INSTITUTO
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DE LISBOA

Contagion Effect of Quantitative Easing Policies in International Financial Markets

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October,2022

BUSINESS SCHOOL

CIÊNCIAS SOCIAIS E HUMANAS

Department of Economics / Department of Political Economy

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Acknowledgments

First, I would like to express my profound gratitude for all the guidance and support from professors Alexandra Ferreira Lopes and Luís Filipe Martins, their vision and massive knowledge allowed me to search for options and follow paths that I would have not considered on my own. Some of the discussions we had motivated me to keep on pushing and explore different processes and outcomes, which is the basis for an Economics profession.

Also, I would like to thank my girlfriend and my family that helped me navigate through more difficult times, especially when feelings of demotivation and hopelessness started to arise. They reminded me of my goals, and what I am striving for.

At last, I would like to give a kind acknowledgement to all ISCTE professors and staff who strive to make ISCTE a better learning institution and who have accompanied me for the last 5 years.

Resumo

A seguinte dissertação apresenta uma análise dos impactos intra- e inter-regiões dos anúncios de políticas de *Quantitative Easing* (QE) no surgimento de bolhas dos preços nos mercados financeiros internacionais, nomeadamente, dos Estados Unidos da América, Reino Unido, Japão e Zona Euro.

Primeiro, foi realizado o teste *Generalized Supremum Augmented Dickey-Fuller/Backward Supremum Augmented Dickey-Fuller* (GSADF/BSADF) (Phillips et al., 2015) para determinar se houve bolhas nos valores dos preços durante o período entre 1995 a 2021 usando observações diárias de índices de mercados financeiros. Em segundo lugar, foi testado, através de um modelo *Vector Autoregressive* (VAR) usando observações mensais entre 1998 e 2021, se os anúncios de QE estavam a afetar a possibilidade de surgir bolhas nos preços, incluindo adicionalmente para a análise uma série de varáveis de controlo.

Os resultados sugerem que existem períodos de explosividade nos mercados para as quatro regiões a serem analisados, especialmente no período entre 2005 e 2015.

Posteriormente, foi demonstrado que para os mercados dos EUA, existe uma forte evidência que os anúncios diminuem a possibilidade de explosividade dos preços. No entanto, para a Zona Euro e Reino Unido existe alguma evidência do contrário. Nos mercados japoneses não existe evidência de efeitos.

Adicionalmente, em todos os mercados existe evidência de efeitos inter-regionais, sendo o banco central com maior influência o BCE, afetando simultaneamente todas as regiões exceto o Japão.

Por fim, considerando apenas as variáveis de controlo, a taxa de juro é a variável que demonstra maior influência no desenvolvimento de explosividade nos mercados.

Palavras-Chave: Flexibilização quantitativa; Política monetária; Mercados financeiros

Códigos *JEL*: C32; F42

Abstract

The following dissertation will present an analysis of the intra- and inter-regional impacts of the Quantitative Easing (QE) policies announcements on the appearance of price bubbles in the financial international markets, namely, United States of America, United Kingdom, Japan, and Eurozone.

First, we have employed the Generalized Supremum Augmented Dickey-Fuller/Backward Supremum Augmented Dickey-Fuller (GSADF/BSADF) test (Phillips et al., 2015), to determine if there were in fact bubbles being created from 1995 to 2021 using daily observations of financial market indexes. Secondly, using a Vector Autoregressive (VAR) model with monthly observations from 1998 until 2021, we tested if QE announcements were impacting the chance of appearing price bubbles, including additionally for the analysis a set of control variables.

Results suggest that there are several periods of explosivity in the markets for all 4 regions being in scope, especially during the periods between 2005 and 2015.

Secondly, findings show that for the US there is strong evidence that these announcements decrease the chance of price explosiveness. However, in Eurozone and UK there is some evidence of the contrary effect. For Japanese markets there is no evidence of effects. Additionally, for all markets there is clear evidence of cross-regional effects being the most influential central bank the ECB affecting all regions except Japan, giving us the suggestion that the announcements could have widespread repercussions. At last, considering only the control variables, the interest rate is the variable that demonstrates the biggest influence in development of explosivity in the markets.

Keyword*s*: Quantitative easing; Monetary policy; Financial markets

JEL codes: C32; F42

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List of Abbreviations

ADF – Augmented Dickey-Fuller

AIC – Akaike’s Information Criterion

BoE – Bank of England

BoJ – Bank of Japan

BSADF – Backwards Sup Augmented Dickey-Fuller

CDS – Credit Default Swaps

DF-GLS – Dickey-Fuller Generalized Least-Squares

ECB – European Central Bank

EONIA - Euro Overnight Index Average

EUGV – European Government Bonds

ETF – Exchange Traded Funds

Fed – Federal Reserve

FPE – final prediction error

GC – Granger Causality

GSADF - Generalized Sup Augmented Dickey-Fuller

HQIC – Hannan-Quinn Information Criterion

IRF – Impulse Response Function

KPSS – Kwiatkowski–Phillips–Schmidt–Shin

PP – Phillips-Perron

QE – Quantitative Easing

SADF - Supremum Augmented Dickey-Fuller

SBIC – Schwarz's Bayesian Information Criterion

SONIA - Sterling Overnight Index Average

US – United States

UK – Unites Kingdom

1. Introduction

Price stability is one of the main pillars of central bank missions. When this pillar starts to be in danger, some type of intervention is mandatory, to restore values that converge according to the target inflation, and at the same time, provide a framework for economic prosperity. It is possible to achieve this through the conventional methods (control of reference interest rate, act as a lender of last resort). The other option is through unconventional methods, when the prior reveals itself not sufficient, which include actions such as negative interest rates, forward guidance, and the one we will be focusing on in this dissertation, large-scale asset purchases, known as Quantitative Easing (QE) (Fabris, 2018). Since the financial crisis of 2008, QE started to be a very important tool for most central banks and its usage rapidly achieved a popularity status. But its usage did not stop there, being also one important tool in the combat of uncertainty caused by the covid-19 crisis (Grasselli, 2022). Despite being a highly reliable tool for central banks, one important question is left to be answered: if the impact of an announcement of large-scale asset purchase is harming the functioning of the financial markets in the country or region that the policy is targeted, as well as in other financial markets across the globe. More specifically, we want to understand the relationship of QE with the price explosiveness phenomenon in financial markets.

For the study we have considered the QE policies announcements during a period comprised between 1995 and 2021, exerted by four central banks: the Federal Reserve (Fed), the Bank of Japan (BoJ), the Bank of England (BoE), and the European Central Bank (ECB). The financial markets regions' that are the scope of our analysis are the United States, Japan, the United Kingdom, and the Eurozone. Since we also perform a cross-region analysis, we will check the impact, for example, of the ECB policies announcements on the Eurozone, but also on the Japanese, US, and UK financial markets.

Several pieces of research presented results on the impact of unconventional monetary policies on financial markets valuations for the US (Al-Jassar & Moosa, 2019; Šafár & Siničáková, 2019), for Japan (Barbon & Gianinazzi, 2019; Otsubo, 2019), for the Eurozone (Eser & Schwaab, 2016; Albu et al., 2014), and for the UK (Chortareas et al., 2019; Steeley & Matyushkin, 2015). However, research that presents results on the impact on price variations does not help us understand if the effect is really harming the markets. That being said, is necessary to study the bubble formations in markets and test the impacts of the QE policies in shaping this phenomenon, as done in the research by Hudepohl et al. (2021) and van Lamoen et al. (2017) where is tested for 10 Eurozone countries the price explosiveness reaction in financial markets to the ECB's QE policies. However, a significant gap found in the literature was the lack of a single study where it was tested the effects of QE measures announcements by the four most important central banks simultaneously on bubble formations for such a wide and predominant set of financial markets, that include the financial markets for the previous mentioned regions. Given the gap found in the literature, the aim of this study is to understand if there is impact on bubble formation for the US, Japan, Eurozone, and UK financial markets of the Quantitative Easing policies announcements of the 4 central banks mentioned before, and to understand which of the central banks is impacting more each of the markets.

Our results revealed after a study with daily data frequency between 1995 and 2021, that in all financial markets analysed we have observed several explosiveness periods in the timeframe considered, especially between 2005 until 2015 when all markets verified some explosive moments, confirming that most likely some variable or set of variables were causing bubbles in the markets. Results revealed that medium- and short-term interest rates are the endogenous economic variables that more frequently appear as a relevant contributor for the variations observed in price explosiveness dynamics. In terms of the impact of QE announcements on price explosiveness, we can observe a significant amount of cross-region impacts, with Japan being the only region not being impacted by any QE announcement. Based on VAR-type models with monthly frequency data between 1998 and 2021, results suggest different impacts of QE announcements depending on the market, with no impact for Japanese market, negative impact on the US market, positive impact on the Eurozone market, and depending on the specifications of the model, the impact can be positive or negative for the UK market. Research demonstrated that the European Central Bank is the most influential bank, impacting simultaneously the USA, UK, and Eurozone markets when a QE policy is announced and the least influential being the Bank of England with no impact in any market.

The present dissertation is organized as follow: In Section 2, we have the literature review that presents the main research done on the subject so far and that supports some decisions made in the empirical methodology. Section 3 describes the data and develops the methods chosen, namely the method to test explosiveness in the markets and the models used. Section 4 is divided in two main blocks, one of them presenting and analysing the results of our bubble detection test, which outcome allow us to proceed to the economic modelling in the second block, that presents, for each regions' financial markets, the determinants of price explosiveness. Also, on section 4 we have a comparative analysis of the four regions. At last, in Section 5 we present the concluding remarks.

2. Literature Review

2.1. Impact of QE Announcements on Financial Markets

A significant bulk of literature has been dedicated to the study of the impacts of asset purchase programs on the financial markets of the 4 regions that this work will be focusing on, namely the United States, Japan, the Eurozone, and the United Kingdom.

For the US, it was shown, through a maximum likelihood function in a time-varying parametric framework, that the Federal Reserve (Fed)'s Quantitative Easing (QE) policy had a substantial effect on the valuations of the Standards and Poor's (S&P) 500 index, although, the effect is not exclusive, due to the significance of the trend and cycle, which indicate that some missing variables may be affecting the prices (Al-Jassar & Moosa, 2019). It was also presented by Corbet et al. (2019) a study of the market volatility in the S&P500 index surrounding a Federal Reserve QE announcement, using high frequency data. The conclusion was similar, demonstrating that there is an impact shortly after the announcement; being the peak in volatility in the first hour after the announcement. Also, that the entire QE programme in the US studied, seemed to have gained a positive impact reaction from investors and markets. Additionally, with the aim of calculating excess returns on the announcement days for Dow Jones Industrial Average, S&P 500, NASDAQ, and Russell2000, the study from Šafár and Siničáková (2019) suggests that, except for the first announcement of QE measure, all the other announcement days would bring profit with 58% probability, while in 42% of situations we face downside risk. So, these articles show clear evidence of the influence of the Federal Reserve actions in expanding their portfolio on financial markets.

For Japan, was studied the effects of the Exchange Traded Funds (ETF) program by the Bank of Japan (BoJ) initiated on April 2013, using 2000 stocks of TOPIX universe, over a period of 3 years (Barbon & Gianinazzi, 2019). The results suggest a long-lasting effect on Japanese equity prices, with portfolio rebalancing effects, with an estimated magnitude of 20 basis points *per* trillion Yen invested into the program. Other study (Otsubo, 2019), using a time-varying parameter Structural Vector Auto-Regression (VAR), with a period that goes from 2001 to 2015, gathered some interesting conclusions, using impulse response functions, regarding the effects of monetary policy shocks on stock prices (and other variables, not important for the scope of this thesis). Using as a monetary policy variable the current account balance of BoJ, the author presented the impulse response functions of stock prices (Nikkei Stock Average) to a positive monetary policy shock, and found that during the Comprehensive Monetary Easing (CME) period (2001-2006), the stock prices' response was initially positive, but tend to zero as we approach the end of the period, but having a positive and increasing trend towards the end of the first decade of 2000. To notice that the response is never negative during the entire period.

Chortareas et al. (2019) using an event study framework for the UK, regressed log returns of a stock index (in this case FTSE 100 index) over the announcements of QE measures by the Bank of England (BoE) in different even time windows. The results obtained by the author, revealed a statistically significant relationship between QE and equity returns, on the days of Monetary Policy Committee announcements. Because this is an intraday study, it was also found that the period of biggest shock starts 10 minutes before the announcement and ends at the end of trading day. Similarly, Steeley and Matyushkin (2015) noticed the impact of the QE announcement on the UK government bonds market, where the authors used 24 different types of UK gilts, during the period between 2004 to 2013, using a GARCH model to model jointly the conditional mean and variance of individual bond returns. The effect that the authors reported on the bonds market was a calming effect, restoring pre-crisis volatility, after 3 phases of QE. This conclusion was firstly discovered by Joyce et al. (2011), that explained that based on investors reactions to news of QE purchases, the impact on medium to long term gilt yields were about 100 bps lower that would have been otherwise, effect that came from a portfolio rebalancing channel.

For the Eurozone, it was evaluated the impact of unconventional monetary policy measures on the bonds market, during the European Central Bank's (ECB's) Securities Market Programme (Eser & Schwaab, 2016). With daily data from 2010 to 2011, using data from 5 Eurozone countries, it was estimated a panel regression model with the dependent variable being the observed change in yield. The results suggest large and statistically significant announcement effects, with an impact ranging from -1 to -21 basis points (bps) on 5-year maturity bonds, for every billion euros of bond purchases. This impact is stronger than the one reported in the US for the period 2008-2009, using the same statistical technique. In a study that uses other type of instrument, credit default swaps (CDS) it was analysed the impact of announcement of the ECB QE measures (Albu et al., 2014). Using daily close prices of 5-year sovereign CDS during a period of 8 years (2005-2013), it was found a clear influence of QE on CDS dynamics, this influence translates into a percentage that ranges from a difference of 73.17% to 92.68% of abnormal results, compared with the expected results.

The idea behind all these studies presented is to illustrate that the financial activity is being impacted by the actions of QE, in the 4 regions that will be studied. Most of the conclusions demonstrate an increase in prices that comes from the injection of money in the markets by the Central Banks.

I would like to emphasize other works that include the effects of unconventional monetary policies of not just one but several central banks on financial markets. For example Ferreira and Serra (2019) tested the effects of unconventional monetary policy (UMP) announcements from the European Central Bank, the Federal Reserve, and the Bank of Japan on the European securities market. The results suggest that UMP significantly affected the European stocks, but not the UK gilts and Euro Area government bonds. When looking to the impact *per* central bank the authors explains that the impacts of the ECB's announcements were positive and significant; the market also suffer some spillover effects from the Fed's announcements, although exclusively on stock markets. Other interesting example on the effect of central banks on other economies without being the domestic market, is a study conducted on the impact of the Federal Reserve, Bank of Japan, and European Central Bank on stock prices of eight Asian emerging markets (AEM) (Miyakoshi et al., 2017). The authors show evidence of QE policies increasing stock prices of the AEM. The central banks that most impacted these markets were the Bank of Japan, before 2008, and the Federal Reserve, after the global financial crisis. It is demonstrated that the European Central Bank has a very limited impact.

2.2. Bubbles and QE Announcements

After being pointed out through the literature that the QE measures have in fact impacted the markets in some way, the main objective is to study not only the effects on prices, but the effect on bubble creation, or in other words, explosive price movements on these four markets. The focus on the creation of asset bubbles is motivated by the negative impacts that asset bubbles may have on the economy. First, asset price bubbles contribute to systemic risk (Chen et al., 2021), because in a boom phase the higher value of a stock price appreciates collateral value, which relaxes credit constraints imposed by banks to customers, as well, given the feeling to the banks that a higher return on investments will encourage them on taking more riskier investments that otherwise would not. This increase stops when people somehow start to panic, or an exogenous negative shock arrives. View complemented by Jarrow and Lamichhane (2021) that explained that the bigger the percentage of economic agents verifying a bubble being created, the more is the chance of systemic risk. Systemic risk can have impact on, among other variables, on business and consumer sentiment, affecting negatively the real GDP growth (Kanas & Zervopoulos, 2021).

The most related literature to what is the goal of this thesis will now be presented. The relationship between exuberant price behaviour in equity prices and quantitative easing policies was studied in 10 countries of the Euro Area countries, between January 1996 and May 2018 (Hudepohl et al., 2021). Based on the GSADF test, there are evidence of multiple explosive periods, in 5 out of 10 countries. If the BSADF statistic is used to detect subperiods of explosive prices behaviour, given that the GSADF only gives us information over the whole sample, the authors indicate that on all 10 countries, throughout the sample, there is indication of some period to have exuberance characteristics, being the 3 most significant periods (above 90% of confidence interval) the year of 2008, 2015, and 2017. A second part of the article also studied the impact on equity prices of the respective countries of the

QE policies. Using a dynamic probit model, it was found that periods of QE seem to be the main driver of exuberance prices, even after controlling for other macroeconomic variables.

A similar approach was also used for the government bonds markets (van Lamoen et al., 2017) where, as above, for 10 Eurozone Countries was investigated if the ECB's expanded asset purchase program had an impact on the creation of exuberant price behaviour in government bonds. Using the GSADF and Generalized Supremum Phillips-Perron (GSPP) statistic, it was found that every country in the sample experience, with at least 95% of confidence, statistical deviance from the fundamental value. When a study by subperiod is conducted, we can see that most of these bubbles occur during the period comprehending the final of 2014 and early 2015 (the Expanded Asset Purchase Program (EAPP) was announced in September 2014).

One of the key and more controversial elements of this study is the technique for detection of bubbles being created on the markets. A process that is gaining popularity is a Supremum Augmented Dickey-Fuller (SADF) test (Homm & Breitung, 2012; Yiu et al., 2013), which is based on forward recursive regressions, using subsets of the sample data, and for each subset apply the ADF test for a unit root, against the alternative of an explosive root (Phillips et al., 2011). This test was then expanded to the Generalized Supremum Augmented Dickey-Fuller (GSADF) test (Phillips et al., 2015), due to the lack of power and possibility of inconsistency when the sample period includes more than one episode of exuberance. This new test takes as a procedure the usage of recursive right tailed ADF tests, but uses flexible window widths in their implementation, so as explained by the authors, this method extends the sample coverage by changing both the starting point and the ending point of the recursion over a feasible range of flexible windows. In this same paper from 2015, it was also introduced a technique to date bubbles' start and end dates (BSADF test). It was used to study bubbles in a variety of different markets, for example the Real Estate Investment Trust (REITs) market, a financial instrument that gives the ownership of a part of a house (then when the house is sold, the profit is distributed among the investors) (Escobari & Jafarinejad, 2016), the housing market (Huang & Shen, 2017), natural gas market (Li et al., 2020), metal markets (Ozgur et al., 2021), and oil markets (Umar et al., 2021). As with any statistical measure, this tool is not perfect and is not exempt from criticism (Monschang & Wilfling, 2021).

Our contribution to the literature is to perform a cross-region study of the impact of the quantitative easing measures announcements by the four major central banks, on asset bubble formation in the stock market. In other words, to test if the bubbles verified in the stock markets were caused by the quantitative easing measures of any of the four central banks, for example if the bubbles in the Japanese stock market were caused by the quantitative easing measures of the Fed, or if the quantitative easing measures of the BoJ impacted the bubbles in European stock markets. The results that we obtain could be very important for the governing monetary policy committees in the major central banks, to be cautious when any of the other CBs injects more money in the markets, but also for any financial institution, such as banks, insurance companies, wealth management firms, that are trying to understand what is explaining the present environment and the future response of the markets.

We include control variables in the estimation, that are identified in the literature as possible drivers of bubbles on the stock prices, besides the variable related to quantitative easing. These control variables include a set of macroeconomic variables, with respect to each of the regions, inspired on a variety of recent literature that relates bubbles in the markets with quantitative easing. The set of variables can be divided in three dimensions: Output measured through industrial production index; Inflation measured through Consumer Price Index (CPI); Interest rates, represented by the overnight interbank money market rate and through government bonds yields of 5-year maturity (Bhar et al., 2016; Caraiani et al., 2021; Galí & Gambetti, 2015; Hudepohl et al., 2021; Jiang et al., 2015; Sun & Liu, 2016; van den End, 2016; van Lamoen et al., 2017; Wang & Chen, 2019).

Given the variables presented above, is expected that the increase in values of the variables representing inflation and output will affect positively the chance of having bubbles in the market, this expected relationship is supported by Fouejieu et al. (2019), that by using a modified New Keynesian model consisting of aggregate demand, aggregate supply equations, a central bank reaction function, and an equation to capture risk accumulation in the financial sector, obtained the main result of the study that central banks will face trade-offs between inflation and asset price stability (suggesting that they came in tandem). Relationship also supported by Bonchi (2022) that by using a three-period overlapping generations (OLG) model without capital and considering the period of the Zero Lower Bound, claims that the output gains that arise from bubble episodes, go side by side with the output losses when the bubble bursts, suggesting a co-movement. Regarding the interest rate component, is expected that a high interest rate, controlled by the Central Bank, will negatively affect the possibility/maintenance of having bubbles in the stock market, following the research of Allen et al. (2017) on leaning against the wind policies of the central banks, a hawkish monetary policy through increases in the interest rates, helps dampen bubbles.

3. Data and Methodology

3.1. Data

In this following section we will present thoroughly how and from what source we have collected the data that we will be using to perform the econometric tests necessary to obtain results. We will start by presenting in depth the two main set of variables that we are analysing, and then the control variables that we will include in a regression model. All variables were chosen having in mind other studies performed on the area, as explained previously.

For a first part analysis, we used data comprehended in a 26 year-period with daily frequency for the stock market indexes and quantitative easing dummies, starting in 1995 until the end of 2021. The number of observations in this first part are for USA region 6797, for Japan 6625, for UK 6915 and for Eurozone 7032. The values for the sample sizes are different due to different holidays/reasons for the markets being closed in each region. On a second part analysis with a VAR, we compile the daily data from previous variables into monthly and consider the control variables on a monthly basis as well, using the period between 1998 and 2021. For this second part, sample size is equal to 286 observations.

- *Stock market Index*, given that we want to discover the correlation between financial markets and quantitative easing policies, the first thing we had to decipher was which variable can represent the financial markets of each of the four regions to be studied. We have chosen stock markets indexes that we consider to be representative of each of the regions' financial markets. The choice was the S&P500 for the United States of America, for the United Kingdom the FTSE100, for Japan the Nikkei225, and for the Euro Area the Eurostoxx50 (SX5E). The dataset for these four variables includes a business calendar data (that we will refer as daily by omission) from 1995 until 2021 of the close prices observed on each day. The data was for the FTSE100 and the Eurostoxx50 were extracted from the Wall Street Journal online database; for the Nikkei225 from Yahoo Finance online database and the S&P500 from the Federal Reserve database.
- *Quantitative easing dummies*, there is a significant number of possibilities for representing quantitative easing that were explored on the literature, but the one that we chose, given the main goal of our study, was to represent the QE with a dummy variable for each of the 4 regions. The dates of the announcements considered are presented in the Appendix Tables A6, A7, A8 and A9. We have decided to proceed with this approach for the QE variables and not to use other measures, for example, the central bank's balance sheet, because the announcement can capture its immediate effect on the price explosiveness in a way that no

other measure can. With a dummy we can understand if the central bank actions are transparent and well communicated to the markets, promoting stability, or if they create volatility. These 4 variables represent all the announcements of asset purchases during the 26-year period we are analysing. We have the dummy equal to 1 whenever there is a QE announcement for a certain central bank, 0 otherwise. For the first part of the analysis, we will have this variable represented daily, so it will be equal to 1 in the date of the announcement. Subsequently, we compiled monthly data for the VAR analysis, and it will be equal to 1 in the month of the announcement, 0 otherwise. With the help of this variable, it will be possible to understand the impact of QE on other variables. The database was done with the help of some papers that already included a table of the dates, with an brief explanation of the action agreed by the Central Bank on the monetary policy meeting (Charoenwong et al., 2019; Ferreira & Serra, 2019; Kobayashi et al., 2006). However, the papers do not have all the QE events for the timeframe we are using. So, for all the remaining dates we look for information on the monetary policy meetings minutes available on each of the Central Bank's websites, to assess if any new measures were implemented.

- *Control variables* are used as endogenous variables on a VAR model, with the objective of having a full explanatory model of the behaviour of explosive price increases. The included variables were, Industrial Production Index (IPI), inflation rate measured through the Consumer Price Index (CPI), the overnight interbank money market rates, and the yield of 5-year government bonds. The data for the VAR model was collected for the period between January 1998 until October 2021.
    - *Industrial Production index* (IPI) - was chosen with the goal of being a proxy for output in our model. This variable represents the value of production of some of the components of the industrial sector, such as electricity or gas. It is an index that compares the values each year with a reference (or base) year, which in this case is 2015. The variable presents as big advantages, compared for example with the GDP, the easiness of analysis and being on a monthly format, agreeing with the time format chosen for our analysis. The IPI variable for each of the regions was obtained through the OECD database.
    - *Inflation rate* **-** the consumer price index (CPI) is the variable that was used to calculate the inflation rate. CPI is an index that is a weighted average of a consumption basket of goods and services. The base year is 2015. The annualized inflation rate was obtained by computing the growth rate of the CPI between month *t* and the same month in the previous year. The CPI values were obtained from the OECD database.

- *Overnight interbank money market rate* **-** is the variable used to represent short-run interest rates. This variable represents the rate at which banks lend to each other, to face any shortage of money necessary for the next business day, and with maturity on the following business day as well. The movements of this rate are influenced by the actions of the central banks, being an important monetary policy instrument. The rate representative of the US market is the Fed Funds Rate and was collected in the Federal Reserve Economic Database; for the Eurozone markets is the EONIA (Euro Overnight Index Average) collected from the ECB website; for Japan is denominated Call Money Markets rate, in which values are available on the BoJ website; and for the UK we have the SONIA (Sterling Overnight Index Average) rate, obtained via the BoE website.
- *Yield of 5-Year government bonds* **-** as a proxy of longer-term interest rates. This variable gives us the return of the 5 years government bonds. The data was obtained via different sources depending on the country of interest. For the US treasury yield we obtained it through the Federal Reserve website, for the UK Gilts the data was obtained via BoE website database, for the EUGVs (Euro Area government bonds) data was collected in the ECB database website, and at last for the JGBs (Japanese government bonds), since data available online on the Ministry of Finance of Japan was only available on a daily format, we averaged to a monthly frequency.

3.1.1. Behaviour of Stock Market Index variables

Will briefly examine the behaviour of the stock market variables in the analysed time period. In Figures 3.1,3.2,3.3, and 3.4 we can see, respectively, the behaviour of the index variables S&P500, N225, FTSE100, and SX5E.

Looking at Figure 3.1, the S&P500 exhibits an upward trend in the whole period, achieving a maximum of 4793.06 points, near the end of the period. The behaviour for this US index seems to be divided into 3 subperiods, one around the time of the dot-com bubble, the other just before the global financial crisis, and the last one starting after the big fall in valuation in 2008 and lasting until the end of the period. In the 2 periods until 2008 the data seemed to follow a roughly stationary process, but in this third period, beginning at the end of 2008, this is not the case anymore. We can notice an explosive increase in the variable, with the pattern at the end of the period (starting around 2020) following an almost vertical trend. Let us keep in mind that most of the regions considered starting their QE policies during the beginning of this third period (2008/2009).

Secondly, we have the plot of the Japanese stock market index N225 in Figure 3.2. Is possible to see a roughly W-shaped pattern in the data, with a downward trend until around 2003, then a period of constant fluctuations, only perturbed by a rise and then plummet of the values at the end of 2008. At last, the data seem to gradually increase from 2013 until the end of the period, reaching a peak near the end of the time series.

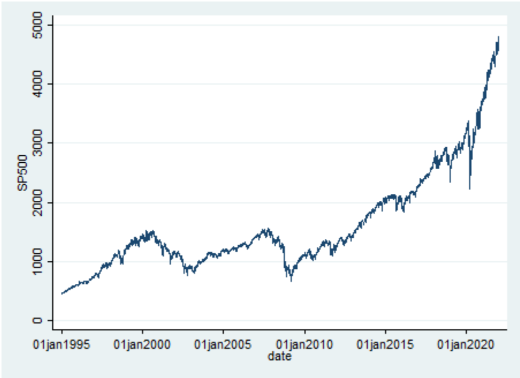

Figure 3.1 –S&P500 Time Series

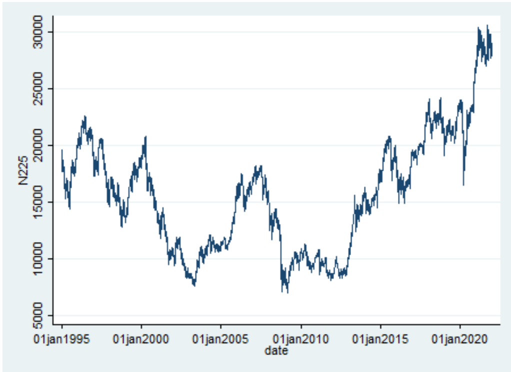

Figure 3.2 – N225 Time Series

Figure 3.3 – FTSE100 Time Series

Figure 3.4 – SX5E Time Series

One interesting feature is the almost vertical straight line in the values, verified in 2020, a period where all the Central Banks actioned QE policies.

Next, in Figure 3.3 is possible to see the time series for the FTSE100, the British stock market index, for the period between 1995 and 2021. In this graph is more difficult to understand what the overall trend for the series is, but we immediately see that until 2010 the data fluctuated around some constant number and only after that period, did the data exhibit an upward trend until the end of the period. Before 2010, 2 periods are characterized by a sharp increase of index points, followed by a big drop afterwards: during the period between 1998 – 2003 and between 2005 – 2009. After 2010, the data has shown a consistent upward trend, only slightly interrupted by a relative temporary period in 2020 but has quickly caught up to previous values.

Finally, in Figure 3.4 we have the graph relative to SX5E, for the period comprehended between 1995 and 2021. Although difficult to recognize a trend for this Euro Area stock market index, we can notice immediately a period characterized by 2 big spikes in the values, like what we saw on the FTSE100 graph in terms of duration and time-period verified, and another period with a slight upward trend with values that oscillate on a smaller interval.

3.2. Methodology

With this thesis we want to understand, first, if there are bubbles being formed in the main international stock markets and lasting for what dates/time periods until they burst. Secondly, what is the effect of the quantitative easing policies on these bubble creations on the markets. Having these research questions to be answered, our empirical methodology was the following: first, we study the bubble creation in each market, using a statistical bubble detection mechanism, regarding explosiveness in prices, and relate it with the announcements of Quantitative Easing. Then, on a second step using a multivariate regression model, assess what variables influence this explosiveness statistic, especially if the QE variables influence the values of the statistic. In this section, we explain in more depth each of the statistics and models used.

3.2.1. Bubble Detection Mechanism – BSADF/GSADF test

The statistical tests we used for detecting the existence of bubbles in financial markets were developed by Phillips et al. (2015) entitled Generalized Supremum Augmented Dickey-Fuller (GSADF) test and the date stamping statistic entitled Backward Supremum Augmented Dickey-Fuller (BSADF) test. As the name suggests, the GSADF test is an extension and more flexible test than the one developed in Phillips et al. (2011) – the SADF test, a recursive right-sided unit root test. Independently, is important to have both SADF and GSADF tests in our research due to the authors conclusions that the GSADF test only performs better than SADF test when multiple bubbles are identified in the data (Phillips et al., 2015). The SADF test outcome is a sup value of the ADF statistic sequence based on several repetitions of the ADF model (see equation 1 below, the $ADF_{r_1}^{r_2}$ statistic is the t-test of the beta, computed using the sample t=$r_1T, \dots, r_2T$), where the window size expands from r_0 to 1 and its' initial point r_1 is fixed at 0 ($r_1 = 0$) with a variable endpoint of each sample r_2 belonging to the interval [r_0,1], so we have a forward expanding sample sequence.

The difference for the GSADF test is that in this case there is a varying endpoint but also a varying starting point belonging to the interval [0, r_2-r_0] (Phillips et al., 2015). On equations 2 and 3 we can see these definitions.

$$\Delta y_t = \hat{\alpha}_{r_1,r_2} + \hat{\beta}_{r_1,r_2} y_{t-1} + \sum_{i=1}^{k} \hat{\psi}^{i}_{r_1,r_2} \Delta y_{t-1} + \hat{\varepsilon}_t \quad (1)$$

$$SADF(r_0) = \sup_{r_2 \in [r_0,1]} \left\{ ADF_0^{r_2} \right\} \quad (2)$$

$$GSADF(r_0) = \sup_{\substack{r_2 \in [r_0,1] \\ r_1 \in [0, r_2 - r_0]}} \left\{ ADF_{r_1}^{r_2} \right\} \quad (3)$$

The value obtained from the GSADF statistic must be compared with its finite sample critical values. The 90%, 95%, and 99% critical values are obtained from Monte Carlo Simulations, with the number of replications fixed on 999. If the value of the GSADF statistic is larger than the corresponding critical value, we can conclude that there is evidence of the existence of multiple bubbles in the whole sample.

In order to estimate the specific dates where explosiveness in prices is observed, it is necessary another tool, a date stamping statistical tool, that performs a double recursive test procedure, called BSADF test (Phillips et al., 2015). As explained by the authors, with this test it is possible to perform sup ADF tests on a backward expanding sequence, but now with the endpoint fixed at r_2 and the start point varies on an interval $[0, r_2\text{-}r_0]$, as we can see in equation 4 below. By including the interval, instead of a fixed term for the start point, it is possible to grant more flexibility to the estimation.

$$BSADF_{r_2}(r_0) = \sup_{r_1 \in [0, r_2 - r_0]} \left\{ ADF_{r_1}^{r_2} \right\} \quad (4)$$

The way to identify a bubble using this test statistic is given by equations 5 and 6, where equation 5 gives the conditions for us to conclude that we have the start of a bubble period, and equation 6 gives the conditions for us to conclude that we have a termination period of the bubble. Whenever the statistic of the backward sup ADF test is bigger than the critical value of the backward sup ADF statistic, we have the origination date of the bubble. The 100(1- β_T)% critical value of the statistic is based on [Tr_2] observations and is denoted on the equations 5 and 6 by $scv_{r_2}^{\beta_T}$. On the contrary, the termination date is consolidated whenever an observation is verified to have a value below the critical value. To put it in simpler terms, if we have an inferior value of the critical value relative to the test statistic, then we can conclude that there is evidence of explosive subperiods in the sample. As a note, with this statistic, any value bigger than the critical value, to be considered as the beginning of a bubble, has to respect a minimal period defined by $\delta \log(T)$, where T is the sample size.

$$\hat{r}_e = \inf_{r_2 \in [r_0,1]} \left\{ r_2 : BSADF_{r_2}(r_0) > scv_{r_2}^{\beta_T} \right\} \quad (5)$$

$$\hat{r}_f = \inf_{r_2 \in \left[\hat{r}_e + \delta \log\frac{T}{T},1\right]} \left\{ r_2 : BSADF_{r_2}(r_0) < scv_{r_2}^{\beta_T} \right\} \quad (6)$$

We can now see, as explained by the authors, that the GSADF test is no more than the backward sup ADF test applied repeatedly on an interval $r_2 \in [r_0,1]$ being the value for r_0 defaulted to $r_0 = 0.01 + 1.8/\sqrt{T}$, and whose statistic is obtained by the sup of this sup ADF value. This relationship is exhibited on equation 7.

$$GSADF(r_0) = \sup_{r_2 \in [r_0,1]} \left\{ BSADF_{r_2}(r_0) \right\} \quad (7)$$

The reason for selecting this method to test for the formation of bubbles instead of other models such as, for example, the Markov-switching unit root test (Hall et al., 1999) or a Log-Periodic Power Law Singularity (LPPLS) model (Papastamatiou & Karakasidis, 2022), is because, as explained earlier, it has been used by a series of empirical studies on other products, financial or not, and for being an innovative method that as a lot of potential, with characteristics such as the minimum duration of the bubble, thus preventing from misidentifying what we are looking for. The authors pointed out that one of the advantages of the BSADF test method is that it is possible to surpass the criticism of Evans, that periodically collapsing bubbles are not detectable by standard tests (Evans, 1991).

3.2.2. Models using VAR

The Vector Autoregressive (VAR) model was first introduced by Sims (1980) after a very well-known review to existing models at that time, where the author claimed that existing identification restrictions on the structural models were causing problems. For this reason, we will use the VAR model to explain the dynamic relationships among the variables

With this model, we consider an equation where the contemporaneous value of a certain variable is explained by its own lagged values as well as other endogenous lagged variables that were determined to be a part of the model. If variables that need to be included in the model are proven to be not endogenous, they enter in the model as exogenous variables. Thus, for a certain optimal lag length *p*, and assuming for sake of simplicity that there aren't exogenous nor deterministic variables, the model is defined in equation 8.

$$x_t = A_0 + A_1 x_{t-1} + A_2 x_{t-2} + \cdots + A_p x_{t-p} + e_t \tag{8}$$

In equation 8, we have the mathematical representation of the model where x_t represents an (nx1) vector that contains the stationary endogenous variables included in the model, A_0 is the vector of intercept terms, A_i are the n-by-n matrices of coefficients and, at last, e_t represents the vector of error terms. The stationarity of the variables is tested using the Augmented Dickey-Fuller test methodologies (Dickey & Fuller, 1979), the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test (Kwiatkowski et al., 1992), the Phillips-Perron (PP) test (Phillips & Perron, 1988) and the Dickey-Fuller Generalized Least Squares (DF-GLS) test (Elliott et al., 1996). Another important property of this model is the assumption of serially uncorrelated error terms and a constant variance. The coefficients can be estimated through the ordinary least squares (OLS) method.

In this dissertation, it was developed for each region a series of VAR models that included as endogenous variables, the industrial production index, the inflation rate, the overnight interbank money market rate, the 5-year government bonds yield and the BSADF statistic, a proxy variable for explosiveness in the financial markets, obtained from the bubble detection mechanism defined previously. All economic variables have a monthly frequency whereas the BSADF statistic is on a daily format. To aggregate it from daily to monthly data, we have various possibilities, which may influence the results in different ways. So, for robustness of the results we estimate a model where the BSADF is the monthly average and a model where the BSADF is the biggest monthly value.

Due to the nature of the QE variables, we include them as exogenous variables on the model. These binary QE variables are defined by a value of 1 whenever we are in the presence of a month where a QE policy is announced, so the idea is to include in both models, for each region, the relevant contemporaneous, lagged or lead values of the four Central Banks QE variables. The statistical relevance of each QE variable was determined using Wald tests that reveal if the variable is significant or not for the fitted model. If significant stays in the model, otherwise it is removed from the model.

In the Table 3.1, we have some measures that characterize the endogenous variables used, namely the mean, standard deviation, the minimum and maximum values. It is interesting to analyse the differences in the 2 methods for obtaining the monthly BSADF, thus explaining the need for the usage of 2 models. We can verify for all regions a similar mean value for the interbank money market rate, 5-year government bond yield and inflation. Also, we can see that the BoE is the bank that most seems to conduct monetary policy more successfully because the inflation’s mean value is the closest to 2%, the target inflation for most of the central banks.

Table 3.1 - Main descriptive statistics of endogenous variables

		Ind. Prod.	Interbank money market rate	5-year Gov. Bond Yield	Inflation	Mean BSADF	Biggest monthly value BSADF
US	Mean	97.51377	1.948707	2.832587	2.208033	0.0963958	0.3091355
	Standard Dev.	4.926083	2.055179	1.649573	1.296827	0.7622497	0.8178971
	Min	79.2271	0.049	0.2666667	-2.09716	-1.13572	-1.000988
	Max	108.2927	6.544516	6.687727	6.221803	2.520786	3.35792
UK	Mean	93.63171	2.525515	2.924317	1.950321	-0.659130	-0.442740
	Standard Dev.	8.517613	2.387144	2.016031	0.8706948	0.6057058	0.7136725
	Min	73.70503	0.0486	-0.0845	0.1998017	-1.678678	-1.644924
	Max	110.2878	7.5534	6.3982	4.790419	1.464226	2.631803
JP	Mean	102.3046	0.0837107	0.4503695	0.0637803	-0.363838	-0.167691
	Standard Dev.	7.161647	0.1537971	0.4761513	0.9779164	0.5781349	0.7220089
	Min	77.19357	-0.071	-0.3469	-2.558869	-1.246653	-1.168823
	Max	119.8188	0.5205238	1.49319	3.699795	2.546119	3.94421
EZ	Mean	97.49895	1.482082	2.526571	1.669838	-0.341405	-0.108155
	Standard Deviation	6.199816	1.740635	1.807948	0.9640479	0.7183227	0.8294065
	Min	73.5	-0.4856	-0.4689	-0.619899	-1.731081	-1.706773
	Max	109.1	5.0642	5.9446	4.121846	2.407321	2.986278

After defining the variables to be included in the VAR model, it is important to determine the appropriate lag length p. Some statistics that can be used for lag-order selection include the Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SBIC), and the Hannan and Quinn information criterion (HQIC) (Lütkepohl, 2005). For this study, we focused on the results of AIC, due to research pointing out to a better accuracy when using this lag order statistic for models with monthly data (Ivanov & Kilian, 2005).

After we estimated the model, some tests were conducted to confirm that it is the "best" model that we could achieve, for example, the test for autocorrelation in the residuals of VAR models using a Lagrange multiplier (LM) (Johansen, 1995). Also, a test for checking the stability of the VAR model that is performed using the eigenvalue stability condition.

As mentioned before, the choice for this type of model is linked with the possibility of using a great number of variables incorporating them as endogenous, exogenous, or deterministic variables. Related to that, the other great advantage is the possibility of the model providing not only the coefficients for each equation, but also allow to infer how shocks in the endogenous variables affect one another through Impulse Response Functions (IRFs), and test how the variables help predicting one another through Granger Causality tests. All these tests help us to understand better the whole dynamics and obtaining a fuller picture of the reality we try to explain, for more information on these tests check Enders (2015).

4. Empirical Results

4.1. Explosive Behaviour in the Prices Indexes

In the empirical results section, I will first present the results related to the explosiveness tests on the time series of the four indexes, which aim to represent each region's financial markets: S&P500, N225, FTSE100, and SX5E. To reinstate the objective, first we analyse if any bubbles are being created in the financial markets and if they are linked to the periods where the quantitative easing policies are taking place. Then, in the second part, we will analyse, using a VAR model, what is the quantitative impact of the quantitative easing and control variables on the occurrence of explosive prices.

The measure used to study the explosiveness of the time series is the GSADF test (Phillips et al., 2015), as previously explained. The optimal lag length for the ADF test and the Monte Carlo minimum window size are given in Table A1 in the Appendix.

With critical values obtained using 999 Monte Carlo Simulations, we have the results presented in Tables A2, A3, A4 and A5 in the Appendix for the SADF and GSADF tests. It is possible to verify that for every time series that we are studying, there is clear evidence of subsamples with explosive price behaviour, with the GSADF test statistic surpassing the value of the 1% right-tail critical values, calculated for each index, during the 26 years starting in 1995 until the end of 2021. The index that presented higher value on the statistic among the four is the Eurostoxx50 and the one with lower value is FTSE100, so we expect that the results in terms of date-stamping reflect this conclusion obtained from the GSADF test.

The SADF statistic can also help us obtain some conclusions regarding explosiveness. This test displays similar results to the above, with the N225 index being the only one for which there is no evidence of a single bubble in the markets. As previously, the Eurostoxx index was the one with the strongest evidence for the existence of bubble, with the test statistic more than doubling the value of the 1% right-tail critical value.

For a more in-depth analysis we now need to use the measure of date-stamping to discover during what dates/periods there was explosiveness in the prices. The measure we will use for this purpose is the BSADF test, with the results presented in the next section. For each one of the indexes, we will present the dates or periods of observed exuberance extracted from the data and next to it try to link with the events of QE announcements. The results will be displayed in graphs where we plot the BSADF statistic entitled "BSADF" against the correspondent 90%, 95% and 99% confidence intervals. Despite the possibility of the results indicating or not some level of correlation, we must take the results with "a grain of salt", due to the possibility of being explained by other exogenous factors, which shall be confirmed in the future VAR analysis.

4.1.1. Date-Stamping Results for S&P500

We have conducted the BSADF test for the period between 1995 and 2021 for the US market using the S&P500 index. The results are presented in Figure 4.1, plotted the daily BSADF values of the statistic and the corresponding sequences of critical values.

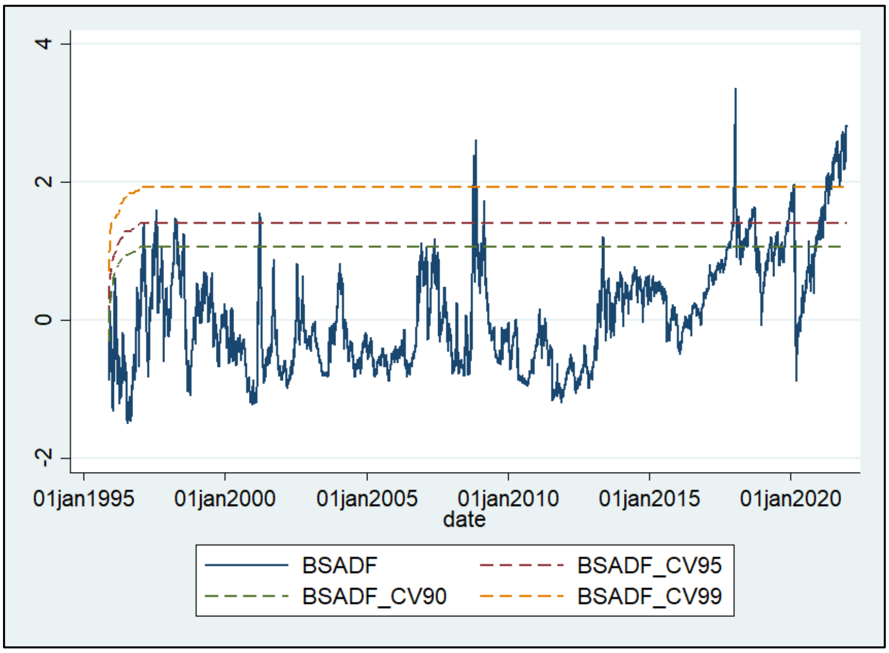

Figure 4.1 - BSADF test to S&P500 with all critical values

The results suggest that there is, for a 99% certainty level, 208 days where exuberance is observed or, in other words, that the hypothesis of no bubble in the market is rejected for these days. From Figure 4.1 it is possible to detect three main periods of exuberance in the data: the first beginning on the 10th of October 2008, the second during the first month of 2018, and the last one beginning on the 4th of April 2021 until the end of the period. If we plot against the 95% critical value sequence, many more days of exuberance arise, but at a cost of less accuracy in the findings, resulting in 410 days of exuberance.

We can try to figure out if there is a relationship between the date of the QE announcements and the values for exuberance. With the 99% level, the only event that exactly coincides with a period of exuberance is a Fed asset purchase in November 2021. If we relax to a lower level, namely 95%, we can associate two more announcements of the central banks whose dates coincide or are close with exuberance in the data. First, the announcement of the BoE of an additional asset purchase package on 5th March 2009 and, second, an announcement of corporate bonds purchases by the BoJ on 19th February 2009.

We could also try to expand to the level of 90%, as a reference, which would lead us to some more coincident episodes between exuberance and the Central Bank portfolio expanding actions, but the main idea is already present, which is that on some occasions it seems that the announcement of the asset purchases by Central Banks, not only the Fed, coincide with exuberance in the S&P index.

If we change the analysis from a daily to monthly scenario, having in mind that we will do a VAR model with monthly data, we can see possible evidence that there is an effect on price explosiveness on the same month, on the previous month and also on the next month from the QE announcements in multiple occasions. If we analyse the November 2008 Fed announcement, we see episodes of exuberance on the same month, on the previous month and on the next month of the announcement, or regarding the Fed announcement in November 2021 we also see that there is evidence of exuberance in the previous, current and next month (in Table A6 of the Appendix is possible to check the full list of exuberance periods for the S&P500 and the temporal relation with QE announcements).

4.1.2. Date-Stamping Results for N225

Now we will present the results of the exuberance test for the period between 1995 and 2021 for the Nikkei 225 Index, which will serve as a proxy for the Japanese financial markets (see Figure 4.2).

The test suggests that, with a 99% confidence, 61 days exhibit an exuberant price behaviour, and with a 95% level there are 116 days. In Figure 4.2 we can detect 2 main periods where exuberance was identified, with one of them reaching a value for the statistic which is 2 times higher than the corresponding critical value.

Comparing with the 99% value, one of the periods represented lasts from the 28th of November 2005 until the 16th of January 2006, and the second one, that was referred earlier, starts on the 8th of March 2013, and goes until the 24th of May 2013. If we extend to the 95% level, one more relevant period is identified during October 2008.

As we did in the case of the S&P500 index, we can try to link these periods with episodes where the central banks practised some quantitative easing policy, having in mind, again, that the level of exuberance may result of a variety of factors. From the values of Figure 4.2 we have that moment from March to May 2013 that coincidentally includes one of the most important periods in terms of unconventional monetary policies from the Bank of Japan, that is the introduction of the Quantitative and Qualitative Monetary Easing. The goal was to double the monetary base and the amount of Japanese Government Bonds and Exchange Traded Funds on the balance sheet for 2 years.

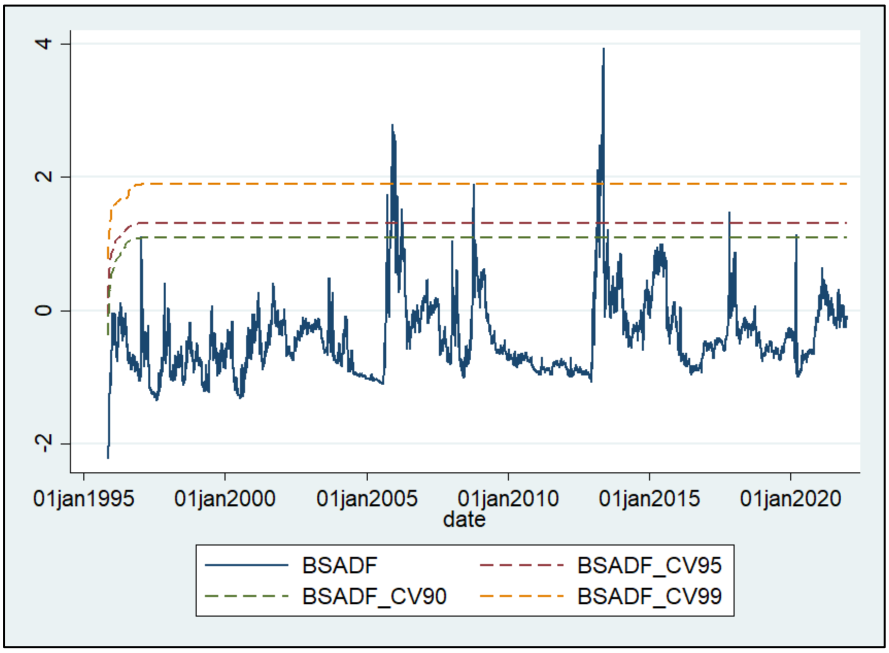

Figure 4.2 - BSADF test to N225 with all critical values

From the 95% level, the additional period of exuberance in October 2008 happens exactly one month before the Fed's big announcement to implement a quantitative easing measure for the first time.

Extending to a comfortable 90% level, we noticed one more interesting date where the markets acted explosively, which is the 19th of March 2020. This day is especially interesting because it is related to the effects of Covid-19 that were affecting the worldwide population, so the four central banks announced in this same week quantitative easing measures to fight against the expected risks for the economy. For example, the PEPP of the ECB was announced on the 18th, the announcement of an increase purchase of commercial paper and corporate bonds of BoJ on the 16th.

Additionally, if we check the results in a monthly scenario, we notice a possible evidence of explosivity effects on the contemporaneous, previous and next month from the QE announcement. Fed announcement in November 2008 allow us to confirm this due to the evidence of exuberance in the previous month of announcement. Another instance that confirms previous conclusion is the BoJ announcement in April 2013, where we see evidence of explosiveness in contemporaneous, previous and next month from the announcement (in Table A7 of the Appendix is possible to check the full list of exuberance periods for the N225 index and the temporal relation with QE announcements).

In a first instance, one more time we can verify some correlation between index explosiveness and the quantitative easing announcements, not only of the BoJ but also of other CBs, on the Japanese financial index.

4.1.3. Date-Stamping Results for FTSE100

In this subsection, we apply the exuberance tests for the 26 years between 1995 and 2021 for the UK financial markets, represented by the FTSE100. The results are presented in Figure 4.3.

From the results we notice that, on a 99% level, the evidence for explosiveness in FTSE100 is almost non-existent, with only 2 observations such that the statistic surpasses the critical value. A piece of stronger evidence only surges with the 95% confidence level, with 70 observations with exuberant price behaviour, and with the 90% where we obtained 115 observations. This confirms that this index is the one with the smallest number of days with explosive behaviour in prices. From the 95% and 90% critical values we can detect mainly 4 periods where exuberance is detected, more precisely, some observations between the one-year period May 1997 to May 1998, 2 isolated observations in 2001 and 2002, a period in October-November 2008, and some observations in March 2020.

As presented in Figure 4.3 there are only 2 episodes that exceed the 99% barrier, being both in March 2020, a month where packages of asset purchases were put in place by all the central banks.

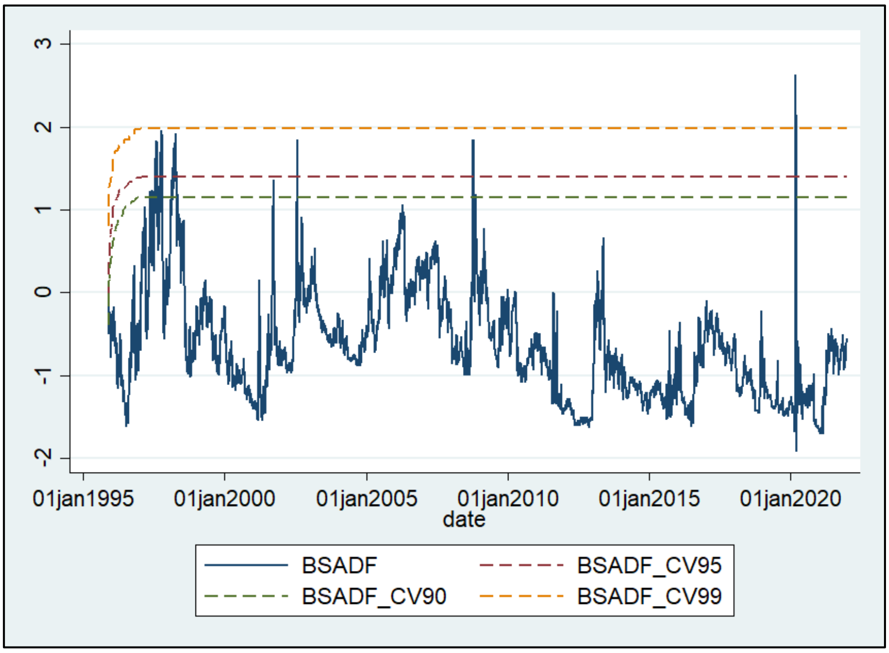

Figure 4.3 - BSADF test to FTSE100 with all critical values

The case for the 95% level does not have much more episodes, confirming March 2020 as a period of exuberant price behaviour, where the simultaneous action of the 4 banks happens at roughly the same time. For a 90% level, we have the appearance of one more day in the same month of the first announcement of quantitative easing by the Federal Reserve. For the case of FTSE100, it seems that the correlation between episodes of quantitative easing and exuberant price behaviour is not so clear but, at a first glance, there are some interesting time-related episodes, which are essentially in 2020.

Changing the analysis from a daily to a monthly scenario, we notice some possible evidence of effects on contemporaneous, previous and next month from the QE announcement. BoJ announcement in September 2001 allow us to confirm this statement due to the evidence of exuberance in the next month of announcement. Another instance that confirms previous conclusion is the Fed announcement in November 2008, where we see evidence of explosiveness in previous and contemporaneous month from the announcement (in Table A8 of the Appendix is possible to check the full list of exuberance periods for the FTSE100 index and the temporal relation with QE announcements). In a monthly scenario we have a clearer evidence of a possible relation between the explosiveness in prices and the announcements.

4.1.4. Date-Stamping Results for SX5E

In the last part of our analysis of the explosive behaviour, we will proceed to the analysis of the European Area region, using as a proxy the SX5E index. Results are present in Figure 4.4.

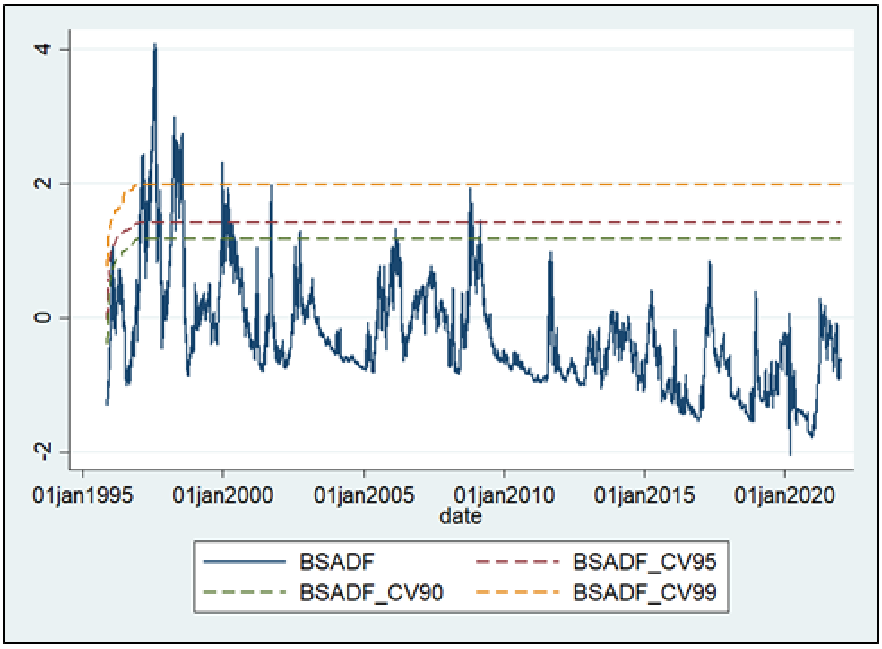

Figure 4.4 - BSADF test to SX5E with all critical values

We obtained for this index 160 observations with the level of the statistic surpassing the reference critical value with 99% certainty. We also obtained 309 observations, for the critical level, and obtained 412 observations for a critical level of 90%. Despite having this number of explosive observations, they are not equally distributed, being most of the observations, roughly ¾ of the observed on a 90% level, verified between in 1996 to the end of 2000. After this big bubble period, we only have another big impact on 2008 until the beginning of 2009.

We can now try to time relate the periods/dates of evidence of explosiveness with the announcements of the Quantitative Easing. At the 99% level we do not have any period or date that is in the same day, month or even year, being the last value of exuberance in 1999, 1 year and 3 months before the first QE policy, that was introduced by the BoJ. If we proceed with the analysis with the 95% level, we could gather an interesting result, with the 2 values of exuberance in March 2009 very close to the date of the announcement of the BoE of injection of 75 million pounds in asset purchasing. Expanding further to an analysis on a 90% level, we can find another interesting period around the first announcement of QE of the Fed in November 2008.

These 2 periods identified can reflect some evidence of the impact on the prices conducted on the financial markets in Europe of the QE policies of Central banks whose purpose is not to serve Europe, but the specific regions.

Changing the analysis from a daily to a monthly scenario, we notice some possible evidence of effects on contemporaneous, previous and next month from the QE announcement. BoJ announcement in September 2001 allow us to confirm this statement due to the evidence of exuberance in the contemporaneous month of announcement. Another instance that confirms previous conclusion is the Fed announcement in November 2008, where we see evidence of explosiveness in previous, contemporaneous and next month from the announcement (in Table A9 of the Appendix is possible to check the full list of exuberance periods for the FTSE100 index and the temporal relation with QE announcements). On a monthly scenario, one more time, there is a clearer evidence of the possible relation between explosiveness and QE announcements.

4.2. VAR Analysis

We will now proceed to the second part of our study, as explained previously. It was developed an econometric model to understand the interaction between the explosiveness of prices in the selected markets and variables related to the announcements of QE policies. It will also be interesting to understand the relevance of the control variables to explain the dynamics of the bubble variable. Recall that a positive impact on the bubble variable will represent a bigger chance of observing periods of market exuberance, either more or less accentuated.

This analysis will be divided into four parts, one for each of the regions that are of interest for the study. It will be considered for each region 2 models, one in which the variable representing explosiveness (that is the BSADF statistic) was aggregated from daily observations to monthly observations, and the other model in which this variable is represented by the largest monthly observation. We use different aggregations of the variable for robustness checks, so we can understand if different calculations of the variables will yield equal or different results.

Part of the specification of the model was also related to understanding how many lags or leads of the QE variables would make sense to include in the model, so to have a clearer picture of the impacts created by central banks on the markets. The relevant monthly lags or leads that appear in any of the following models were confirmed economically and econometrically.

4.2.1. USA

4.2.1.1. Specification Results

Before we proceed with the analysis of the estimated model, we will discuss some specification statistics that demonstrates the adequacy of the model. One of the necessary conditions is that the variables demonstrate a stationary behaviour. For the stationary test, we can resort in several options, but we will consider mainly the Augmented Dickey-Fuller (ADF) test and only if any variable doesn't show stationarity, will investigate using other measures. Results demonstrate that all variables except the yield of the 5-year UST are stationary. For the USA, we expect that for economic reasons the yield of the 5-year UST will be stationary due to the expected relationship with inflation (this variable demonstrates stationarity for a 5% level). We can see that the ADF test with a constant validates stationarity on a 10% level. Remaining tests applied did not demonstrate such result, namely the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test, the Phillips–Perron (PP) test and the DF-GLS test. So, by the ADF test with constant and by the economic definition of the variable, including similarity of movement over time with inflation variable, we will conclude that the variables are stationary.

Moving from the variables analysis to the model specification, the optimal lag length obtained based on the AIC statistic is 3 lags for both models. In terms of the stability condition, we can also see that the models pass the test because all eigenvalues lie inside the unit circle. At last, the 2 models satisfy the non-correlation of the residuals of the models because all the p-values do not reject H0 that is of no autocorrelation at any lag order. So, based on this analysis we can proceed with taking conclusion using the estimated models.

4.2.1.2. Main Results

First, we consider the model where the monthly mean was used as a method of aggregation of our BSADF variable. The QE variables found relevant for the model were: the QE announcement at time t from the ECB and BoJ, the 1-month lagged QE announcement of Fed, and the 2-month lagged QE variable from BoJ and Fed. Results suggest that the explosiveness of the price variable, which we have entitled as "BSADF_mean", has only 2 relevant exogenous variables contributors for price exuberance, that are the ECB QE variable at contemporaneous time, but also the 2-month lagged BoJ QE variable. So, it is possible to conclude that there is a contemporaneous impact of the ECB QE policy and a lagged impact of the BoJ policy on the explosiveness variable. All these variables were found relevant at the 99% confidence value, results displayed in Appendix Table A10.

Regarding how they affect the BSADF variable, if we take a look to these 2 variables that are relevant, the QE variables, we can see that actually the announcements of the European Central Bank and of the 2-month lag announcement of the Bank of Japan have a negative impact on the main variable under study, being the lagged QE effect from the BoJ the one with the most significant impact in the variable. Recalling that the bigger the value of the statistic the more probable is to find evidence of a bubble we can then deduce that the announcements of these 2 central banks have actually a "calming effect" on the US financial markets.

In the second model the price explosiveness is given by the biggest monthly value of the BSADF value, entitled "BSADF_Biggest" (results available in Table A11 of Appendix). This model in terms of relevant exogenous variables to the model yields the same result as previously. Additionally, the results suggest that our variable of interest is impacted with some degree of certainty by the same exogenous variables as in the first model plus with less certainty degree, failing the 95% critical value of the T-test, the 1-month lagged Fed QE announcement.

When we check if the impact of relevant variables is positive or negative the results go hand in hand with the previous model, meaning that the results can be considered robust. All QE variables included are negative, including the lagged QE from the Fed. This means that QE announcements are well received by the US markets, in terms of not creating a run for the markets. This is especially true if we focus on both lagged effects from the BoJ and Fed that have the most substantial effects on the explosiveness variable both with a coefficient value of negative 0.23.

Any impact of leads on these 2 models proven not relevant for the explosiveness variable.

We will present the conclusions regarding endogenous variables in the model using the Impulse Response functions and Granger causality results. On Figure 4.5 and 4.6 we have depicted the response in the BSADF variable until 8 months ahead after a 1-unit shock of any of the other 4 endogenous variables of the VAR model. Results help us conclude that the explosiveness indicator, for the 2 models, does not react to any variables' shock, because 0 is always inside the 95% confidence interval. It is also interesting to check the other way around, if a BSADF variable shock impacts any other variables, results on Figures 4.7 and 4.8. For the first model, we can clearly see a positive impact on the industrial production variable one step ahead, meaning that a shock in explosiveness causes industrial production to react. For the second model at the 95% confidence interval, there is no clear reaction from any of the endogenous variables.

With respect to the Granger causality test (Figures 4.9 and 4.10), we can see that in both cases the only variable that Granger causes the explosiveness statistic is the yield of 5-year USTs which means that this variable helps predicting the value of the BSADF statistic. This result may seem to go against our results in the IRFs because in theory, following Enders (2015), the results obtained from the IRFs should be the same as in Granger causality tests. This can be signalling for further research using other models or variable specifications as this is not the only region we notice this conflict. In this case, we may surpass this conflicting result if we instead of a confidence interval of 95% for the IRF, we use an 90% confidence interval. This way we will have the IRF result on the same line as the GC analysis for the last lags in scope. Interesting also to see that the explosiveness statistic also helps predicting some variables in both models, particularly the Industrial Production for the first model and, for the second model, the industrial production and the Fed Funds Rate, results that one more time may seem conflicting if considering only a 95% confidence interval. Variance decomposition dynamics were not presented due to its results not yielding any relevant result for the study, meaning that is concluded that almost all the variance is given by the BSADF variable itself.

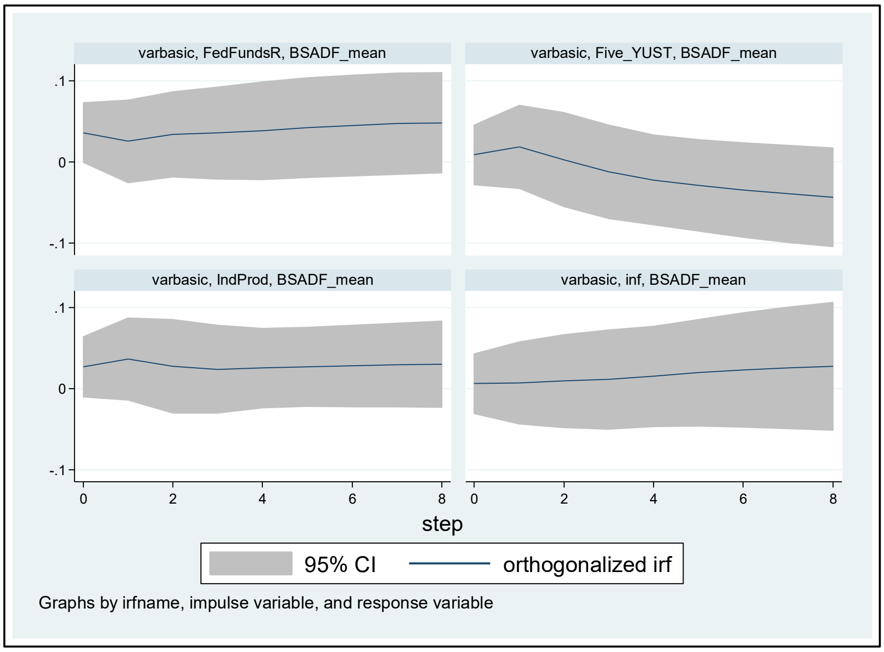

Figure 4.5 - IRFs for the USA case (1)

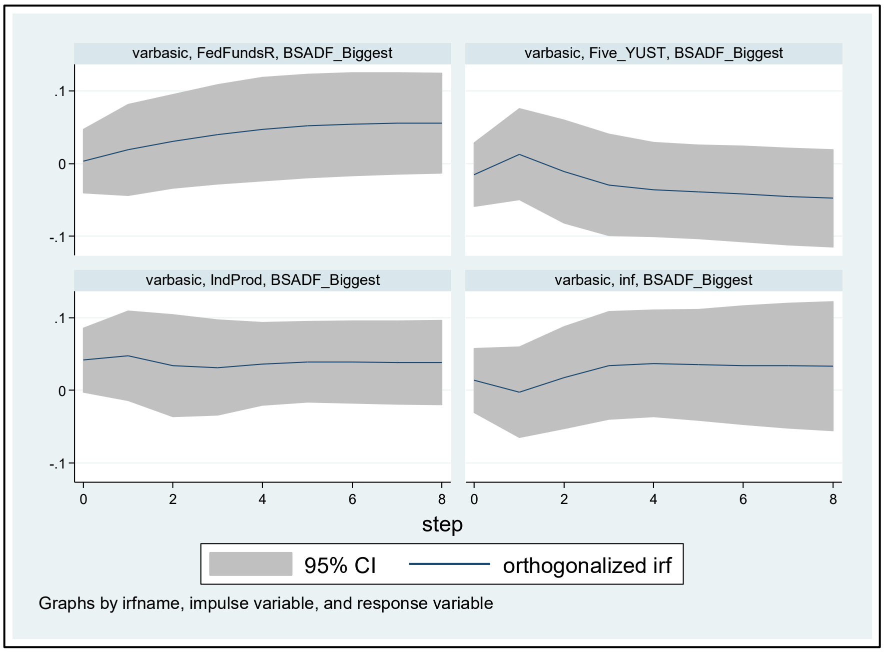

Figure 4.6 - IRFs for the USA case (2)

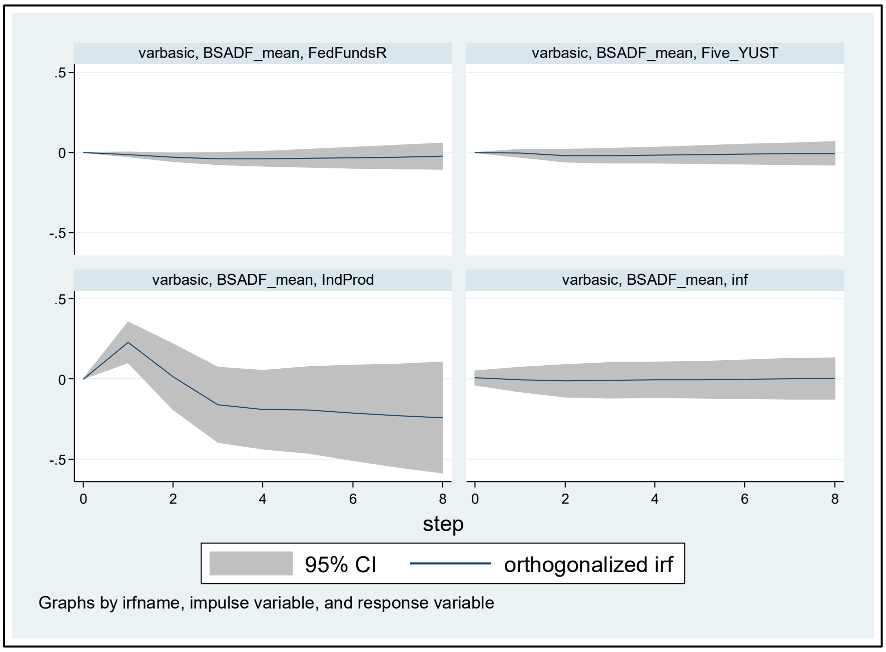

Figure 4.7 - IRFs with explosiveness variable as impulse (1)

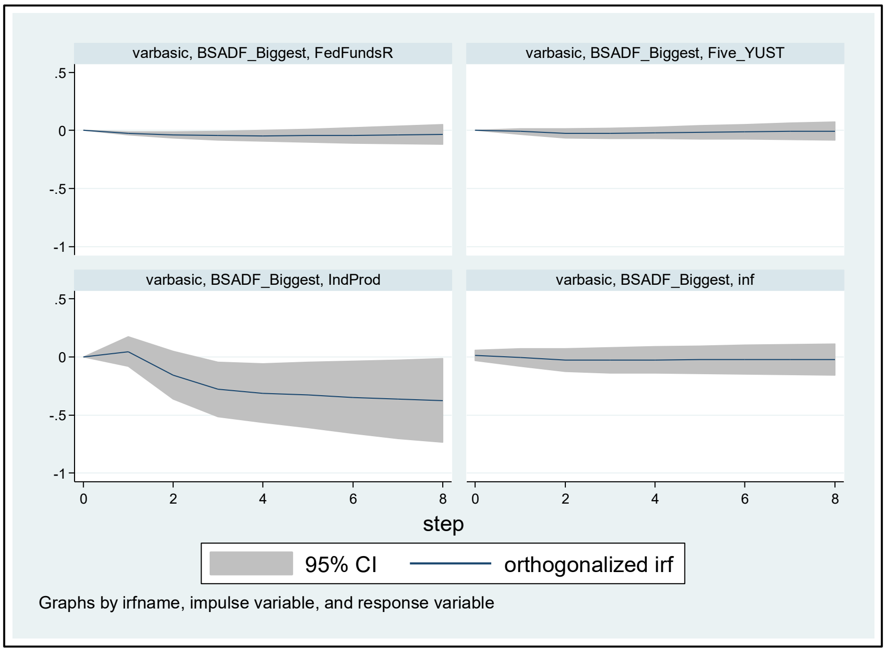

Figure 4.8 - IRFs with explosiveness variable as impulse (2)

Equation	Excluded	chi2	df	Prob > chi2
IndProd	FedFundsR	50.859	3	0.000
IndProd	Five_YUST	15.053	3	0.002
IndProd	BSADF_mean	28.435	3	0.000
IndProd	inf	2.9114	3	0.405
IndProd	ALL	114.57	12	0.000
FedFundsR	IndProd	1.6364	3	0.651
FedFundsR	Five_YUST	30.988	3	0.000
FedFundsR	BSADF_mean	6.1617	3	0.104
FedFundsR	inf	4.2349	3	0.237
FedFundsR	ALL	41.689	12	0.000
Five_YUST	IndProd	.5606	3	0.905
Five_YUST	FedFundsR	1.5252	3	0.676
Five_YUST	BSADF_mean	1.3386	3	0.720
Five_YUST	inf	3.2572	3	0.354
Five_YUST	ALL	8.1513	12	0.773
BSADF_mean	IndProd	2.6836	3	0.443
BSADF_mean	FedFundsR	4.0727	3	0.254
BSADF_mean	Five_YUST	9.3388	3	0.025
BSADF_mean	inf	.99812	3	0.802
BSADF_mean	ALL	20.082	12	0.066
inf	IndProd	2.6186	3	0.454
inf	FedFundsR	14.263	3	0.003
inf	Five_YUST	8.9049	3	0.031
inf	BSADF_mean	.91536	3	0.822
inf	ALL	23.997	12	0.020

Figure 4.9 - Granger causality results for the USA (1)

Equation	Excluded	chi2	df	Prob > chi2
IndProd	FedFundsR	55.624	3	0.000
IndProd	Five_YUST	17.587	3	0.001
IndProd	BSADF_Biggest	14.007	3	0.003
IndProd	inf	2.5721	3	0.462
IndProd	ALL	95.989	12	0.000
FedFundsR	IndProd	1.6511	3	0.648
FedFundsR	Five_YUST	29.246	3	0.000
FedFundsR	BSADF_Biggest	11.848	3	0.008
FedFundsR	inf	4.1101	3	0.250
FedFundsR	ALL	48.104	12	0.000
Five_YUST	IndProd	.55985	3	0.906
Five_YUST	FedFundsR	1.3773	3	0.711
Five_YUST	BSADF_Biggest	1.9698	3	0.579
Five_YUST	inf	3.1999	3	0.362
Five_YUST	ALL	8.7983	12	0.720
BSADF_Biggest	IndProd	1.8117	3	0.612
BSADF_Biggest	FedFundsR	2.9434	3	0.400
BSADF_Biggest	Five_YUST	13.378	3	0.004
BSADF_Biggest	inf	2.8868	3	0.409
BSADF_Biggest	ALL	20.133	12	0.065
inf	IndProd	2.4251	3	0.489
inf	FedFundsR	13.744	3	0.003
inf	Five_YUST	8.7785	3	0.032
inf	BSADF_Biggest	1.5617	3	0.668
inf	ALL	24.698	12	0.016

Figure 4.10 - Granger causality results for the USA (2)

4.2.2. Japan

4.2.2.1. Specification Results

Similarly, as before first will do a model analysis and after we will check the results of such model. For Japan, the only variable that did not reject non-stationarity on the ADF test was the yield of 5-year JGB with a p-value of 0.58. The trend with the next tests performed is similar to the case of the USA. For the ADF test with constant, the statistic obtained allow us to conclude stationarity of this variable with a p-value of 0.08, so we reject non-stationarity on a 10% level of confidence. Next, we tested the stationarity with the KPSS test and PP test, and the results were contradicting the ones achieved with the ADF test, something that we observed also on the other regions. In both tests, the results do not allow us to confirm the stationarity of the variable being tested. Also, the same result was obtained with the DF-GLS test evidence of non-stationarity in the variable.

Despite the somewhat conflicting results, we will confirm stationarity for the same reasons as before, a positive result with the ADF constant test and an expected result of stationarity of the variable.

On the models, we test through the AIC to obtain the correct lag length for the model and confirmed that both models use the same lag, namely 2 lags. The result of this 2 lag was also confirmed by HQIC method. One more time, both models pass the tests regarding stability of the model and the autocorrelation of residuals, giving a strong indication regarding the results from the model and the reliability of the results that will analyse next.

4.2.2.2. Main Results

We will now check the results of the model, using the same type of variables but having the Japanese economy as a focus. We will start by using a model where the explosiveness statistic is compiled on a monthly mean. For this first model, the exogenous variables that were found relevant are the announcement of QE from the BoJ and the 2-month lagged announcement from the Fed. Compared with the other countries, it seems that the QE announcements are less relevant for the Japanese economy due to the reduced number of exogenous variables, see Table A12 in Appendix for more information.

Regarding the exogenous QE variables, no variable was found relevant for explaining exuberance, meaning that QE announcements do not have any direct impact on the behaviour of the explosiveness of prices on the Japanese financial market.

We want now to confirm if in the second model, where we used another format of compilation for the BSADF the results, the biggest monthly value, are likewise the ones found previously for Japan. So, for the exogenous variables to be used and the optimal lag length we achieve the same conclusion as in the first model, meaning exogenous variables include the contemporaneous QE announcement of BoJ and 2-month lagged QE from the Fed and optimal lag length of 2.

The non-effect of the QE announcements is confirmed on this second model as well, directly or indirectly, results in Table A13 in Appendix. The interesting conclusion we obtain is that bubbles in the markets will never be the result of policies that fit in the QE definition, from either of the big 4 central banks. But the same conclusion can be read in another form when there is a situation of a bubble in the financial markets the announcements on QE will not help in any way the prices to be pushed down and navigate around their true value.

No effect of leads was captured on both models, meaning that in both cases no lead variable from the QE was found relevant to explain the price explosiveness on the Japanese index.

Will now proceed to an endogenous variables analysis using IRFs and GC. From the IRF trends, demonstrated in Figures 4.11 and 4.12, we notice that for all the variables the 0 is always inside the 95% confidence variable, meaning that is not possible to conclude that any of these shocks on the endogenous variable, that is giving the impulse, will have certainly an effect on the explosiveness value in any of the 8 steps ahead. If we test the hypothesis of an impulse shock of the BSADF affecting any of the endogenous variables we will obtain the results in Figures 4.13 and 4.14. The results are similar to the ones obtained so far, with no impact from the shock on BSADF for the 95% confidence interval.

From the models, we also obtained the GC results in Figures 4.15 and 4.16, where we found causality when the null hypothesis is rejected. We can check that no variable seems to be Granger Causing the explosiveness variable, being the only variable that closer can achieve to the status of a causality variable is the Japanese interbank rate with a p-value of 0,11 on the model with the biggest monthly value, that reject causality by a small fraction. However, we can also see that explosiveness variable, also on the model previously referred, seems to be Granger causing the value of the JGBs yields, meaning that will be some relationships between explosiveness in the markets and the other endogenous variables. Variance decomposition dynamics were similar to the case of the USA. The variance of the explosiveness variable is given almost entirely by its own dynamics and not any other variable.

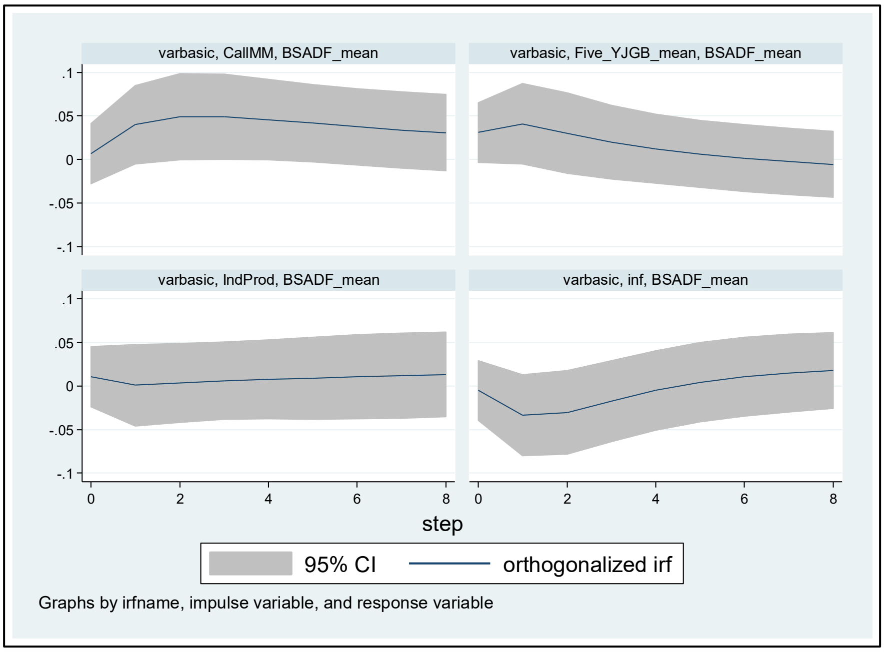

Figure 4.11 - IRFs for the Japan case (1)

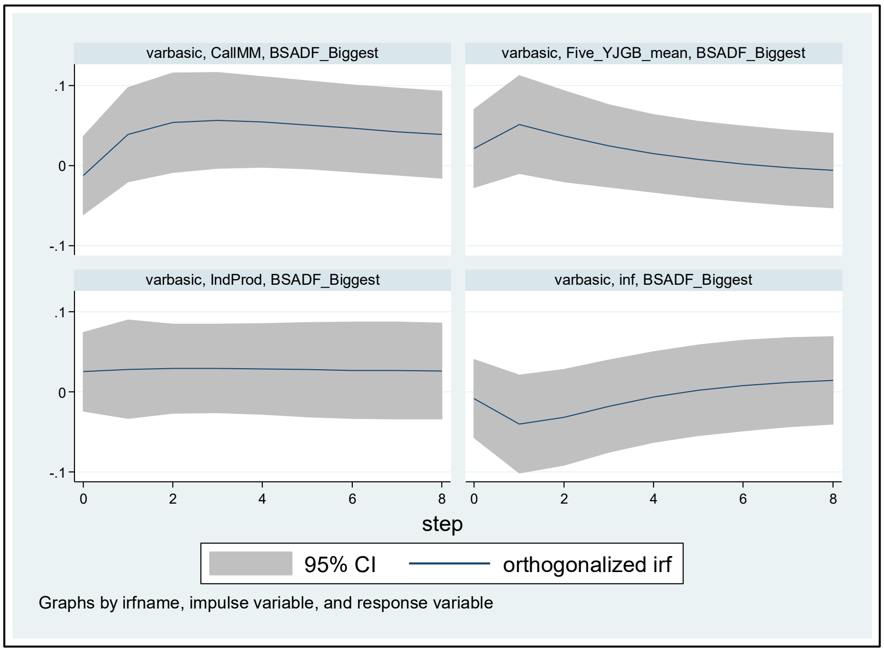

Figure 4.12 - IRFs for the Japan case (2)

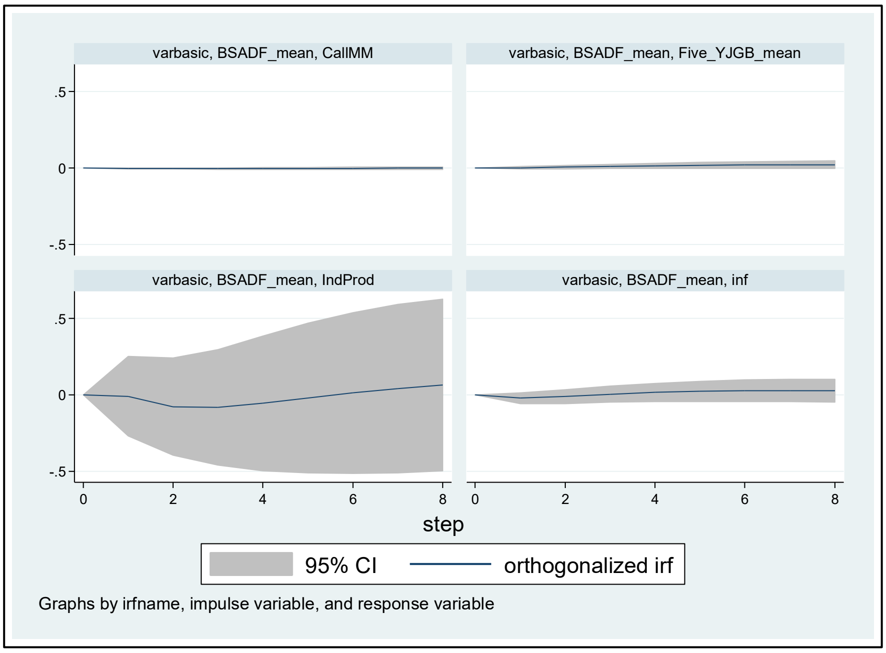

Figure 4.13 - IRFs with explosiveness variable as impulse (1)

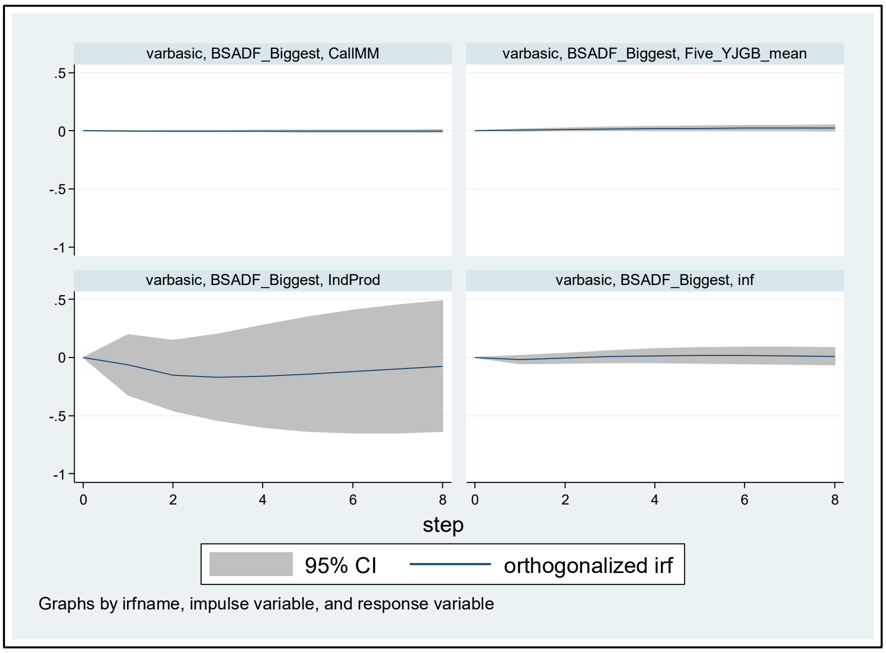

Figure 4.14 - IRFs with explosiveness variable as impulse (2)

Equation	Excluded	chi2	df	Prob > chi2
IndProd	inf	7.3383	2	0.025
IndProd	CallMM	8.4057	2	0.015
IndProd	Five_YJGB_mean	2.7389	2	0.254
IndProd	BSADF_mean	.21992	2	0.896
IndProd	ALL	25.792	8	0.001
inf	IndProd	9.6391	2	0.008
inf	CallMM	1.3784	2	0.502
inf	Five_YJGB_mean	10.438	2	0.005
inf	BSADF_mean	3.4764	2	0.176
inf	ALL	19.208	8	0.014
CallMM	IndProd	4.2627	2	0.119
CallMM	inf	.7456	2	0.689
CallMM	Five_YJGB_mean	3.2738	2	0.195
CallMM	BSADF_mean	3.2577	2	0.196
CallMM	ALL	16.115	8	0.041
Five_YJGB_mean	IndProd	5.3825	2	0.068
Five_YJGB_mean	inf	4.2877	2	0.117
Five_YJGB_mean	CallMM	2.5163	2	0.284
Five_YJGB_mean	BSADF_mean	3.6943	2	0.158
Five_YJGB_mean	ALL	11.927	8	0.155
BSADF_mean	IndProd	.5826	2	0.747
BSADF_mean	inf	4.1763	2	0.124
BSADF_mean	CallMM	4.279	2	0.118
BSADF_mean	Five_YJGB_mean	2.3382	2	0.311
BSADF_mean	ALL	10.484	8	0.233

Figure 4.15 - Granger causality results for Japan (1)

Equation	Excluded	chi2	df	Prob > chi2
IndProd	inf	7.1797	2	0.028
IndProd	CallMM	8.0391	2	0.018
IndProd	Five_YJGB_mean	2.9299	2	0.231
IndProd	BSADF_Biggest	.97181	2	0.615
IndProd	ALL	26.615	8	0.001
inf	IndProd	9.4755	2	0.009
inf	CallMM	1.409	2	0.494
inf	Five_YJGB_mean	10.412	2	0.005
inf	BSADF_Biggest	2.9142	2	0.233
inf	ALL	18.614	8	0.017
CallMM	IndProd	4.4592	2	0.108
CallMM	inf	.82104	2	0.663
CallMM	Five_YJGB_mean	3.3341	2	0.189
CallMM	BSADF_Biggest	2.9366	2	0.230
CallMM	ALL	15.779	8	0.046
Five_YJGB_mean	IndProd	5.0619	2	0.080
Five_YJGB_mean	inf	4.1307	2	0.127
Five_YJGB_mean	CallMM	2.695	2	0.260
Five_YJGB_mean	BSADF_Biggest	5.2168	2	0.074
Five_YJGB_mean	ALL	13.495	8	0.096
BSADF_Biggest	IndProd	.07252	2	0.964
BSADF_Biggest	inf	3.1611	2	0.206
BSADF_Biggest	CallMM	4.479	2	0.107
BSADF_Biggest	Five_YJGB_mean	3.7865	2	0.151
BSADF_Biggest	ALL	11.087	8	0.197

Figure 4.16 - Granger causality results for Japan (2)

4.2.3. UK

4.2.3.1. Specification Results

Regarding the case of the UK we will now proceed with some checks necessary to confirm, in order to have an appropriate model. After a first test we obtained for UK indicators namely, the industrial production index, SONIA rate and 5-year Gilt yield a non-stationary result. The preliminary test was the ADF test, where we obtained a p-value of 0.24, 0.22 and 0.53 which means that the variables do not reject H0 of non-stationary. After applying a battery of tests to these 3 variables the results are somewhat conflicting. The results of the ADF test with constant gives a p-value result that allows us to reject non-stationarity in all variables by a comfortable margin.

However, the KPSS test, the PP test and DF-GLS, will not yield the same kind of results. Nevertheless, we will conclude stationarity of the 3 variables due to a positive result on one of the tests (ADF with constant) and similarly as in the USA (and that will be transversal to the 4 regions) we expect for economic reasons to be stationary.

Advancing now for the model analysis, we have checked what is the optimal lag length for this model after applying AIC procedure and it was 5 lags, for the model using monthly mean for BSADF and the model with the biggest monthly value. Also, none of the models have issues with stability this because after applying the tests, the eigenvalues lie inside the unit circle. At last, both models pass the test for no autocorrelation, meaning that does not seem to have any specification issues and we can move on with the results.

4.2.3.2. Main Results

We will observe now how the results are different for the UK economy. The first model to be analysed is the one with the BSADF statistic compiled in a monthly mean format (output from model in Table A14 in Appendix). For this model, after testing the relevance of the QE variables to include, it was concluded that the ones necessary to the model are the contemporaneous QE events from ECB and BoJ, the 1-month lagged QE from ECB, BoJ and Fed and 2-month lagged event from ECB and BoJ. For the impact of exogenous QE variables on BSADF equation, we notice that the ECB has a particularly strong effect on the statistic with both the contemporaneous and first lag having a relevant impact on the BSADF, but also the 2-month lagged QE from the BoJ. This impact from the ECB can demonstrate the strong link that the UK economy has with the Euro Area.

Through a signal analysis of the impact, we see that all the QE variables found relevant have a negative impact on the statistic with the major negative impact coming from the 2-month lagged value of the BoJ QE announcement, but if we consider the joint effect of the contemporaneous and lagged effect of the QE announcement from the ECB the negative impact is larger than the prior, meaning that the news is well transmitted and received, not causing any hoarding in the markets.

Next, to have a more reliable representation of the results will do the analysis also with BSADF compiled through the biggest monthly value (output from model in Table A15 in Appendix). The relevant exogenous variables to include were a little different from the previous model for the UK economy. The exogenous variables, in this case, include the contemporaneous QE from the ECB, Fed and BoJ, lagged values of ECB and Fed and the 2-month lagged QE announcement of the ECB. For the exogenous variables impact on BSADF, we have some interesting results that we did not find in the previous model. First, the relevant exogenous variables for the explosiveness equation are, the first lag of the announcement of the ECB, the contemporaneous QE policy of the Fed and of the BoJ. The novelty introduced in this model is that has evidence of a positive effect of the announcements contemporaneously of the Fed and of the BoJ on the price explosiveness for the UK market meaning that when there is an announcement from any of these banks the statistic will have a higher value increases the possibility of verification of bubbles in the financial market. The Fed is the central bank that mostly contributes to the equation with a positive contemporaneous effect of 0.3. However, the impact of the lagged announcement of the ECB will be negative, as it was verified in the previous model but as a remark, this negative effect does not outweigh the positive impact not even surpassing the positive impact from the Fed announcement.

The analysis with the leads was not relevant to the UK financial markets reality, because no lead was found relevant to explain explosiveness.

Analysing the impact of the endogenous variables in our model, now we will see the reaction of the endogenous variables in an IR function plus the Granger Causality equation. The IRF gives us some information regarding the time length of the impact of a shock in the impulse variable and how the response variable reacts. We have made the analysis in Figures 4.17 and 4.18, where we test a shock on our endogenous variables and how the explosiveness variable reacts, and we can see that a shock on Industrial Production and the inflation variable are creating an impact in more periods ahead, this because we see that in some periods the value of 0 is not inside the confidence interval meaning that we are 95% certain of a positive impact on the explosiveness variable. We can see that, for both models, the impact of the shock industrial production variable has a response that starts on the 6th step ahead, so the explosiveness variable takes some time to assimilate this shock. The shock on the inflation variable has a response on explosiveness from the 4th until the 6th step ahead. The inflation variable seems to have a bigger influence on the BSADF variable than industrial production. In real terms means that output and inflation cause a positive reaction in the explosiveness of the markets, but not immediately, it will take some periods for this effect to be observed.

Is interesting also to check what is the impact of a shock of the explosiveness variable on the other endogenous variables, which results are in Figures 4.19 and 4.20. The result that immediately catches our attention is the immediate negative effect of the shock on the output variable in both models, which goes from the 1st period until the 3rd. This negative shock can be explained by a perception of the economics agents on better opportunities in investing in financial markets than in commodities.

Switching to GC analysis, the conclusions we obtain from this test allow us to conclude if a variation of the explosiveness variable is explained by a variation of any of the 5 lagged endogenous variables, results in Figures 4.21 and 4.22. Our null hypothesis is that endogenous variable x does not granger cause variable y, meaning the variables that reject the null hypothesis in the explosiveness indicator equation are the SONIA rate and, the yield of the 5-year Gilt. Interestingly, the results here largely differ from the ones obtained in the IRFs regarding the impact of a shock on the 8 lags ahead of the BSADF variable, at least for the specified confidence interval. Additionally, we notice that explosiveness variable Granger causes industrial production, SONIA rate and the yield of the 5-year gilt. Variance decomposition dynamics give us that the variance of the explosiveness variable is seemingly totally explained by the variable itself.

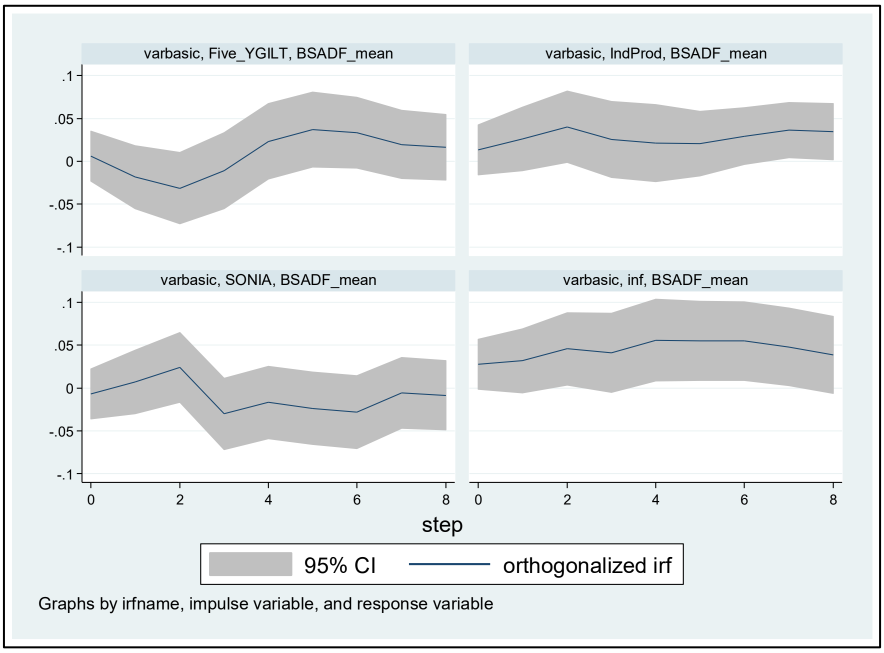

Figure 4.17 - IRFs for the UK case (1)

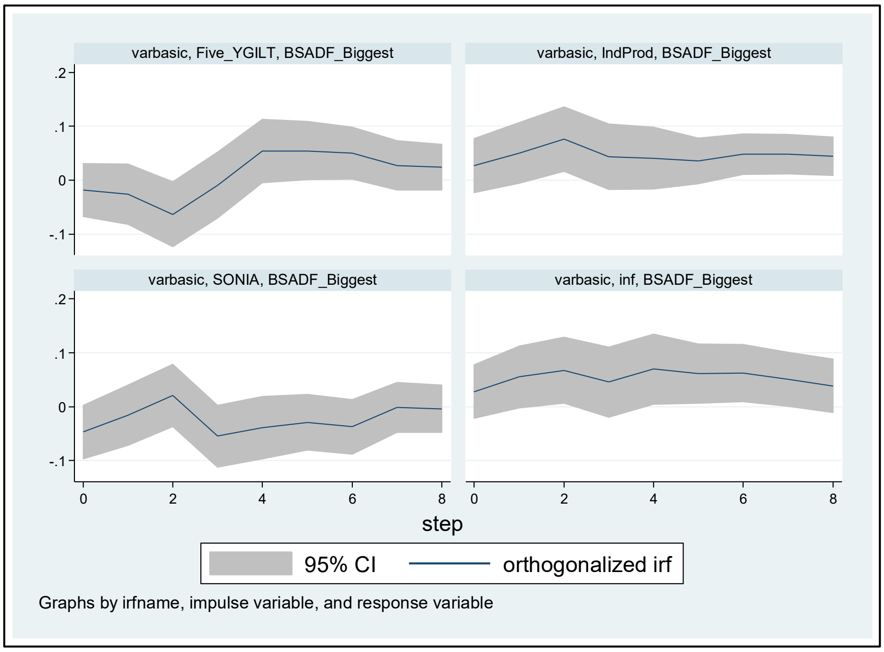

Figure 4.18 - IRFs for the UK case (2)

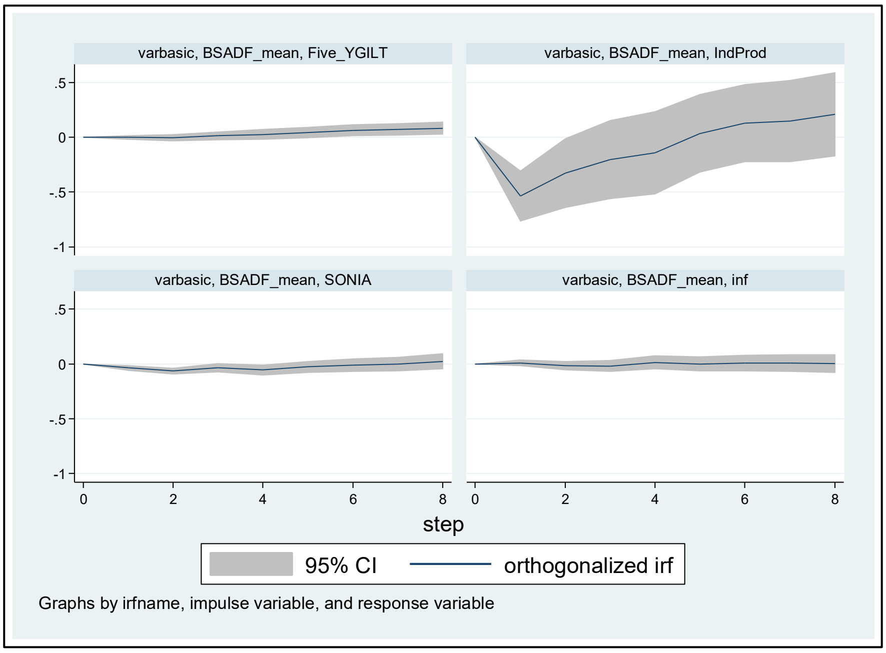

Figure 4.19 - IRFs with explosiveness variable as impulse (1)

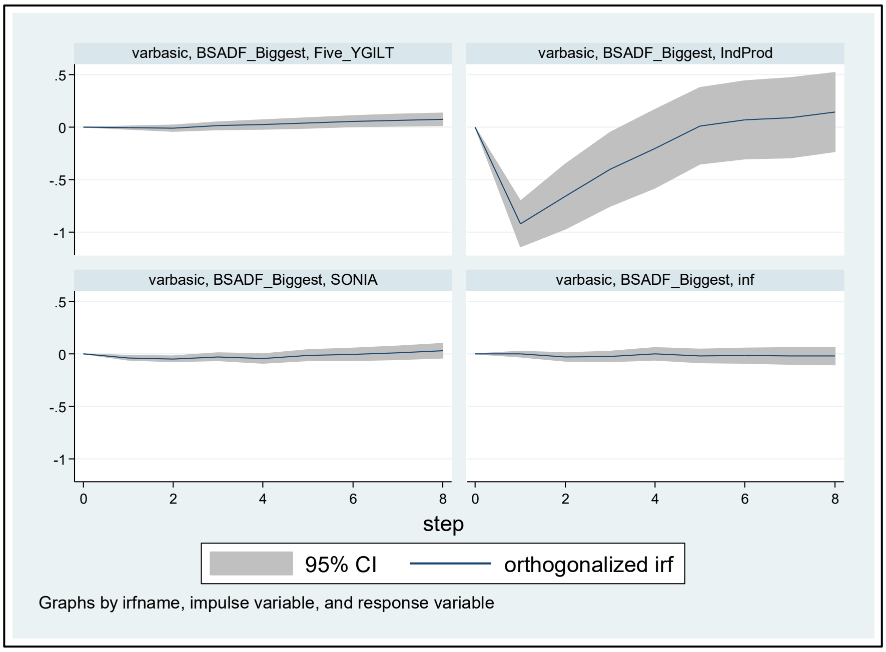

Figure 4.20 - IRFs with explosiveness variable as impulse (2)

Equation	Excluded	chi2	df	Prob > chi2
IndProd	inf	4.757	5	0.446
IndProd	SONIA	20.588	5	0.001
IndProd	Five_YGILT	10.603	5	0.060
IndProd	BSADF_mean	30.558	5	0.000
IndProd	ALL	66.215	20	0.000
inf	IndProd	4.9258	5	0.425
inf	SONIA	4.9572	5	0.421
inf	Five_YGILT	6.212	5	0.286
inf	BSADF_mean	8.6298	5	0.125
inf	ALL	31.864	20	0.045
SONIA	IndProd	.97053	5	0.965
SONIA	inf	11.904	5	0.036
SONIA	Five_YGILT	27.669	5	0.000
SONIA	BSADF_mean	40.002	5	0.000
SONIA	ALL	90.035	20	0.000
Five_YGILT	IndProd	8.7191	5	0.121
Five_YGILT	inf	8.2826	5	0.141
Five_YGILT	SONIA	12.377	5	0.030
Five_YGILT	BSADF_mean	15.581	5	0.008
Five_YGILT	ALL	35.161	20	0.019
BSADF_mean	IndProd	2.4876	5	0.778
BSADF_mean	inf	3.8233	5	0.575
BSADF_mean	SONIA	22.539	5	0.000
BSADF_mean	Five_YGILT	13.495	5	0.019
BSADF_mean	ALL	41.37	20	0.003

Figure 4.21 - Granger causality results for UK (1)

Equation	Excluded	chi2	df	Prob > chi2
IndProd	inf	3.1258	5	0.681
IndProd	SONIA	23.88	5	0.000
IndProd	Five_YGILT	12.134	5	0.033
IndProd	BSADF_Biggest	79.758	5	0.000
IndProd	ALL	123.22	20	0.000
inf	IndProd	2.7298	5	0.742
inf	SONIA	5.6974	5	0.337
inf	Five_YGILT	5.1822	5	0.394
inf	BSADF_Biggest	6.613	5	0.251
inf	ALL	28.896	20	0.090
SONIA	IndProd	2.4855	5	0.779
SONIA	inf	9.5064	5	0.090
SONIA	Five_YGILT	24.806	5	0.000
SONIA	BSADF_Biggest	23.196	5	0.000
SONIA	ALL	67.105	20	0.000
Five_YGILT	IndProd	10.239	5	0.069
Five_YGILT	inf	7.795	5	0.168
Five_YGILT	SONIA	10.685	5	0.058
Five_YGILT	BSADF_Biggest	15.921	5	0.007
Five_YGILT	ALL	36.071	20	0.015
BSADF_Biggest	IndProd	6.5781	5	0.254
BSADF_Biggest	inf	4.4753	5	0.483
BSADF_Biggest	SONIA	10.484	5	0.063
BSADF_Biggest	Five_YGILT	16.168	5	0.006
BSADF_Biggest	ALL	38.187	20	0.008

Figure 4.22 - Granger causality results for UK (2)

4.2.4. Eurozone

4.2.4.1. Specification Results

Now we will check variables and model specifics for the Eurozone region, first we verified that the variables that fail stationarity, similarly to the previous cases are the interbank rate EONIA and the yield of the 5-year EUGV that did not reject H0, being H0 non stationarity. When applying the ADF test with constant the results prove the contrary, especially in the case of EONIA and in the case of the govies by a large margin.

Switching to the remaining tests, the results contradict what we obtained with the ADF test, looking first at the KPSS test where the behaviour of the variables demonstrated no stationarity after selecting the optimal lag length. The same kind of result is obtained with the PP test and DF-GLS where stationarity is rejected.

We will also consider these variables stationarity and proceed with the VAR model because of the same reasons applied in the previous cases: The results of the ADF test and the expected stationary behaviour of the variables.

Advancing for model specifics, the model with the BSADF aggregated with monthly mean and the model with the same variable aggregated with the biggest monthly value demonstrated the same lag to be used for the VAR through AIC, namely 3. One more time, is indicated reliability in the model through stability test and autocorrelation of residuals tests, where both variations of the model for the

Eurozone passed the tests, or in other words, there are no stability issues and the residuals are not autocorrelated.

4.2.4.2. Main Results

We will pass now to the analysis of our last region considered, the Eurozone area; this region differs a bit from the other 3 because it is an area composed of various countries but with a unified action from a central bank. The first model to consider similarly, to before is the model with the monthly mean compression of the BSADF statistic. The exogenous variables to include in the model are the contemporaneous QE announcement from ECB and BoJ and also the lagged effect of the QE from the Fed (results in Table A16 in Appendix).

No exogenous QE variable is found relevant in this model for explaining the BSADF variable equation.

We are also in conditions to test if the exogenous leads of the QEs will have any effect on the explosiveness, model output in Table A18 in Appendix. This model with the same configuration as the above in terms of endogenous variables will also include the contemporaneous effects of the ECB and BoJ but 2 new elements, the lead of the ECB and from the Fed that was found relevant to the model. When we check the results, we can observe that interestingly both leads considered are affecting the BSADF equation with a high confidence level. Despite both leads affecting the values of the equation, they have contrary signals, with the lead of ECB being negative and from Fed positive, which can mean some difference in the way the information is expected from investors or communicated when referring to the Fed or the ECB. The results tend to make us believe that for the Euro Area financial markets the expected announcement of the Fed causes more uncertainty/volatility than the ones from the ECB, in fact, the expected announcement of the ECB will tend to make the explosiveness variable decrease.

For a robustness check, we will now make the same model calculations with the other form of representing the BSADF, through the biggest monthly value. In terms of exogenous variables, no variable or its lag was found relevant to explain BSADF in this model, the same result as in the first model, as possible to see in Appendix Table A17.

Through a model with the leads, we will now try to see if the results match the previous case. The model will include the leads of ECB and Fed QE announcements (model output in Appendix Table A19). In terms of the exogenous variables, in this case, considering the contemporaneous values plus the lead values, we can see that differently from the model with the mean the only lead that is considered actually relevant is the pre-effect of the announcement that comes from the Fed, with a high level of confidence. Similar to the above, the impact of this variable is positive, meaning that the preannouncement of the US central bank affects the statistic of explosivity positively. In this model, there is no doubt that for the Euro area zone, the prices tend to be increasing more rapidly and irrationally when there is speculation around the announcement of quantitative easing policies from the Fed.

Will check now the reaction of endogenous variables that we can detect using the IRFs and Granger Causalities that we obtained from the models. In Figures 4.23 and 4.24, as happened in other regions we can see that no specific lag of the explosiveness variable seems to be certainly impacted by one of the other endogenous variables in either of the models. Although we can detect some trends, as 0 is always inside the confidence interval we cannot conclude a trend for sure. To have a bigger picture we can study how the impact of a shock on the explosiveness variable impacts the endogenous variables, results in Figures 4.25 and 4.26. Results go in the same line as the first case, with the only exception being the negative impact on industrial production at 1-step ahead because we notice that 0 is outside of the 95% confidence interval.

Switching to the GC results in Figures 4.27 and 4.28, in the second model, EONIA is causing the variations in values of our explosive variable, as the p-value rejects the null hypothesis of no causality. Interesting to see that the explosiveness variable Granger causes the output variable meaning that will have some effect on the values for this variable, being this only verified in the second model. As per other cases, variance decomposition dynamics of the explosiveness variable is only explained by the variable itself and no other endogenous variables.

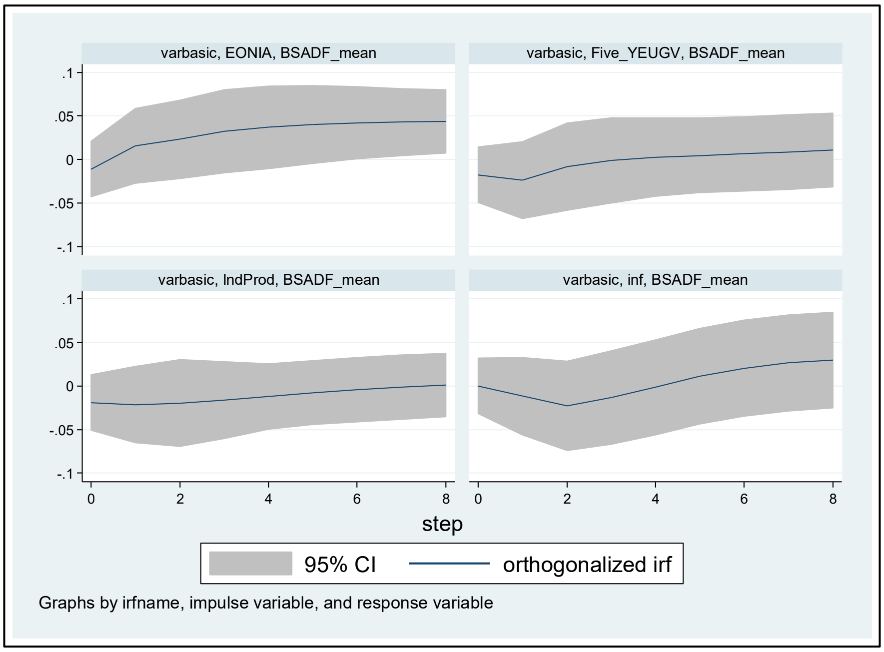

Figure 4.23 - IRFs for the Eurozone case (1)

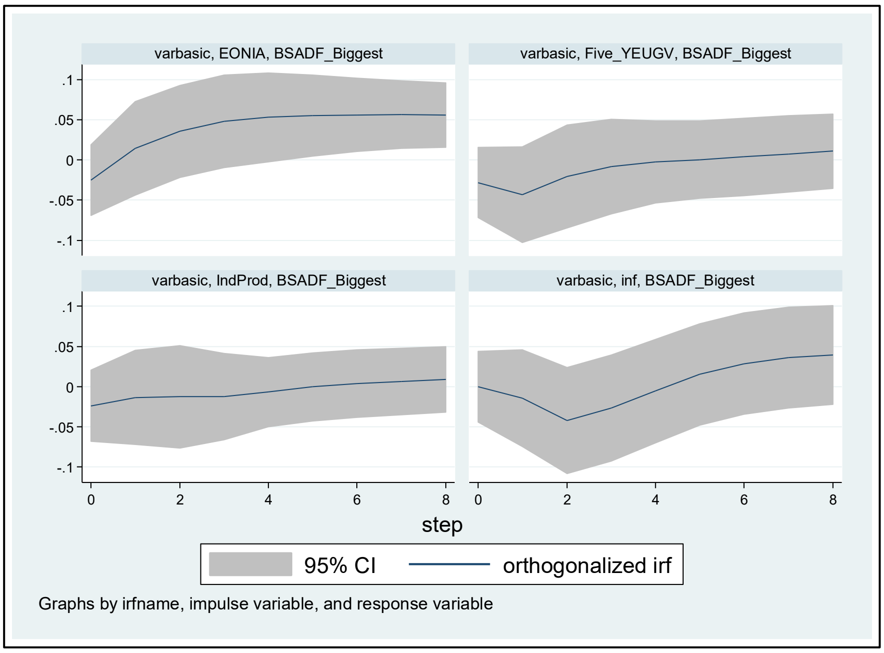

Figure 4.24 - IRFs for the Eurozone case (2)

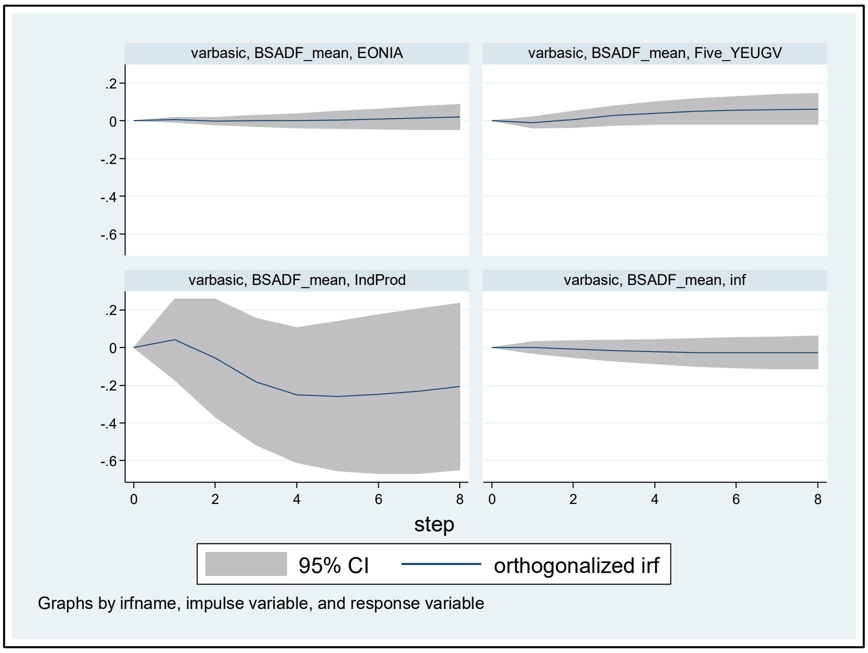

Figure 4.25 - IRFs with explosiveness variables as impulse (1)

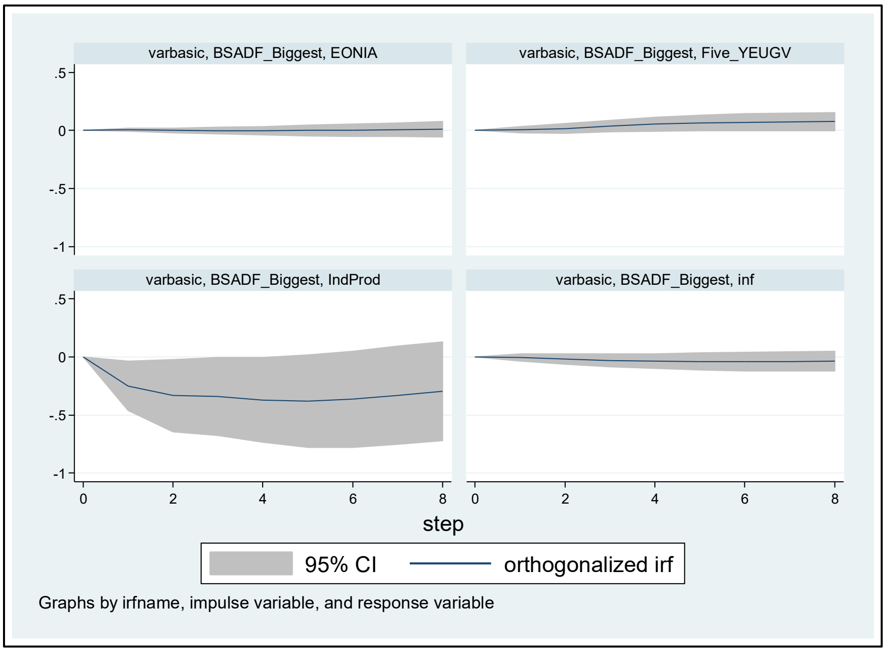

Figure 4.26 - IRFs with explosiveness variable as impulse (2)

Equation	Excluded	chi2	df	Prob > chi2
IndProd	inf	5.8801	3	0.118
IndProd	EONIA	10.172	3	0.017
IndProd	Five_YEUGV	.52364	3	0.914
IndProd	BSADF_mean	3.6548	3	0.301
IndProd	ALL	28.569	12	0.005
inf	IndProd	6.1003	3	0.107
inf	EONIA	.79762	3	0.850
inf	Five_YEUGV	3.2866	3	0.350
inf	BSADF_mean	.93179	3	0.818
inf	ALL	11.263	12	0.507
EONIA	IndProd	3.4659	3	0.325
EONIA	inf	6.2868	3	0.098
EONIA	Five_YEUGV	9.6604	3	0.022
EONIA	BSADF_mean	3.1121	3	0.375
EONIA	ALL	23.802	12	0.022
Five_YEUGV	IndProd	4.1184	3	0.249
Five_YEUGV	inf	9.4206	3	0.024
Five_YEUGV	EONIA	3.15	3	0.369
Five_YEUGV	BSADF_mean	4.3322	3	0.228
Five_YEUGV	ALL	19.391	12	0.080
BSADF_mean	IndProd	.22468	3	0.974
BSADF_mean	inf	2.4432	3	0.486
BSADF_mean	EONIA	5.2148	3	0.157
BSADF_mean	Five_YEUGV	.26889	3	0.966
BSADF_mean	ALL	16.037	12	0.190

Figure 4.27 - Granger causality results for the Eurozone case (1)

Equation	Excluded	chi2	df	Prob > chi2
IndProd	inf	6.0864	3	0.107
IndProd	EONIA	10.756	3	0.013
IndProd	Five_YEUGV	.28671	3	0.963
IndProd	BSADF_Biggest	9.4345	3	0.024
IndProd	ALL	34.873	12	0.000
inf	IndProd	5.8269	3	0.120
inf	EONIA	.84524	3	0.839
inf	Five_YEUGV	3.1601	3	0.368
inf	BSADF_Biggest	1.3252	3	0.723
inf	ALL	11.671	12	0.472
EONIA	IndProd	2.7351	3	0.434
EONIA	inf	6.8018	3	0.078
EONIA	Five_YEUGV	10.86	3	0.013
EONIA	BSADF_Biggest	1.8693	3	0.600
EONIA	ALL	22.465	12	0.033
Five_YEUGV	IndProd	3.8499	3	0.278
Five_YEUGV	inf	9.9086	3	0.019
Five_YEUGV	EONIA	2.5385	3	0.468
Five_YEUGV	BSADF_Biggest	4.4576	3	0.216
Five_YEUGV	ALL	19.523	12	0.077
BSADF_Biggest	IndProd	.14368	3	0.986
BSADF_Biggest	inf	3.998	3	0.262
BSADF_Biggest	EONIA	7.4941	3	0.058
BSADF_Biggest	Five_YEUGV	.35939	3	0.948
BSADF_Biggest	ALL	19.332	12	0.081

Figure 4.28 - Granger causality results for the Eurozone case (2)

4.3. Summary of the Results Across Regions

After all the testing that was done, it is possible to do a cross-region analysis focusing on the similarities and differences among models and regions. The first point to analyse is in terms of the QE variables that are relevant for models. We can see a large influence of the QE framework that comes from BoJ in impacting our economic variables for the set of regions, with this variable impacting all models/regions despite not being always in the same time period. We see particularly a relevant contemporaneous impact from the QE BoJ variable in every model, excluding the models with leads. USA and the UK models are additionally also affected by the lagged variables of the BoJ. On contrary, the QE from the BoE does not seem to be influencing any model maybe demonstrating a lower appetence for the BoE in shaping the economic environment in United Kingdom and worldwide. Interestingly, it seems that the economic variables in the UK are more influenced by the QE policies from the Eurozone with the announcements of ECB being present for 3 time periods: current, one lag and two lags of delay. This is demonstrated by the relevance of these variables for the UK models, tested with the Wald tests.

In terms of the exogenous variables impacting the explosiveness variable, we see a lot of cross region impacts, with the only regions' BSADF statistic not being impacted by any QE announcement the region of Japan. In terms of the sign of the coefficients, we can see that the announcements of the central banks do not have a positive impact on explosiveness, but rather the impact is negative on the BSADF statistic for the USA and first model of UK. In the second model for the UK, we see a positive impact on explosiveness on the markets after the announcement of the Fed and BoJ at the contemporaneous period. For the Eurozone, the models captured also positive impacts on the BSADF variable but in this case the impact was not from a contemporaneous or lagged value of the QE, but from a lead, namely the policy of the US Federal Reserve. This demonstrates that some markets respond better to the announcements from the Central Banks that others, especially the European and British markets seem to be positively shaped by these.

Regarding the endogenous variables impacting the explosiveness variable which conclusions are obtained through the IRFs and Granger Cause analysis, we can see that results of IRFs demonstrate that for most of the regions, shocks in the economic endogenous variables seem to not being affecting future values of the explosiveness indicator. The only region where we can see an impact of the control variables is in the UK, with the industrial production and inflation creating a positive impact in future values, for industrial production starting on the sixth step until the eight and for inflation from the fourth to the sixth step ahead. For the Granger causality analysis, only Japan does not demonstrate any variable granger causing the BSADF statistic. We see a big influence of interest rates for some of the markets, namely USA, UK, and Eurozone where variables of interbank rates and yields of government bonds seem to granger cause price explosiveness. This demonstrates the responsiveness of financial markets to the actions to the conventional monetary policies.

Another interesting result was that through the IRFs we could see that industrial production seems to be particularly reactive to a shock on the explosiveness variable for all markets, except Japan. The impact is registered mainly one step ahead, but in the case for the UK extended for a longer period, until the third step ahead. In terms of signal analysis, the impact is negative for the UK and Eurozone and positive for USA. This demonstrates a strong link between the financial world and real world, meaning that explosive prices in the stock markets can directly influence the levels of production. Additionally, our analysis led to the conclusion that the exuberance variable is Granger causing the IPI variables (it is the case for USA, UK and Eurozone) and also the variables representing interest rates (for the regions of USA, Japan and UK). One more time, a big connection between the BSADF statistic and the interest rate variables.

It is possible to see that despite the different models and regions there seems to exist similarities in terms of the results among models, namely in one of the most important issues, that the QE announcements are shaping some of the dynamics we observe in the financial markets.

5. Conclusion

Since the 2008 recession, the use of unconventional monetary policies has spread to many central banks. Despite some studies on the effects of these policies on the stock markets, there was a lack of studies of the cumulative effect of the announcements on explaining bubble phenomenon on stock markets. This study adds to the literature on the effects of central banks on stock markets, as well as to the research of bubble determinants in stock markets.

In this dissertation we studied the impact of Quantitative Easing in shaping the price explosiveness verified in the USA, UK, Eurozone, and Japan financial markets using daily data between 1995 and 2021. We have done a study on the bubble dynamics on these markets, on a first instance, to assess the existence of bubbles using the GSADF/BSADF method developed by (Phillips et al., 2015). On a second phase, a VAR model was employed to check the determinants of explosiveness with monthly data from 1998 until 2021. The study's goal was to determine if there is any impact from central bank QE announcements in shaping explosiveness on each of the markets. For this goal we developed a VAR model using, besides the variables representing explosiveness in the markets and the one representing the QE announcements, also included a set of control variables which are output measure through industrial production index, inflation measured through the CPI and interest rates measured with the overnight interbank money market rate and the yield of 5-year government bonds.

Results suggest that, on a first moment, there is evidence of several price bubbles' events in all markets between 1995 and 2021, being the markets with more days where it was verified explosiveness, the US and Eurozone markets.

On a second moment, it was studied the impact of a set of variables on the explosiveness indicator, considered by the literature to be the ones more suitable to explain their behaviour. Results demonstrate a predominance of interest rate in explaining variations on the explosiveness indicator, with a predominance for the US and the UK markets. Relatively to the effects of QE announcements on the explosiveness indicator, we can confirm that is verified cross region effects of the QE policies from each central bank. The specific effects of each QE announcement seem to have different impacts regarding different markets/models, with a negative impact on the US market, positive impact on the Eurozone, no impact on Japanese markets, and at last, for the UK, depending on the specification of the model, we can have positive or negative impacts.

This study faced some limitations that could have influenced the results demonstrated. First, given the specification and usage of quantitative easing announcements, we had to input the variable as exogenous in the model, which does not allow for further analysis on the impact of announcements on the explosiveness variable, for example through IRFs or Granger Causality studies. Other limitation is the choice of our variables representing financial markets, because if we chose other variable than stock market indexes the results could be differ. Additionally, because the variable is in an index format, how this index is constructed can give a distorted perspective of how markets are behaving.

Further investigation could be pursued by using other proxies for QE policies and also for financial markets. Additionally, the individual study of the 19 Eurozone member countries would be interesting, to assess which country is most affected by the QE policies events. At last, given some of the results in terms of IRFs and Granger causality further research could be important in terms of the reasons for the conflict of some results and new models that could be employed.

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Appendix

Table A1 - Results of optimal lag length and Monte Carlo minimum window size

	Optimal lag length	Minimum window size
S&P500	9	216
N225	1	218
FTSE100	7	212
SX5E	6	221

Table A2 - Results of SADF and GSADF test on S&P500

	TEST STAT	90% CV	95% CV	99% CV
SADF	2.62868398521025	1.09813261777952	1.43340266316996	1.97610255943097
GSADF	3.35792042881599	1.96817830293142	2.19340123931201	2.56952853406711

Table A3 - Results of SADF and GSADF test on N225

	TEST STAT	90% CV	95% CV	99% CV
SADF	-0.186175682716355	1.11992616315748	1.35131460246103	1.90567487516694
GSADF	3.94421029678443	1.97752238140072	2.18422586293801	2.63539349145661

Table A4 - Results of SADF and GSADF test on FTSE100

	TEST STAT	90% CV	95% CV	99% CV
SADF	1.82952695354811	1.20069769966843	1.42117199079606	2.01497827780657

GSADF	2.6318027155912	1.90919828848057	2.16155838770515	2.51055757323442

Table A5 - Results of SADF and GSADF test on SX5E

	TEST STAT	90% CV	95% CV	99% CV
SADF	4.0184018601661	1.1861294514704	1.4207784944335	1.98592370511478
GSADF	4.08576433784248	1.93107719269261	2.17126338273937	2.68149402589662

Table A6 - Explosiveness in the US markets and QE announcements

Periods of explosiveness the markets (90% confidence level)	Fed Quantitative easing announcements	BoJ Quantitative easing announcements	BoE Quantitative easing announcements	ECB Quantitative easing announcements
12/02/1997 – 26/02/1997				
19/06/1997 – 20/06/1997				
03/07/1997 – 11/08/1997				
17/03/1998 – 04/05/1998				
08/07/1998 – 20/07/1998				
16/03/2001 – 06/04/2001		19/03/2001		
		14/08/2001		
		18/09/2001		
		19/12/2001		
		30/10/2002		
		25/03/2003		
		30/04/2003		
		20/05/2003		
		10/10/2003		
		20/01/2004		
14/12/2006 – 19/12/2006				
21/05/2007 – 05/06/2007				

07/10/2008 – 15/12/2008	25/11/2008			
		19/12/2008		
			19/01/2009	
20/01/2009				
		03/02/2009		
18/02/2009 – 16/03/2009		19/02/2009	05/03/2009	
	18/03/2009	18/03/2009		
			07/05/2009	07/05/2009
				02/07/2009
			06/08/2009	
	04/11/2009			
			05/11/2009	
		17/03/2010		
				09/05/2010
		05/10/2010		
	03/11/2010			
		14/03/2011		
		04/08/2011		
				07/08/2011
	21/09/2011			
			06/10/2011	06/10/2011
		27/10/2011		
				03/11/2011
				08/12/2011
				21/12/2011
			09/02/2012	
		14/02/2012		
				29/02/2012
		13/03/2012		
		27/04/2012		
	20/06/2012			
			05/07/2012	
			13/07/2012	
				06/09/2012
	13/09/2012			
		19/09/2012		
		30/10/2012		
	12/12/2012			
		20/12/2012		
		04/04/2013		
15/05/2013 – 21/05/2013				
			07/08/2013	

		18/02/2014		
				05/06/2014
				04/09/2014
				16/09/2014
				20/10/2014
		31/10/2014		
				21/11/2014
				09/12/2014
				22/01/2015
				09/03/2015
				17/03/2015
				16/06/2015
				22/09/2015
				09/12/2015
		18/12/2015		
				10/03/2016
				22/03/2016
				08/06/2016
		29/07/2016		
			04/08/2016	
		21/09/2016		
19/10/2017 – 19/04/2018				
09/05/2018 – 08/11/2018				
				07/03/2019
10/04/2019 – 02/09/2020	15/03/2020 | 23/03/2020	16/03/2020 | 27/04/2020	19/03/2020 | 18/07/2020	12/09/2019 | 18/03/2020 | 30/04/2020 | 04/06/2020
	03/11/2021			
			05/11/2020	
16/11/2020 – 30/12/2021		18/12/2020		10/12/2020

Table A7 - Explosiveness in the Japanese markets and QE announcements

Periods of explosiveness the markets (90% confidence level)	Fed Quantitative easing announcements	BoJ Quantitative easing announcements	BoE Quantitative easing announcements	ECB Quantitative easing announcements
10/01/1997				
		19/03/2001		
		14/08/2001		
		18/09/2001		

		19/12/2001		
		30/10/2002		
		25/03/2003		
		30/04/2003		
		20/05/2003		
		10/10/2003		
		20/01/2004		
26/09/2005 - 05/10/2005				
04/11/2005 - 17/01/2006				
26/01/2006 - 09/02/2006				
29/03/2006 - 21/04/2006				
10/10/2008				
16/10/2008 - 28/10/2008				
	25/11/2008			
		19/12/2008		
			19/01/2009	
		03/02/2009		
		19/02/2009		
			05/03/2009	
	18/03/2009	18/03/2009		
			07/05/2009	07/05/2009
				02/07/2009
			06/08/2009	
	04/11/2009			
			05/11/2009	
		17/03/2010		
				09/05/2010
		05/10/2010		
	03/11/2010			
		14/03/2011		
		04/08/2011		
				07/08/2011
	21/09/2011			
			06/10/2011	06/10/2011
		27/10/2011		
				03/11/2011
				08/12/2011
				21/12/2011
			09/02/2012	
		14/02/2012		

				29/02/2012
		13/03/2012		
		27/04/2012		
	20/06/2012			
			05/07/2012	
			13/07/2012	
				06/09/2012
	13/09/2012			
		19/09/2012		
		30/10/2012		
	12/12/2012			
		20/12/2012		
25/02/2013				
06/03/2013 - 29/05/2013		04/04/2013		
18/07/2013				
23/07/2013				
24/07/2013				
			07/08/2013	
		18/02/2014		
				05/06/2014
				04/09/2014
				16/09/2014
				20/10/2014
		31/10/2014		
				21/11/2014
				09/12/2014
				22/01/2015
				09/03/2015
				17/03/2015
				16/06/2015
				22/09/2015
				09/12/2015
		18/12/2015		
				10/03/2016
				22/03/2016
				08/06/2016
		29/07/2016		
			04/08/2016	
		21/09/2016		
07/11/2017- 09/11/2017				
				07/03/2019

	15/03/2020			
		16/03/2020		
				18/03/2020
19/03/2020			19/03/2020	
	23/03/2020			
		27/04/2020		
				30/04/2020
				04/06/2020
			18/07/2020	18/07/2020
			05/11/2020	
				10/12/2020
		18/12/2020		
	03/11/2021			

Table A8 - Explosiveness in the UK markets and QE announcements

Periods of explosiveness the markets (90% confidence level)	Fed Quantitative easing announcements	BoJ Quantitative easing announcements	BoE Quantitative easing announcements	ECB Quantitative easing announcements
13/05/1997 – 16/05/1997				
13/06/1997				
14/07/1997 – 21/08/1997				
22/09/1997 – 21/10/1997				
17/02/1998 – 23/04/1998				
01/05/1998				
11/05/1998				
		19/03/2001		
		14/08/2001		
		18/09/2001		
21/09/2001				
		19/12/2001		
24/07/2002				
		30/10/2002		
		25/03/2003		
		30/04/2003		
		20/05/2003		
		10/10/2003		
		20/01/2004		
10/10/2008 – 28/10/2008				

21/11/2008				
	25/11/2008			
		19/12/2008		
			19/01/2009	
		03/02/2009		
		19/02/2009		
			05/03/2009	
	18/03/2009	18/03/2009		
			07/05/2009	07/05/2009
				02/07/2009
			06/08/2009	
	04/11/2009			
			05/11/2009	
		17/03/2010		
				09/05/2010
		05/10/2010		
	03/11/2010			
		14/03/2011		
		04/08/2011		
				07/08/2011
	21/09/2011			
			06/10/2011	06/10/2011
		27/10/2011		
				03/11/2011
				08/12/2011
				21/12/2011
			09/02/2012	
		14/02/2012		
				29/02/2012
		13/03/2012		
		27/04/2012		
	20/06/2012			
			05/07/2012	
			13/07/2012	
				06/09/2012
	13/09/2012			
		19/09/2012		
		30/10/2012		
	12/12/2012			
		20/12/2012		
		04/04/2013		
			07/08/2013	
		18/02/2014		
				05/06/2014

				04/09/2014
				16/09/2014
				20/10/2014
		31/10/2014		
				21/11/2014
				09/12/2014
				22/01/2015
				09/03/2015
				17/03/2015
				16/06/2015
				22/09/2015
				09/12/2015
		18/12/2015		
				10/03/2016
				22/03/2016
				08/06/2016
		29/07/2016		
			04/08/2016	
		21/09/2016		
				07/03/2019
12/03/2020 – 23/03/2020	15/03/2020 | 23/03/2020	16/03/2020	19/03/2020	18/03/2020
		27/04/2020		
				30/04/2020
				04/06/2020
			18/07/2020	18/07/2020
			05/11/2020	
				10/12/2020
		18/12/2020		
	03/11/2021			

Table A9 - Explosiveness in the Eurozone markets and QE announcements

Periods of explosiveness the markets (90% confidence level)	Fed Quantitative easing announcements	BoJ Quantitative easing announcements	BoE Quantitative easing announcements	ECB Quantitative easing announcements
24/01/1996 - 02/02/1996				
13/01/1997 - 31/03/1997				
09/04/1997				

16/04/1997 - 17/04/1997				
23/04/1997 - 27/08/1997				
02/09/1997 - 10/09/1997				
16/09/1997 - 16/10/1997				
25/02/1998 - 04/08/1998				
22/12/1999 - 03/01/2000				
14/01/2000				
17/01/2000				
02/02/2000 - 31/03/2000				
07/04/2000				
10/04/2000				
28/04/2000				
01/05/2000 - 05/05/2000				
16/05/2000				
02/06/2000				
		19/03/2001		
		14/08/2001		
14/09/2001 - 25/09/2001		18/09/2001		
		19/12/2001		
23/09/2002 - 25/09/2002				
30/09/2002				
08/10/2002 - 09/10/2002				
		30/10/2002		
		25/03/2003		
		30/04/2003		
		20/05/2003		
		10/10/2003		
		20/01/2004		
22/02/2006 - 27/02/2006				
10/10/2008				
15/10/2008 - 30/10/2008				
17/11/2008 - 26/11/2008	25/11/2008			
01/12/2008				
05/12/2008				

		19/12/2008		
			19/01/2009	
		03/02/2009		
		19/02/2009		
24/02/2009 - 25/02/2009				
02/03/2009 - 11/03/2009			05/03/2009	
	18/03/2009	18/03/2009		
			07/05/2009	07/05/2009
				02/07/2009
			06/08/2009	
	04/11/2009			
			05/11/2009	
		17/03/2010		
				09/05/2010
		05/10/2010		
	03/11/2010			
		14/03/2011		
		04/08/2011		
				07/08/2011
	21/09/2011			
			06/10/2011	06/10/2011
		27/10/2011		
				03/11/2011
				08/12/2011
				21/12/2011
			09/02/2012	
		14/02/2012		
				29/02/2012
		13/03/2012		
		27/04/2012		
	20/06/2012			
			05/07/2012	
			13/07/2012	
				06/09/2012
	13/09/2012			
		19/09/2012		
		30/10/2012		
	12/12/2012			
		20/12/2012		
		04/04/2013		
			07/08/2013	
		18/02/2014		
				05/06/2014

				04/09/2014
				16/09/2014
				20/10/2014
		31/10/2014		
				21/11/2014
				09/12/2014
				22/01/2015
				09/03/2015
				17/03/2015
				16/06/2015
				22/09/2015
				09/12/2015
		18/12/2015		
				10/03/2016
				22/03/2016
				08/06/2016
		29/07/2016		
			04/08/2016	
		21/09/2016		
				07/03/2019
	15/03/2020			
		16/03/2020		
				18/03/2020
			19/03/2020	
	23/03/2020			
		27/04/2020		
				30/04/2020
				04/06/2020
			18/07/2020	18/07/2020
			05/11/2020	
				10/12/2020
		18/12/2020		
	03/11/2021			

Table A10 - VAR model estimation results for USA (1)

	(1)	(2)	(3)	(4)	(5)
VARIABLES	IndProd	FedFundsR	Five_YUST	BSADF_mean	inf
L.IndProd	0.956***	0.00266	0.00141	0.00491	0.00673
	(0.0595)	(0.00735)	(0.0122)	(0.0183)	(0.0226)
L2.IndProd	-0.0740	-0.00470	0.000820	-0.0303	0.0246

	(0.0774)	(0.00954)	(0.0159)	(0.0238)	(0.0294)
L3.IndProd	0.0482	0.00447	-0.00434	0.0222	-0.0313
	(0.0522)	(0.00644)	(0.0107)	(0.0161)	(0.0198)
L.FedFundsR	3.631***	1.504***	0.105	-0.164	0.681***
	(0.513)	(0.0633)	(0.105)	(0.158)	(0.195)
L2.FedFundsR	-5.368***	-0.444***	-0.122	0.398	-1.190***
	(0.889)	(0.110)	(0.183)	(0.273)	(0.338)
L3.FedFundsR	1.955***	-0.0914	0.0336	-0.198	0.556***
	(0.501)	(0.0618)	(0.103)	(0.154)	(0.190)
L.Five_YUST	0.603**	0.183***	1.220***	0.0607	0.215*
	(0.296)	(0.0366)	(0.0609)	(0.0912)	(0.113)
L2.Five_YUST	-1.086**	-0.144**	-0.286***	-0.205	-0.471***
	(0.460)	(0.0568)	(0.0945)	(0.141)	(0.175)
L3.Five_YUST	0.163	-0.00540	0.0328	0.0544	0.203*
	(0.315)	(0.0389)	(0.0648)	(0.0970)	(0.120)
L.BSADF_mean	0.618***	-0.0417*	-0.0202	0.929***	-0.0684
	(0.193)	(0.0238)	(0.0396)	(0.0593)	(0.0733)
L2.BSADF_mean	-1.055***	0.00453	-0.0212	-0.136	0.0805
	(0.270)	(0.0334)	(0.0556)	(0.0832)	(0.103)
L3.BSADF_mean	0.152	0.0413	0.0419	0.0892	-0.0169
	(0.207)	(0.0256)	(0.0426)	(0.0638)	(0.0789)
L.inf	0.216	-0.0364*	0.0392	-0.0165	1.401***
	(0.158)	(0.0195)	(0.0324)	(0.0486)	(0.0600)
L2.inf	-0.198	0.0346	-0.0806	0.00544	-0.629***
	(0.253)	(0.0312)	(0.0520)	(0.0779)	(0.0963)
L3.inf	-0.0410	-0.00555	0.0325	0.0243	0.152**
	(0.163)	(0.0201)	(0.0334)	(0.0500)	(0.0618)
QE_ECB	-0.241	-0.0382	-0.0737*	-0.168**	-0.196**
	(0.214)	(0.0264)	(0.0439)	(0.0658)	(0.0813)
QE_BoJ	-0.800***	-0.0217	-0.105***	-0.0145	-0.0829
	(0.198)	(0.0244)	(0.0407)	(0.0609)	(0.0753)
L2.QE_BoJ	0.306	-0.0119	0.0208	-0.240***	0.00774
	(0.201)	(0.0248)	(0.0414)	(0.0619)	(0.0766)
L.QE_FED	-1.515***	0.0392	0.0554	-0.122	-0.100
	(0.333)	(0.0411)	(0.0685)	(0.103)	(0.127)
L2.QE_FED	-0.961***	0.0652	0.0179	-0.0244	-0.0809
	(0.354)	(0.0437)	(0.0727)	(0.109)	(0.135)
Constant	7.634***	-0.255	0.291	0.535	0.282
	(1.731)	(0.214)	(0.356)	(0.532)	(0.658)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A11 - VAR model estimation results for USA (2)

VARIABLES	(1) IndProd	(2) FedFundsR	(3) Five_YUST	(4) BSADF_Biggest	(5) inf
L.IndProd	0.936***	0.000555	0.000198	-0.00865	0.00816
	(0.0587)	(0.00700)	(0.0118)	(0.0211)	(0.0218)
L2.IndProd	-0.0651	-0.00371	0.00302	-0.0168	0.0218
	(0.0779)	(0.00928)	(0.0156)	(0.0280)	(0.0289)
L3.IndProd	0.0544	0.00533	-0.00527	0.0215	-0.0301
	(0.0541)	(0.00644)	(0.0108)	(0.0194)	(0.0200)
L.FedFundsR	3.880***	1.507***	0.0934	0.0348	0.664***
	(0.527)	(0.0628)	(0.105)	(0.189)	(0.195)
L2.FedFundsR	-5.877***	-0.438***	-0.0996	0.127	-1.154***
	(0.912)	(0.109)	(0.183)	(0.328)	(0.338)
L3.FedFundsR	2.238***	-0.0981	0.0224	-0.111	0.541***
	(0.513)	(0.0612)	(0.103)	(0.184)	(0.190)
L.Five_YUST	0.636**	0.176***	1.216***	0.150	0.206*
	(0.304)	(0.0362)	(0.0608)	(0.109)	(0.113)
L2.Five_YUST	-1.203**	-0.133**	-0.280***	-0.414**	-0.453***
	(0.471)	(0.0562)	(0.0943)	(0.169)	(0.175)
L3.Five_YUST	0.215	-0.0142	0.0304	0.157	0.188
	(0.323)	(0.0385)	(0.0647)	(0.116)	(0.120)
L.BSADF_Biggest	0.0594	-0.0661***	-0.0263	0.993***	-0.0757
	(0.165)	(0.0196)	(0.0330)	(0.0592)	(0.0610)
L2.BSADF_Biggest	-0.266	0.0629**	-0.00884	-0.236***	0.0818
	(0.234)	(0.0278)	(0.0467)	(0.0839)	(0.0866)
L3.BSADF_Biggest	-0.106	7.44e-05	0.0356	0.0971	-0.0207
	(0.174)	(0.0207)	(0.0348)	(0.0625)	(0.0645)
L.inf	0.214	-0.0352*	0.0391	-0.0629	1.402***
	(0.162)	(0.0193)	(0.0324)	(0.0582)	(0.0600)
L2.inf	-0.200	0.0324	-0.0807	0.132	-0.632***
	(0.260)	(0.0309)	(0.0519)	(0.0932)	(0.0962)
L3.inf	-0.0316	-0.00429	0.0330	-0.0520	0.156**
	(0.166)	(0.0198)	(0.0333)	(0.0598)	(0.0617)
QE_ECB	-0.280	-0.0382	-0.0753*	-0.142*	-0.197**
	(0.219)	(0.0261)	(0.0439)	(0.0788)	(0.0812)
QE_BoJ	-0.822***	-0.0238	-0.105***	0.0106	-0.0829
	(0.202)	(0.0241)	(0.0405)	(0.0727)	(0.0750)
L2.QE_BoJ	0.282	-0.0172	0.0207	-0.234***	0.00275
	(0.207)	(0.0246)	(0.0414)	(0.0743)	(0.0766)
L.QE_FED	-1.600***	0.0340	0.0575	-0.233*	-0.0989
	(0.341)	(0.0406)	(0.0682)	(0.122)	(0.126)
L2.QE_FED	-1.026***	0.0539	0.0169	-0.116	-0.0886
	(0.362)	(0.0431)	(0.0724)	(0.130)	(0.134)
Constant	8.199***	-0.221	0.285	0.660	0.294
	(1.779)	(0.212)	(0.356)	(0.639)	(0.659)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A12 - VAR model estimation results for Japan (1)

VARIABLES	(1) IndProd	(2) inf	(3) CallMM	(4) Five_YJGB_mean	(5) BSADF_mean
L.IndProd	0.949***	0.00345	0.00115*	-0.00147	-0.00576
	(0.0572)	(0.00820)	(0.000631)	(0.00204)	(0.00790)
L2.IndProd	-0.0571	0.00741	-0.000793	0.00323	0.00603
	(0.0577)	(0.00828)	(0.000637)	(0.00206)	(0.00797)
L.inf	0.844**	1.082***	0.00365	-0.0212	-0.105*
	(0.411)	(0.0590)	(0.00454)	(0.0147)	(0.0568)
L2.inf	-1.035**	-0.194***	-0.00385	0.0113	0.114**
	(0.404)	(0.0579)	(0.00445)	(0.0144)	(0.0558)
L.CallMM	14.47***	0.435	1.352***	0.195	1.323*
	(5.118)	(0.734)	(0.0565)	(0.183)	(0.707)
L2.CallMM	-14.60***	-0.223	-0.403***	-0.240	-1.099
	(5.041)	(0.723)	(0.0556)	(0.180)	(0.697)
L.Five_YJGB_mean	1.345	0.221	0.00802	1.150***	0.172
	(1.703)	(0.244)	(0.0188)	(0.0607)	(0.235)
L2.Five_YJGB_mean	-0.701	-0.406	0.000371	-0.184***	-0.247
	(1.721)	(0.247)	(0.0190)	(0.0614)	(0.238)
L.BSADF_mean	0.00954	-0.0753	-0.00865*	0.00686	0.921***
	(0.436)	(0.0626)	(0.00481)	(0.0156)	(0.0602)
L2.BSADF_mean	-0.114	0.110*	0.00779	0.00919	-0.0819
	(0.434)	(0.0623)	(0.00479)	(0.0155)	(0.0600)
QE_BoJ	-1.971***	-0.0358	-0.00375	-0.0222	-0.0220
	(0.410)	(0.0588)	(0.00453)	(0.0146)	(0.0567)
L2.QE_FED	-2.392***	-0.119	-0.00407	-0.00290	0.0268
	(0.704)	(0.101)	(0.00778)	(0.0251)	(0.0973)
Constant	11.10***	-1.018***	-0.0362	-0.159*	-0.0622
	(2.429)	(0.349)	(0.0268)	(0.0866)	(0.336)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A13 - VAR model estimation results for Japan (2)

VARIABLES	(1) IndProd	(2) inf	(3) CallMM	(4) Five_YJGB_mean	(5) BSADF_Biggest
L.IndProd	0.948***	0.00408	0.00118*	-0.00152	0.00182
	(0.0573)	(0.00824)	(0.000633)	(0.00204)	(0.0112)
L2.IndProd	-0.0564	0.00669	-0.000819	0.00320	-0.000669
	(0.0577)	(0.00830)	(0.000638)	(0.00206)	(0.0113)
L.inf	0.843**	1.084***	0.00387	-0.0206	-0.131
	(0.410)	(0.0590)	(0.00454)	(0.0146)	(0.0800)
L2.inf	-1.026**	-0.196***	-0.00403	0.0109	0.140*

	(0.403)	(0.0579)	(0.00445)	(0.0143)	(0.0786)
L.CallMM	14.20***	0.430	1.348***	0.202	1.824*
	(5.122)	(0.737)	(0.0566)	(0.182)	(0.999)
L2.CallMM	-14.29***	-0.215	-0.399***	-0.248	-1.462
	(5.045)	(0.726)	(0.0558)	(0.180)	(0.984)
L.Five_YJGB_mean	1.548	0.197	0.00668	1.145***	0.456
	(1.701)	(0.245)	(0.0188)	(0.0606)	(0.332)
L2.Five_YJGB_mean	-0.897	-0.383	0.00187	-0.178***	-0.559*
	(1.713)	(0.246)	(0.0189)	(0.0610)	(0.334)
L.BSADF_Biggest	-0.153	-0.0472	-0.00585*	0.0166	0.779***
	(0.308)	(0.0444)	(0.00341)	(0.0110)	(0.0602)
L2.BSADF_Biggest	-0.0291	0.0732	0.00475	-0.00246	0.0373
	(0.310)	(0.0445)	(0.00342)	(0.0110)	(0.0604)
QE_BoJ	-1.971***	-0.0359	-0.00381	-0.0228	0.0439
	(0.410)	(0.0589)	(0.00453)	(0.0146)	(0.0799)
L2.QE_FED	-2.403***	-0.127	-0.00449	-0.00263	0.00675
	(0.704)	(0.101)	(0.00779)	(0.0251)	(0.137)
Constant	11.08***	-1.017***	-0.0368	-0.153*	-0.126
	(2.425)	(0.349)	(0.0268)	(0.0864)	(0.473)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A14 - VAR model estimation results for UK (1)

	(1)	(2)	(3)	(4)	(5)
VARIABLES	IndProd	inf	SONIA	Five_YGILT	BSADF_mean
L.IndProd	0.889***	-0.000541	-0.00399	-0.00301	0.00173
	(0.0587)	(0.00766)	(0.00591)	(0.00483)	(0.00804)
L2.IndProd	-0.112	-0.00890	0.00566	0.00464	-0.000102
	(0.0764)	(0.00997)	(0.00769)	(0.00629)	(0.0105)
L3.IndProd	-0.0355	0.00157	-0.00497	-0.00493	-0.00567
	(0.0767)	(0.0100)	(0.00772)	(0.00631)	(0.0105)
L4.IndProd	0.131*	0.0122	0.00297	0.00376	0.00376
	(0.0740)	(0.00965)	(0.00745)	(0.00608)	(0.0101)
L5.IndProd	0.0238	-0.00277	0.000710	-0.00567	0.00423
	(0.0524)	(0.00684)	(0.00528)	(0.00431)	(0.00718)
L.inf	0.258	0.952***	0.0612	0.0399	0.0195
	(0.476)	(0.0621)	(0.0479)	(0.0392)	(0.0652)
L2.inf	-1.051	0.160*	-0.0937	-0.0691	0.0622
	(0.652)	(0.0850)	(0.0656)	(0.0536)	(0.0892)
L3.inf	0.210	-0.0994	-0.0803	-0.0149	-0.0306
	(0.674)	(0.0879)	(0.0679)	(0.0555)	(0.0923)
L4.inf	0.518	-0.00599	0.0579	-0.0246	0.0179
	(0.689)	(0.0898)	(0.0694)	(0.0567)	(0.0943)
L5.inf	0.0528	-0.0645	0.0248	0.0474	-0.0649
	(0.499)	(0.0650)	(0.0502)	(0.0410)	(0.0683)
L.SONIA	1.384**	0.0739	0.763***	-0.0583	0.0952

	(0.620)	(0.0808)	(0.0624)	(0.0510)	(0.0849)
L2.SONIA	-0.294	-0.131	0.496***	0.105*	0.0481
	(0.738)	(0.0962)	(0.0742)	(0.0607)	(0.101)
L3.SONIA	-0.102	0.0925	0.0282	0.0495	-0.469***
	(0.785)	(0.102)	(0.0790)	(0.0646)	(0.108)
L4.SONIA	-2.835***	0.0513	-0.423***	-0.119*	0.234**
	(0.750)	(0.0978)	(0.0755)	(0.0617)	(0.103)
L5.SONIA	2.100***	-0.0979	0.0954	0.0553	0.0945
	(0.602)	(0.0785)	(0.0606)	(0.0495)	(0.0824)
L.Five_YGILT	-0.0932	0.0855	0.357***	1.400***	-0.128
	(0.751)	(0.0980)	(0.0756)	(0.0618)	(0.103)
L2.Five_YGILT	-1.075	-0.0752	-0.382***	-0.544***	-0.00900
	(1.271)	(0.166)	(0.128)	(0.105)	(0.174)
L3.Five_YGILT	0.179	-0.167	0.0476	0.118	0.176
	(1.294)	(0.169)	(0.130)	(0.106)	(0.177)
L4.Five_YGILT	0.577	0.0559	0.129	-0.0196	0.224
	(1.247)	(0.163)	(0.125)	(0.103)	(0.171)
L5.Five_YGILT	-0.237	0.103	-0.114	-0.0211	-0.242**
	(0.751)	(0.0980)	(0.0756)	(0.0618)	(0.103)
L.BSADF_mean	-2.010***	0.00324	-0.143***	-0.00769	0.778***
	(0.433)	(0.0564)	(0.0436)	(0.0356)	(0.0593)
L2.BSADF_mean	2.618***	-0.125*	-0.0496	-0.0317	0.0410
	(0.555)	(0.0723)	(0.0558)	(0.0456)	(0.0760)
L3.BSADF_mean	-0.303	0.0397	0.286***	0.124***	0.00148
	(0.553)	(0.0721)	(0.0557)	(0.0455)	(0.0758)
L4.BSADF_mean	-0.602	0.152**	-0.143**	-0.0283	-0.0729
	(0.580)	(0.0757)	(0.0584)	(0.0477)	(0.0795)
L5.BSADF_mean	0.487	-0.0943	0.0586	0.0131	0.0736
	(0.454)	(0.0592)	(0.0457)	(0.0374)	(0.0622)
QE_ECB	-1.117***	-0.115**	-0.0208	-0.0411	-0.0949*
	(0.396)	(0.0517)	(0.0399)	(0.0326)	(0.0543)
L.QE_ECB	-0.781*	-0.116**	0.0268	-0.0440	-0.143***
	(0.402)	(0.0524)	(0.0405)	(0.0331)	(0.0551)
L2.QE_ECB	0.280	-0.161***	-0.0249	0.0172	0.0344
	(0.414)	(0.0539)	(0.0416)	(0.0340)	(0.0567)
QE_BoJ	-1.077***	0.0150	-0.0256	-0.0591**	0.0527
	(0.356)	(0.0464)	(0.0358)	(0.0293)	(0.0487)
L.QE_BoJ	-0.926**	3.79e-05	0.00200	0.0249	0.0703
	(0.368)	(0.0480)	(0.0370)	(0.0303)	(0.0504)
L2.QE_BoJ	0.236	-0.0507	0.0354	-0.0350	-0.156***
	(0.366)	(0.0478)	(0.0369)	(0.0301)	(0.0502)
L.QE_FED	-2.528***	0.0582	-0.105*	0.0542	-0.0267
	(0.614)	(0.0801)	(0.0618)	(0.0505)	(0.0841)
Constant	11.79***	0.0144	0.0162	0.696***	-0.553
	(2.749)	(0.358)	(0.277)	(0.226)	(0.376)

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A15 - VAR model estimation results for UK (2)

VARIABLES	(1) IndProd	(2) inf	(3) SONIA	(4) Five_YGILT	(5) BSADF_Biggest
L.IndProd	0.954***	-0.00203	-0.00386	-0.00402	0.0114
	(0.0576)	(0.00815)	(0.00631)	(0.00512)	(0.0146)
L2.IndProd	-0.168**	-0.00347	0.00692	0.0116*	0.00748
	(0.0787)	(0.0111)	(0.00862)	(0.00699)	(0.0199)
L3.IndProd	-0.0296	0.000930	-0.0112	-0.0119*	-0.0165
	(0.0790)	(0.0112)	(0.00864)	(0.00702)	(0.0200)
L4.IndProd	0.140*	0.00786	0.0110	0.00744	0.0103
	(0.0761)	(0.0108)	(0.00833)	(0.00676)	(0.0193)
L5.IndProd	0.0170	-0.000678	-0.00271	-0.00715	0.000128
	(0.0503)	(0.00710)	(0.00550)	(0.00446)	(0.0127)
L.inf	0.276	0.950***	0.0490	0.0402	0.141
	(0.441)	(0.0623)	(0.0482)	(0.0392)	(0.112)
L2.inf	-0.709	0.154*	-0.0669	-0.0781	-0.0430
	(0.607)	(0.0857)	(0.0664)	(0.0539)	(0.154)
L3.inf	-0.0791	-0.0883	-0.0944	-0.00317	-0.0575
	(0.627)	(0.0887)	(0.0687)	(0.0557)	(0.159)
L4.inf	0.338	0.000915	0.0462	-0.0271	0.0909
	(0.640)	(0.0904)	(0.0700)	(0.0568)	(0.162)
L5.inf	0.215	-0.0730	0.0440	0.0493	-0.117
	(0.461)	(0.0651)	(0.0504)	(0.0409)	(0.117)
L.SONIA	1.091*	0.0980	0.755***	-0.0548	0.0837
	(0.562)	(0.0794)	(0.0615)	(0.0499)	(0.142)
L2.SONIA	0.0383	-0.162*	0.495***	0.0923	0.131
	(0.666)	(0.0941)	(0.0729)	(0.0591)	(0.168)
L3.SONIA	0.0958	0.0938	0.0170	0.0569	-0.551***
	(0.721)	(0.102)	(0.0789)	(0.0640)	(0.182)
L4.SONIA	-2.986***	0.0392	-0.416***	-0.118*	0.102
	(0.683)	(0.0965)	(0.0748)	(0.0607)	(0.173)
L5.SONIA	1.981***	-0.0807	0.107*	0.0522	0.230
	(0.554)	(0.0783)	(0.0606)	(0.0492)	(0.140)
L.Five_YGILT	-0.160	0.0733	0.343***	1.412***	-0.106
	(0.694)	(0.0980)	(0.0759)	(0.0616)	(0.175)
L2.Five_YGILT	-0.812	-0.0592	-0.374***	-0.548***	-0.164
	(1.175)	(0.166)	(0.129)	(0.104)	(0.297)
L3.Five_YGILT	-0.471	-0.157	0.0620	0.135	0.460
	(1.198)	(0.169)	(0.131)	(0.106)	(0.303)
L4.Five_YGILT	1.500	0.0517	0.0974	-0.0424	0.291
	(1.160)	(0.164)	(0.127)	(0.103)	(0.294)
L5.Five_YGILT	-0.604	0.0989	-0.0896	-0.0125	-0.404**
	(0.701)	(0.0990)	(0.0767)	(0.0622)	(0.177)
L.BSADF_Biggest	-1.973***	-0.0241	-0.0769***	-0.00612	0.513***
	(0.238)	(0.0337)	(0.0261)	(0.0212)	(0.0603)
L2.BSADF_Biggest	1.739***	-0.0550	-0.00804	-0.0196	0.135*
	(0.294)	(0.0416)	(0.0322)	(0.0261)	(0.0744)

L3.BSADF_Biggest	0.0920	0.0323	0.106***	0.0916***	0.0333
	(0.304)	(0.0430)	(0.0333)	(0.0270)	(0.0770)
L4.BSADF_Biggest	-0.272	0.0635	-0.0829**	-0.0399	-0.0227
	(0.312)	(0.0442)	(0.0342)	(0.0278)	(0.0791)
L5.BSADF_Biggest	0.359	-0.0533	0.0572**	0.0231	0.00806
	(0.264)	(0.0373)	(0.0289)	(0.0234)	(0.0668)
QE_ECB	-0.844**	-0.113**	-0.00518	-0.0510	-0.0621
	(0.367)	(0.0518)	(0.0401)	(0.0326)	(0.0927)
L.QE_ECB	-0.822**	-0.111**	0.0312	-0.0345	-0.265***
	(0.367)	(0.0518)	(0.0402)	(0.0326)	(0.0928)
L2.QE_ECB	-0.187	-0.168***	-0.0378	0.0108	0.0178
	(0.386)	(0.0545)	(0.0422)	(0.0343)	(0.0976)
QE_FED	-1.151**	2.91e-05	-0.173***	0.0195	0.304**
	(0.575)	(0.0813)	(0.0629)	(0.0511)	(0.146)
L.QE_FED	-2.379***	0.0558	-0.126**	0.0560	0.0157
	(0.573)	(0.0809)	(0.0627)	(0.0509)	(0.145)
QE_BoJ	-0.955***	0.0143	-0.0209	-0.0639**	0.176**
	(0.334)	(0.0471)	(0.0365)	(0.0296)	(0.0844)
Constant	9.655***	-0.106	0.0311	0.537***	-1.622***
	(2.301)	(0.325)	(0.252)	(0.204)	(0.582)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A16 - VAR model estimation results for Eurozone, model with lags (1)

	(1)	(2)	(3)	(4)	(5)
VARIABLES	IndProd	inf	EONIA	Five_YEUGV	BSADF_mean
L.IndProd	1.004***	0.0135	0.00567	-0.00844	-0.00352
	(0.0572)	(0.00830)	(0.00352)	(0.00780)	(0.00900)
L2.IndProd	-0.324***	-0.0114	-0.00319	0.00967	0.00263
	(0.0804)	(0.0117)	(0.00495)	(0.0110)	(0.0126)
L3.IndProd	0.232***	0.00666	-0.000626	-0.00810	-0.000630
	(0.0566)	(0.00821)	(0.00348)	(0.00772)	(0.00890)
L.inf	0.422	1.073***	0.00593	0.138**	-0.0682
	(0.425)	(0.0616)	(0.0261)	(0.0579)	(0.0668)
L2.inf	-1.173*	-0.00456	0.0166	-0.0329	0.0132
	(0.618)	(0.0896)	(0.0380)	(0.0843)	(0.0972)
L3.inf	0.461	-0.175***	-0.0462*	-0.0691	0.0666
	(0.434)	(0.0630)	(0.0267)	(0.0592)	(0.0683)
L.EONIA	1.355	0.103	1.266***	-0.0121	0.245*
	(0.942)	(0.137)	(0.0580)	(0.128)	(0.148)
L2.EONIA	0.390	-0.0866	-0.0132	0.160	-0.244
	(1.559)	(0.226)	(0.0959)	(0.213)	(0.245)
L3.EONIA	-1.812*	-0.0166	-0.277***	-0.121	0.0362
	(0.934)	(0.135)	(0.0575)	(0.127)	(0.147)
L.Five_YEUGV	0.255	0.0719	0.0577**	1.104***	-0.00249
	(0.454)	(0.0658)	(0.0279)	(0.0619)	(0.0713)

L2.Five_YEUGV	-0.251	-0.0671	-0.0416	-0.153*	0.0380
	(0.675)	(0.0978)	(0.0415)	(0.0920)	(0.106)
L3.Five_YEUGV	0.0847	0.0331	0.00970	-0.00904	-0.0336
	(0.444)	(0.0644)	(0.0273)	(0.0605)	(0.0698)
L.BSADF_mean	-0.0265	-0.0198	0.0167	-0.0346	0.960***
	(0.389)	(0.0564)	(0.0239)	(0.0530)	(0.0611)
L2.BSADF_mean	-0.302	-0.0262	-0.0488	0.0863	-0.132
	(0.537)	(0.0779)	(0.0331)	(0.0732)	(0.0844)
L3.BSADF_mean	-0.103	0.0230	0.0416*	0.000554	-0.0331
	(0.395)	(0.0573)	(0.0243)	(0.0539)	(0.0621)
QE_ECB	-0.908**	-0.172***	-0.0474**	0.0553	-0.0675
	(0.379)	(0.0550)	(0.0233)	(0.0517)	(0.0596)
QE_BoJ	-1.044***	0.000294	-0.0118	-0.126***	0.0387
	(0.348)	(0.0505)	(0.0214)	(0.0475)	(0.0547)
L.QE_FED	-2.015***	0.158*	-0.0499	0.0699	-0.114
	(0.580)	(0.0841)	(0.0357)	(0.0791)	(0.0912)
Constant	9.268***	-0.755*	-0.167	0.736**	-0.000130
	(2.695)	(0.391)	(0.166)	(0.367)	(0.424)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A17 - VAR model estimation results for Eurozone, model with lags (2)

	(1)	(2)	(3)	(4)	(5)
VARIABLES	IndProd	inf	EONIA	Five_YEUGV	BSADF_Biggest
L.IndProd	0.997***	0.0124	0.00485	-0.00766	0.00317
	(0.0567)	(0.00830)	(0.00353)	(0.00781)	(0.0124)
L2.IndProd	-0.318***	-0.0104	-0.00238	0.00982	-0.00534
	(0.0794)	(0.0116)	(0.00495)	(0.0109)	(0.0173)
L3.IndProd	0.231***	0.00667	-0.000676	-0.00872	0.00112
	(0.0561)	(0.00822)	(0.00350)	(0.00773)	(0.0123)
L.inf	0.432	1.073***	0.00445	0.139**	-0.0760
	(0.420)	(0.0616)	(0.0262)	(0.0579)	(0.0919)
L2.inf	-1.229**	-0.00376	0.0167	-0.0291	-0.0547
	(0.612)	(0.0896)	(0.0381)	(0.0843)	(0.134)
L3.inf	0.526	-0.176***	-0.0465*	-0.0747	0.155*
	(0.430)	(0.0630)	(0.0268)	(0.0593)	(0.0940)
L.EONIA	1.117	0.106	1.267***	0.00946	0.371*
	(0.937)	(0.137)	(0.0584)	(0.129)	(0.205)
L2.EONIA	0.956	-0.0860	-0.0152	0.122	-0.287
	(1.546)	(0.226)	(0.0964)	(0.213)	(0.338)
L3.EONIA	-2.116**	-0.0196	-0.275***	-0.107	-0.0227
	(0.924)	(0.135)	(0.0576)	(0.127)	(0.202)
L.Five_YEUGV	0.161	0.0704	0.0620**	1.103***	-0.0347
	(0.448)	(0.0657)	(0.0279)	(0.0618)	(0.0980)
L2.Five_YEUGV	-0.174	-0.0687	-0.0440	-0.158*	0.0740

	(0.668)	(0.0978)	(0.0416)	(0.0920)	(0.146)
L3.Five_YEUGV	0.0836	0.0350	0.00883	-0.00234	-0.0500
	(0.440)	(0.0645)	(0.0274)	(0.0607)	(0.0962)
L.BSADF_Biggest	-0.751***	-0.0220	0.0156	0.00942	0.918***
	(0.277)	(0.0406)	(0.0173)	(0.0382)	(0.0605)
L2.BSADF_Biggest	0.582	-0.0206	-0.0314	0.00564	-0.207**
	(0.374)	(0.0547)	(0.0233)	(0.0515)	(0.0817)
L3.BSADF_Biggest	-0.305	0.0229	0.0186	0.0418	0.0360
	(0.283)	(0.0415)	(0.0176)	(0.0390)	(0.0618)
QE_ECB	-0.952**	-0.170***	-0.0469**	0.0552	-0.0811
	(0.375)	(0.0549)	(0.0234)	(0.0516)	(0.0819)
QE_BoJ	-1.066***	-0.000186	-0.0112	-0.125***	0.120
	(0.345)	(0.0505)	(0.0215)	(0.0475)	(0.0753)
L.QE_FED	-2.018***	0.163*	-0.0526	0.0789	-0.122
	(0.576)	(0.0843)	(0.0359)	(0.0793)	(0.126)
Constant	9.478***	-0.749*	-0.164	0.694*	-0.0379
	(2.672)	(0.391)	(0.167)	(0.368)	(0.584)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A18 - VAR model estimation results for Eurozone, model with leads (1)

	(1)	(2)	(3)	(4)	(5)
VARIABLES	IndProd	inf	EONIA	Five_YEUGV	BSADF_mean
L.IndProd	1.035***	0.0113	0.00672*	-0.00807	-0.00388
	(0.0578)	(0.00812)	(0.00348)	(0.00762)	(0.00876)
L2.IndProd	-0.369***	-0.00684	-0.00494	0.00997	0.00221
	(0.0814)	(0.0114)	(0.00490)	(0.0107)	(0.0123)
L3.IndProd	0.248***	0.00545	0.000319	-0.00951	0.000527
	(0.0583)	(0.00819)	(0.00351)	(0.00768)	(0.00884)
L.inf	0.488	1.042***	0.00552	0.148**	-0.0712
	(0.438)	(0.0616)	(0.0264)	(0.0578)	(0.0664)
L2.inf	-1.223*	-0.0174	0.0166	-0.0270	0.00722
	(0.634)	(0.0891)	(0.0382)	(0.0836)	(0.0961)
L3.inf	0.432	-0.151**	-0.0468*	-0.0730	0.0659
	(0.449)	(0.0631)	(0.0270)	(0.0592)	(0.0681)
L.EONIA	1.559	0.0865	1.263***	-0.0362	0.288**
	(0.965)	(0.136)	(0.0581)	(0.127)	(0.146)
L2.EONIA	0.307	-0.0942	-0.00815	0.208	-0.309
	(1.599)	(0.225)	(0.0963)	(0.211)	(0.242)
L3.EONIA	-1.884**	0.000252	-0.280***	-0.143	0.0609
	(0.957)	(0.134)	(0.0576)	(0.126)	(0.145)
L.Five_YEUGV	0.0781	0.0863	0.0533*	1.122***	-0.0264
	(0.465)	(0.0653)	(0.0280)	(0.0613)	(0.0705)
L2.Five_YEUGV	0.112	-0.0762	-0.0431	-0.212**	0.124
	(0.701)	(0.0985)	(0.0422)	(0.0924)	(0.106)

L3.Five_YEUGV	-0.148	0.0445	0.0172	0.0297	-0.0995
	(0.471)	(0.0662)	(0.0283)	(0.0621)	(0.0714)
L.BSADF_mean	-0.0269	-0.0162	0.0160	-0.0387	0.965***
	(0.397)	(0.0559)	(0.0239)	(0.0524)	(0.0603)
L2.BSADF_mean	-0.435	-0.0243	-0.0554*	0.0893	-0.131
	(0.548)	(0.0770)	(0.0330)	(0.0723)	(0.0831)
L3.BSADF_mean	0.0711	0.00519	0.0488**	-0.00152	-0.0310
	(0.402)	(0.0565)	(0.0242)	(0.0530)	(0.0609)
QE_ECB	-0.885**	-0.165***	-0.0490**	0.0344	-0.0414
	(0.392)	(0.0551)	(0.0236)	(0.0517)	(0.0594)
QE_BoJ	-1.156***	0.00291	-0.0126	-0.106**	0.0118
	(0.359)	(0.0504)	(0.0216)	(0.0473)	(0.0544)
F.QE_ECB	-0.239	-0.0496	-0.00785	0.131***	-0.140**
	(0.383)	(0.0539)	(0.0231)	(0.0505)	(0.0581)
F.QE_FED	0.319	-0.0247	-0.0566	-0.114	0.227**
	(0.604)	(0.0849)	(0.0364)	(0.0796)	(0.0915)
Constant	9.028***	-0.869**	-0.191	0.784**	-0.00869
	(2.773)	(0.390)	(0.167)	(0.366)	(0.420)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A19 - VAR model estimation results for Eurozone, model with leads (2)

	(1)	(2)	(3)	(4)	(5)
VARIABLES	IndProd	inf	EONIA	Five_YEUGV	BSADF_Biggest
L.IndProd	1.025***	0.0105	0.00575	-0.00755	0.00296
	(0.0575)	(0.00815)	(0.00350)	(0.00766)	(0.0121)
L2.IndProd	-0.358***	-0.00629	-0.00395	0.0103	-0.00446
	(0.0806)	(0.0114)	(0.00491)	(0.0107)	(0.0169)
L3.IndProd	0.246***	0.00560	0.000241	-0.0101	0.000644
	(0.0578)	(0.00820)	(0.00352)	(0.00770)	(0.0122)
L.inf	0.505	1.043***	0.00394	0.149**	-0.0761
	(0.434)	(0.0616)	(0.0265)	(0.0578)	(0.0913)
L2.inf	-1.273**	-0.0165	0.0166	-0.0233	-0.0676
	(0.628)	(0.0891)	(0.0383)	(0.0837)	(0.132)
L3.inf	0.489	-0.151**	-0.0471*	-0.0777	0.158*
	(0.445)	(0.0632)	(0.0271)	(0.0593)	(0.0936)
L.EONIA	1.337	0.0857	1.265***	-0.0165	0.434**
	(0.960)	(0.136)	(0.0585)	(0.128)	(0.202)
L2.EONIA	0.876	-0.0890	-0.0108	0.172	-0.366
	(1.589)	(0.225)	(0.0969)	(0.212)	(0.334)
L3.EONIA	-2.204**	-0.00418	-0.278***	-0.129	0.00238

	(0.948)	(0.135)	(0.0578)	(0.126)	(0.199)
L.Five_YEUGV	-0.00447	0.0843	0.0578**	1.121***	-0.0567
	(0.460)	(0.0652)	(0.0280)	(0.0612)	(0.0966)
L2.Five_YEUGV	0.154	-0.0778	-0.0455	-0.218**	0.184
	(0.695)	(0.0987)	(0.0424)	(0.0927)	(0.146)
L3.Five_YEUGV	-0.125	0.0463	0.0162	0.0373	-0.148
	(0.468)	(0.0664)	(0.0285)	(0.0624)	(0.0984)
L.BSADF_Biggest	-0.756***	-0.0205	0.0148	0.00326	0.927***
	(0.284)	(0.0403)	(0.0173)	(0.0379)	(0.0598)
L2.BSADF_Biggest	0.478	-0.0148	-0.0365	0.00822	-0.202**
	(0.382)	(0.0541)	(0.0233)	(0.0508)	(0.0802)
L3.BSADF_Biggest	-0.164	0.00768	0.0240	0.0394	0.0339
	(0.288)	(0.0408)	(0.0175)	(0.0383)	(0.0605)
QE_ECB	-0.938**	-0.163***	-0.0483**	0.0351	-0.0526
	(0.388)	(0.0550)	(0.0236)	(0.0516)	(0.0815)
QE_BoJ	-1.167***	0.00282	-0.0121	-0.105**	0.0900
	(0.355)	(0.0504)	(0.0217)	(0.0473)	(0.0747)
F.QE_ECB	-0.172	-0.0471	-0.00764	0.129**	-0.125
	(0.381)	(0.0541)	(0.0232)	(0.0508)	(0.0801)
F.QE_FED	0.277	-0.0280	-0.0554	-0.115	0.379***
	(0.599)	(0.0850)	(0.0365)	(0.0798)	(0.126)
Constant	9.237***	-0.855**	-0.189	0.745**	-0.0301
	(2.749)	(0.390)	(0.168)	(0.366)	(0.578)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1