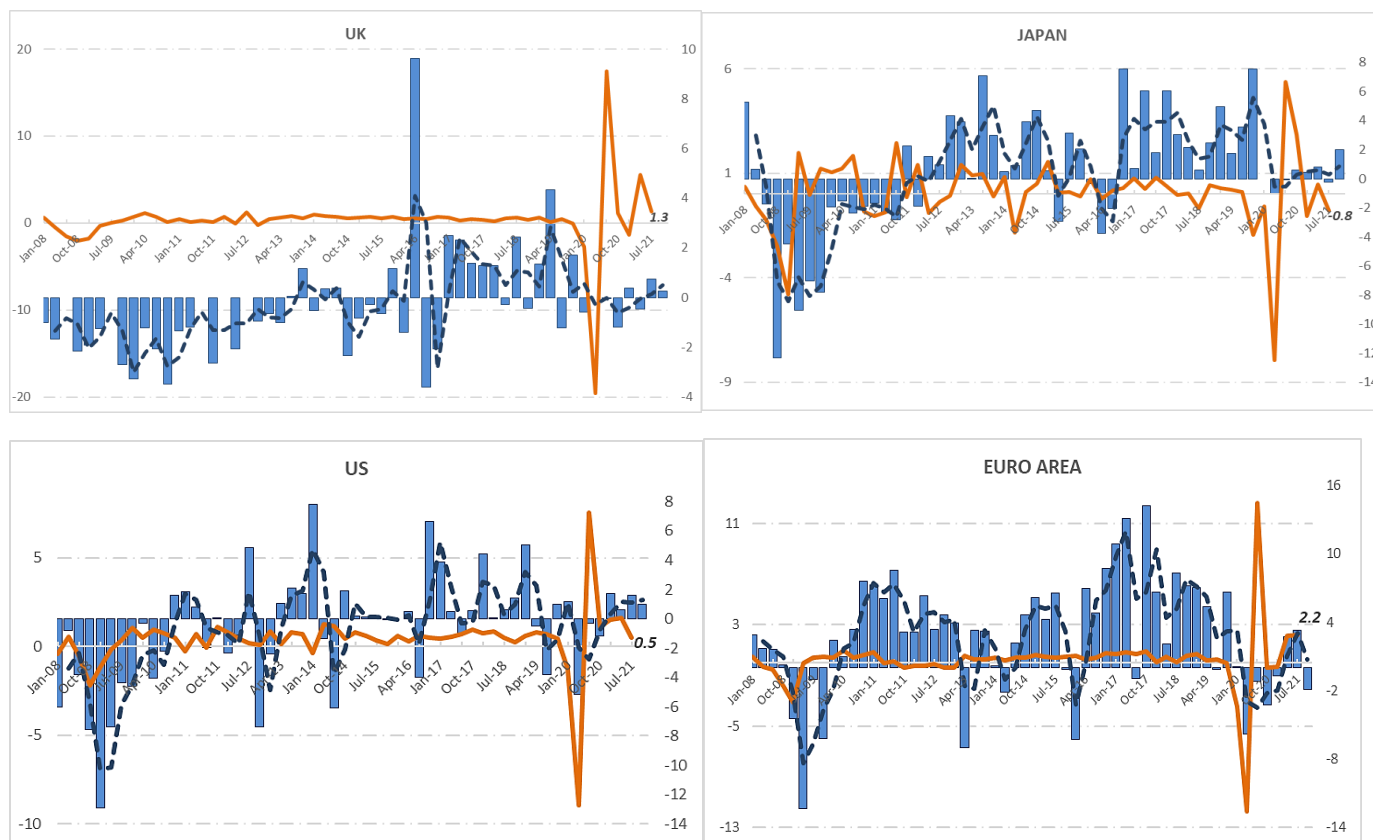
Note. – In the left x-axis the quarterly economic growth rate (in orange) and in the right x-axis, the quarterly sentiment index (in blue), the dashed line represents its moving average (dark blue).

In Table 3 we provide some summary statistics over the sample period (2008-2021) and for two different subsamples, namely the period of the crisis (2008-2010), the subsequent decade (2011-2019), and the COVID-19 period (2020-2021).

Table 3. Summary statistics

|	2008-2010		2011-2019		2020-2021	
	MPSS	GDP growth	MPSS	GDP growth	MPSS	GDP growth
Federal Reserve	-0.6999	-0.04	0.148	1.86	-0.022	-3.64
European Central Bank	0.02	-0.49	0.611	1.06	-0.088	-5.96
Bank of England	-1.4787	-0.79	-0.2386	1.46	-0.0772	-9.69
Bank of Japan	-0.6909	-0.94	0.5035	0.63	0.1148	-4.59

Note. – We consider average values for the MPSS and the GPD growth, GPD growth is represented in percentage.

Studying the above three different periods for the MPSS and the GDP growth, we found that the BoE was the only monetary institution with a negative tone for all subsamples, although England has one of the highest average GDP growth for 2011-2019 of 1.46%, its average MPSS was of -0.239. Considering the Covid-19 period, we see that the BoJ is the only institution with a positive sentiment tone of 0.115, probably this is due that Asian countries having more experience handling massive epidemics.

The MPSS during the Covid-19

During the evolution of the Covid-19, we see that the sentiment expressed by the monetary authorities was uncertain, also it is important to mention that other monetary and economic factors have influenced the communique's tone. The negative MPSS recorded during this period was due to global economic uncertainties and the negative effects of the pandemic.

Figure 3.1. Economic growth and the sentiment index: Covid-19
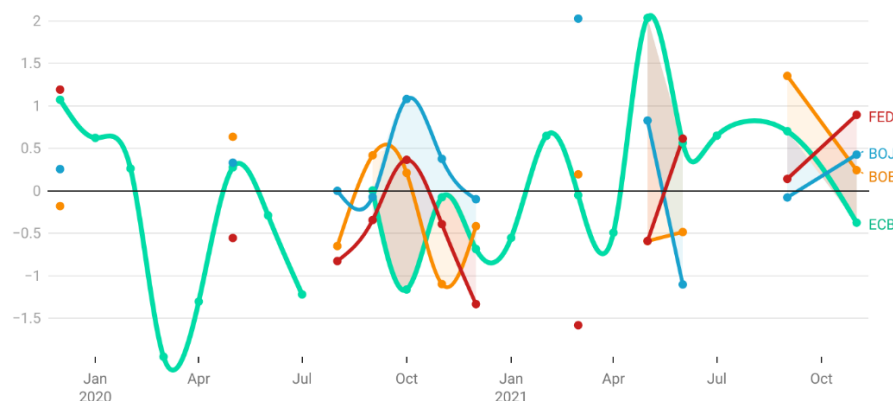
In that way, for example, in Figure 3.2 we will only analyze the topics behind the ECB communique for the last two years (which includes the Covid-19 period), to see which were the most important topics in each Governor's communique.

Figure 3.2. COVID-19: Topics and Word cloud Euro area

For the XX documents selected in the sample, we applied the LDA algorithm for the Topics selection, we only considered the 10 most important topics, and then we graph the Word Cloud, as we can see the most important words were:

| Words	TF-IDF
inflation	0.11692833
pandemic	0.10207315
economic	0.08632163
measures	0.0687651
climate	0.06578374
term	0.06309913
recovery	0.06061861
conditions	0.05929811
growth	0.05733647
support	0.05444348

Reflecting the concerns on growth recovery, support and favorable conditions, green investment, and most important the inflation phenomenon generated by the Covid-19 pandemic.

Comparison between Central Banks

Sentiment analysis of the central bank's communications yields an overview of the total development of its messages over time. In this section, we survey the developmental trajectory of the interest rate and monetary policy sentiments. Developments in the economic condition sentiment index during the 2008-2021 period reveal significant differences between countries.

Hence, for descriptive purposes, we minimize these sentiment index disturbances by using a specific number of moving averages for each country due to the extension of each database. Second, our methodological approach to calculating the sentiment index does not differ between lexicons. Thus, one should compare sentiment index trends and raw absolute numbers too. Also, each plot indicates the date when the interest rate changed due to the introduction of central banks purchasing longer-term securities.

Figure 4.1 BoE: Sentiment analysis evolution
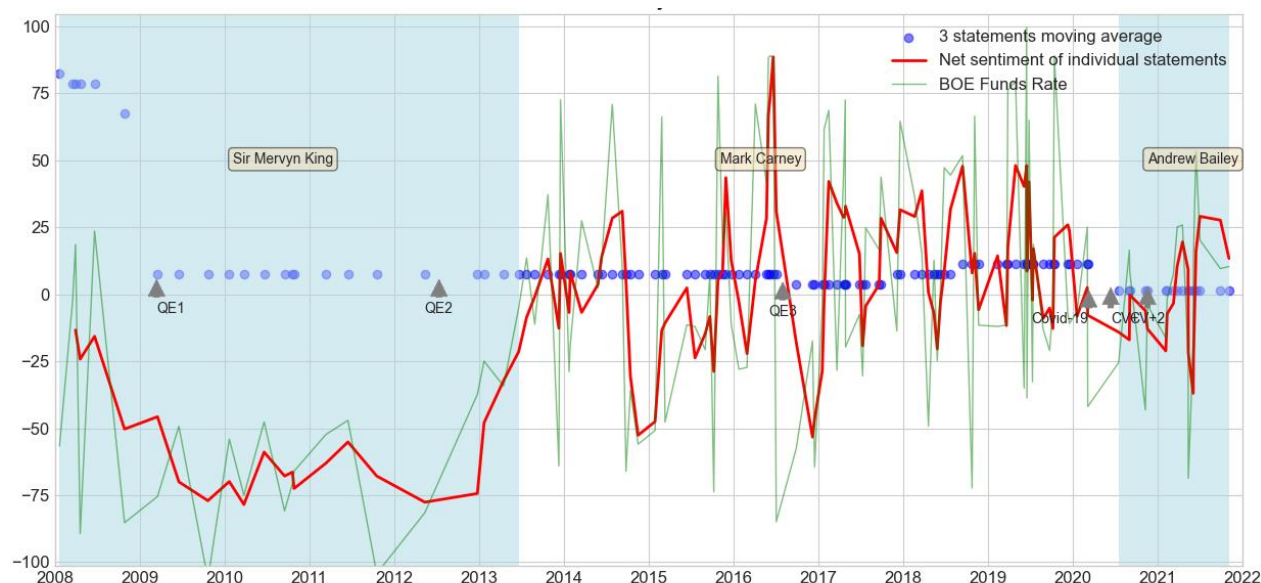
For example, in the Figure 4.1 we can see that the economic sentiment for the BoE communications were pessimist during 2008 and mid-2013, although its tone improved later, in line with the recovery of the euro area in the aftermath of the financial crisis, from 2014 until mid-2019 swaying, with the appearance of Covid-19 the index starts a decline phase until the beginning of 2021.

The ECB's economic sentiment presented a deterioration from 2008 and recovered slightly until mid-2011, after that it showed a constant negative trend registering dips in 2013 and the first quarter of 2016 with the onset of the euro-area financial/debt crisis. The ECB announced a significant downward forecast revision in their press conferences in November 2011. The negative economic outlook during the euro area crisis culminated in mid-2016. In 2017, the economic sentiment started gradually improving again, in line with the onset of the euro area's economic recovery until the appearance of Covid-19, the index faced a dip decline for mid-2021.

On the other hand, for the Fed, Figure 4.3 shows similar developments in the monetary policy sentiment index over the past decade and a half, its evolution shows a similar pattern, with the only difference of the absence of the 2016 dip, regarding the Covid-19, the sentiment index declined in the first quarter of 2019[2]. Finally, in Figure 4.4 the evolution of the index for the BoJ, it shows a negative sentiment during 2008 until 2012, its negative dip was registered at the beginnings of 2009, after 2013, it showed a stable path, and even it shows a more positive tone from 2018 until the appearance of Covid-19, where it followed a negative trend, it doesn't seem to recover an optimistic tone for the following months.

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[2] In 2019 the real gross domestic product (GDP) of the United States increased by 2.2 percent compared to 2018. This rate of annual growth is around the average for the 2010's, although much lower than the rates of around three to five percent seen for much of the decade between 1995 and 2005. It is certain that 2020 will see a dramatic decline in the GDP growth rate due to the coronavirus (COVID-19) pandemic. Initial quarterly projections of Real GDP suggest a fall by as much as 30 percent. Our topic analysis shows the following results: unemployment, recession, financial stress, uncertainty, all these topics are before the start of the Covid-19 pandemic.

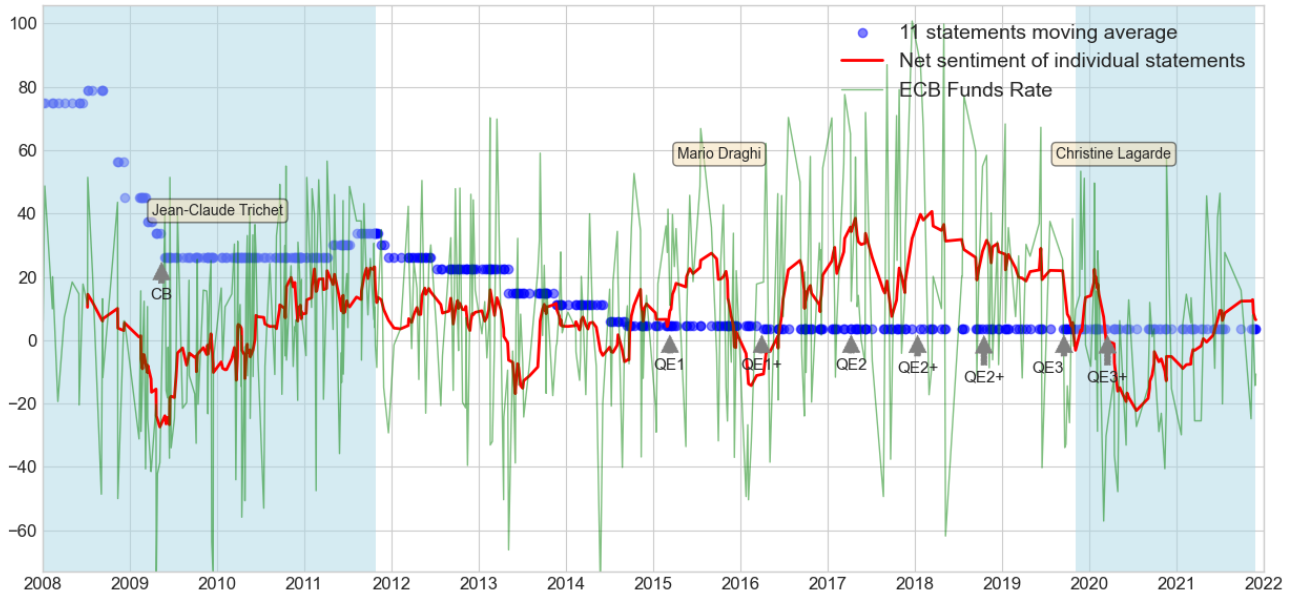Figure 4.2 ECB: Sentiment analysis evolution

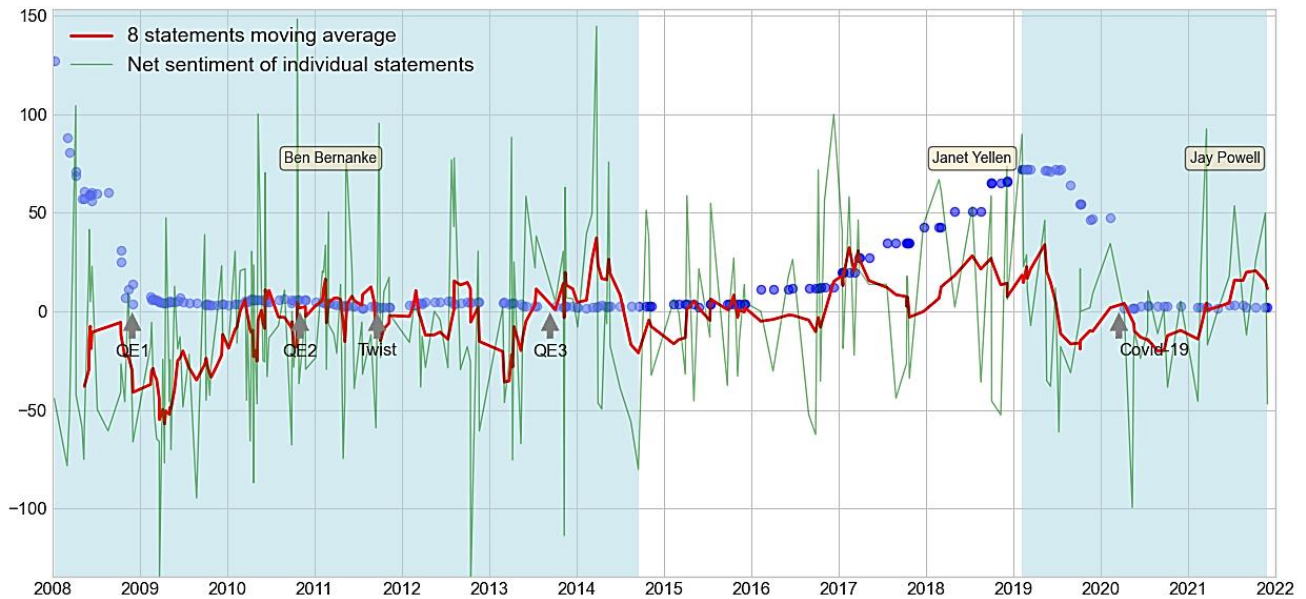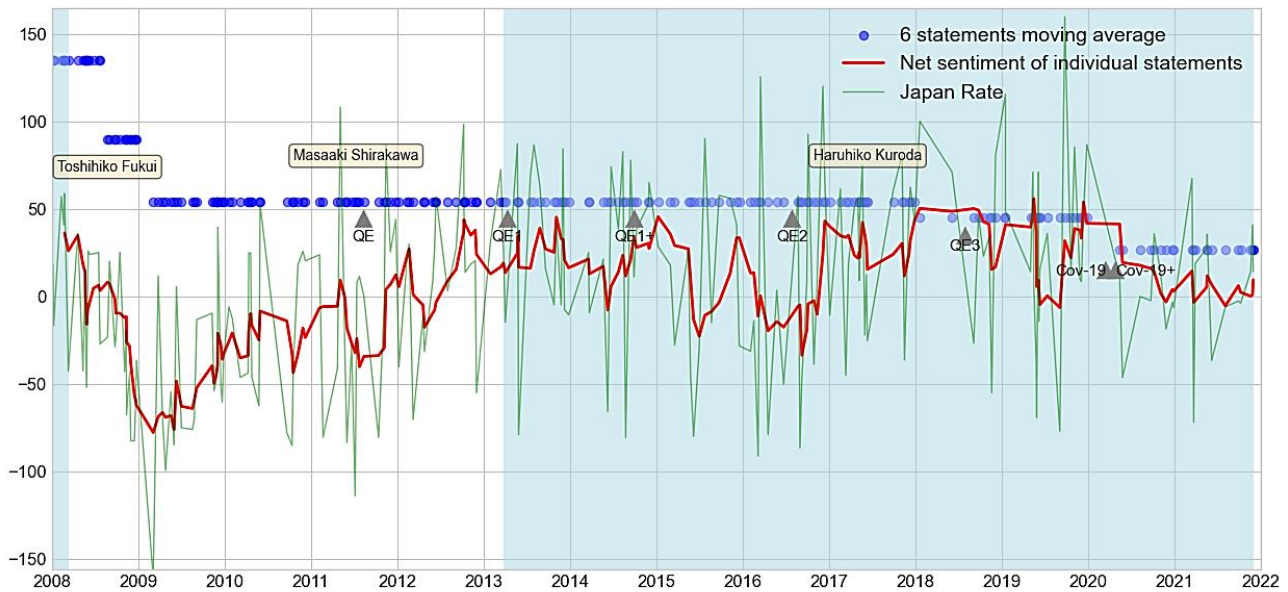Figure 4.3 Fed: Sentiment analysis evolution

Figure 4.4 BoJ: Sentiment analysis evolution

A positive shock to Central Bank communication seems to have a positive and significant impact on the interest rate, but negative on the yield curve slope (consistently with Armelius et al., 2020). The Central Banks' sentiment indexes appear to be connected (with the sole exception of BoE and BoJ) and the most relevant spillovers are between the Fed and the ECB.

This finding could signal a permanent change in communication by central banks: the financial crisis might have induced them to become more cautious when communicating with the public. Releases and speeches are in effect less positive in their content. Moreover, it is important to consider that the recovery from the Great Recession was not synchronized among economic areas, with the Eurozone struggling more than the other countries to return to pre-crisis growth levels. This fact might have contributed to the higher negative impact on ECB sentiment vis-`a-vis other CBS. Despite a lower indicator on average than at the beginning of the period of analysis, the CBSIs improved after the crisis. In particular, the Federal Reserve reached its lowest point in sentiment in 2008 (-0.55), but then sentiment steadily increased in the 2010s. In addition, for the BoE and the BoJ, the CBS improved during the period of economic recovery, although Brexit affected the BoE. This is not the case for the ECB. Indeed, ECB's average CBSI over the period 2011-2019 is even lower than the average for the period 2008-2010. This might be due to the European debt crisis that characterized the years from 2010 to 2015. Finally, it is remarkable the dramatic drop in sentiment for all Central Banks in 2020 following the worldwide spread of the Covid-19 crisis. In particular, ECB's sentiment reached its historical minimum in April 2020 (-0.52).

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