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Faculty of Business and Economics

Comparison of Monetary Policy of European Central Bank and Bank of England

Diploma Thesis

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Abstract

König, R. Comparison of Monetary Policy of European Central Bank and Bank of England. Diploma thesis, Mendel University in Brno, Brno 2016.

The aim of this diploma thesis is to compare monetary policy of European Central Bank and Bank of England during observed period from 2000Q1 to 2014Q2. Research is focused on responsiveness of real output upon money supply and real interest rate. Testing for Granger causality is used as a main tool to estimate relationship between selected variables. Structural breaks analysis, inflation targeting and monetary rules as Taylor rule, Mankiw rule and Galí rule are used as well. The empirical results of this thesis are compared and suggest that there has been a difference in performing monetary policy between the euro area and the United Kingdom. However, responsiveness on monetary policy is very similar.

Keywords

Bank of England, BREXIT, European Central Bank, Granger causality, Inflation Targeting, Monetary Policy, Monetary Rules, Structural Breaks, Real output.

Abstrakt

König, R. Comparison of Monetary Policy of European Central Bank and Bank of England. Diplomová práce, Mendelova univerzita v Brně, Brno 2016.

Hlavním úkolem této diplomové práce je porovnání monetární politiky Evropské centrální banky a Centrální banky Velké Británie během období 2000Q1 do 2014Q2. Výzkum se zabývá reakcí reálného ekonomického výstupu na změny v měnové zásobě a změny v reálné úrokové míře. Testování Grangerovy kauzality je použito jako hlavní způsob měření vztahů mezi vybranými proměnnými. Předmětem diplomové práce je i testování strukturálních zlomů, inflačního cílení a měnových pravidel jako je Taylorovo pravidlo, Mankiwovo pravidlo a Galího pravidlo. Empirické výsledky jsou porovnány a potvrzuje se, že monetární politiky Eurozóny a Spojeného království jsou rozdílné, avšak reakce na kroky monetární politiky jsou velice podobné.

Klíčová slova

Centrální banka Velké Británie, BREXIT, Evropská centrální banka, Grangerova kauzalita, Inflační cílení, Monetární politika, Monetární pravidla, Strukturální zlomy, Reálný produkt.

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1 Introduction

Withdrawal of the United Kingdom from the European Union, also called BREXIT, became very often discussed topic during last year. There are many political parties, public persons and individuals, who are supporting Britain to exit the EU. But there are also many groups, who stand for Britain remaining in the EU. David Cameron, the British Prime Minister announced a date for public referendum on the United Kingdom's membership on a date of 23rd June 2016. One of the main reasons, why the UK wants to leave the EU is fear from full fiscal and political union forming inside the EU to make euro work. Therefore, if the UK will stick to their own currency, it would be very uncomfortable for them to be part of the EU but not part of a monetary union.

The monetary integration process in the EU is heading clear way to higher integration in the future. Almost all member states have already adopted Euro as their national currency or they soon will have to. There are only two states that have permanent opt-out from this process. The two states are Denmark and the United Kingdom.

In 2008 the whole world economy was hit by financial crisis, which started in the United States and moved to the European Union and other states outside of the European Union. This situation brought very interesting tool for economists to measure and compare different monetary and fiscal policies, how to handle crisis. Also it brought opportunity to find out if monetary unions with their central banks are able to drive their policies to handle crisis better than central banks outside of monetary unions.

Therefore, my motivation for this thesis "*Comparison of Monetary Policy of European Central Bank and Bank of England"* is to examine differences between monetary policies during period before and after crisis in case of European Central Bank and Bank of England. These differences should be measured and evaluated in this thesis.

Results from this thesis should not only find out if reactions of central banks were similar or different between compared economies, but this thesis should also answer a question, how successful central banks were with their monetary policies to affect economic output. Last but not least this thesis should also evaluate possibility of further integration process in case of the United Kingdom to join the monetary union, maintain their monetary sovereignty or to exit from the European Union from the point of view of monetary integration.

2 Objectives and Methodology

2.1 Objectives

The goal is to evaluate monetary policies in the euro area and in the United Kingdom and their impact upon economic performance. Results of this research should answer questions, such as:

1. *What are the main differences between the euro area and the UK economy responsiveness to the monetary policy?*

This thesis is going to provide answers for partial questions such as:

2. *Do the euro area and the UK conduct similar tools of monetary policy?*
3. *Did the euro area and the UK used the same strategies to handle the situation during crisis and after crisis?*

2.2 Methodology

Methodology used in empirical part of this thesis consists of Granger Causality testing in form of Vector Autoregressive modelling (VAR). Correct form of input dataset is tested by Augmented Dickey-Fuller test for stationarity. Also structural breaks analysis with connection of ordinary least squares (OLS) model and Chow test are used for observation of time-series. Monetary rules as Taylor rule, Mankiw rule and Galí rule are compared with actual short-term interest rates for the euro area and the United Kingdom. At the end of the thesis deductive and comparative methods are used as well.

Structure of the thesis is as follows:

The first two chapters are cover by *Introduction* and motivations of the author to write this thesis and it is followed by *Objectives and Methodology* of the diploma thesis.

The following chapter 3 is about *Literature review*. This part includes important theoretical background needed for further empirical analysis. Books and research papers focused on monetary policy, transmission mechanism, liquidity trap, monetary integration and BREXIT are cover in this part. System of central banking systems in the European Union and the United Kingdom are covered as well.

The chapter 4 is separated into four other sub-chapters. Each sub-chapter is focused on a different way of how to analyze effectiveness and methods of monetary policies. The first part covers detection of structural breaks in Gross Domestic Product (GDP) and in supply of money, more specific in monetary aggregate M2. QLR and Chow test have been used for detection of these breaks. Results enable to detect peak of the crisis to separate time-series into two parts – before crisis and after crisis. Results also show how fast each central bank reacted on emerging crisis.

The next sub-chapter 4.2 covers the inflation targeting of both the EA and the UK economies is compared. This comparison is based on an assumption, that modern economists believe, that the one of the best tools to optimally stabilize monetary policy is inflation targeting. Therefore, this part compares actual inflations in the EA and the UK with their targeted inflations.

The third sub-chapter 4.3 focuses on application of monetary rules upon selected economies. Examination of selected monetary rules should provide representative conclusion for central bankers if it is suitable for them to use these rules as guidelines to drive interest rate to influence positive economic growth in given economic conditions. Taylor rule, Mankiw rule and Galí rule were selected for this analysis and were compared with actual interest rates issued by the European Central Bank and the Bank of England.

Last sub-chapter 4.4 examines effect of changes in real economy output, represented by real GDP, caused by changes in monetary aggregates M1 and M2 and changes in real interest rate. This analysis has been divided into two parts before and after crisis periods. Because as Kapounek and Poměnková (2009) proved, external shocks in observer time-series could lead to misinterpretation of the whole statistical model. For the examination of relationship between selected variables Gretl software and regression analysis in form of Granger causality have been used. In a way to improve model informative value, lagged variables have been used as well.

As for the basic variables used in Granger causality testing, the money base has been represented by monetary aggregates M1 and M2. Real interest rate has been calculated from 3-months EURIBOR rate in case of the euro area and 3-months LIBOR rate in case of the UK.

The Chapter 5 includes *Conclusion* of the thesis based on results obtained in empirical analysis of this thesis.

Last two chapters are consisting of *References* and *Appendices*. References includes list of all literature sorted in alphabetical order, which have been covered in literature review. Appendices are divided into three parts – Structural break testing, Correlograms, Granger causality results.

All sub-chapters in Chapter 4 are followed by short summary at the end of each sub-chapter. Those summaries cover obtained results and short comments.

The datasets and time-series used in this thesis have been calculated by author or obtained in the following databases:

- EUROSTAT database
- EUROPEAN CENTRAL BANK database
- BANK OF ENGLAND database

All the datasets were obtained for period from the first quarter of 2000 to the second quarter of 2014. No more recent data were available in the time of preparation of this thesis. Then all the data were converted into 10-base logarithms and they were also tested by ADF test for stationarity. As results from ADF tests suggested, variables were containing trend and hence it was necessary to convert them into their first differences. Variables in their form of 10-based logarithms and first differences should be non-stationary and therefore, suitable for further testing.

3 Literature Review

3.1 Monetary policy

This part of this thesis is focused on, how interest rate and monetary base as monetary variables could be used to effect economic growth. This policy is called monetary policy.

Institution, who is responsible for monetary policy is central bank. In the euro area the responsibility has European Central Bank and in the United Kingdom it is Bank of England.

The central banks don't have direct influence over interest rate or monetary base and therefore, they have to use other monetary instruments to indirectly affect these variables. These instruments are:

- Open market operations
- Minimal bid rate
- Foreign exchange market interventions

The open market operations offer possibility to purchase or sell state bonds. Therefore, they control how much money is in an economy circulation. Monetarists believe that money supply affects price level and therefore, it also affects the real output.

The minimal bid rate is interest rate for landing money offered to commercial banks by central bank. Economist Taylor (1993) wanted to create crucial formula, which would allow to calculate the ideal level of s-t interest rate fitted to present economic conditions. Other economists, for example Svensson (2003) argues, that monetary rules are suitable just for guidelines and not for current monetary policy in euro area or in United Kingdom.

There are four different goals of monetary policy – stable growth of price level, continuous economic growth, natural rate of unemployment and equilibrium in balance of payments (Mandel & Tomšík, 2003). According to Fender (2012), central banks can use different strategies to obtain the goals of monetary policy:

- Monetary Targeting
- Inflation Targeting
- Nominal Income as a target

The monetary targeting of monetary aggregates M2 and M3 was considered as a primary policy until 90s of 20th century, when inflation targeting took the lead. Even though, the monetary targeting has still its own role in monetary policies of central banks. Right now the second pillar of monetary policy in ECB is focused on growth of monetary agreggate (Polouček, 2003). Miles, Scott and Breedon (2012) see the setback of monetary targeting in monetary base control. CB can influence interest rate to affect the cost of loans to commercial banks, but there is a still uncertainty, that this step will affect the real demand for money in form of loans.

Currently since the 90s of 20th century the inflation targeting is the most common primary goal of central banks in Europe. Greenspan (1996) describes this situation with inflation set to be on a level of 2 percent, that economical agents do not calculate their predictions of future consumption based on inflation. The inflation is not part of their calculation.

According to Fender (2012), the best alternative of monetary policy for central banks is to combine nominal GDP targeting and inflation targeting at the same time. He also mentions, that this strategy has never been used or even tried.

In present day money has three main functions, such as: Medium of exchange, Unit of account and Store of value. The money supply is consists of deposits and currency. There are many different definitions of money supply depending on what particular deposits are part of the money supply. Economic output and its relationship with money supply is cover by Quantitative theory of money. This theory explains that there is a relationship between money supply and price level and it has been described by Irving Fisher's equation:

$$Money\ supply \times Velocity\ of\ Money = GDP\ deflactor \times real\ GDP \quad (1)$$

The equation states, that if money supply increases then also GDP deflator, which stands for inflation increases as well. But the velocity of money and real GDP must not be affected (Friedman and Schwartz, 1982).

McCallum and Nelson (2011) explains the theory, that exogenous growth of nominal money supply influences the price level. They also state that nominal homogeneity is the same both in quantity theory of money and money neutrality. It means that there is ceteris paribus connection between inflation and money growth.

As Miles (2012) comments, similar effect of different money supply aggregates works just in theory. In reality, the relationship is different from one to another. It makes it difficult for central bank, to find out, which aggregate should be used for targeting policy. Central banks tried to measure this relationship and switched between the aggregates, but no reliable result has been obtained. According to Goodhart's law (1984), the statistical regularity, which has been observed will incline to fail as soon as any control mechanism would try to exploit its true nature.

3.2 Transmission mechanism

Functional transmission mechanism is key for monetary policy to influence aggregate demand thought changes in short-term interest rate. Therefore, the correct understanding of this mechanism is in place. There are two ways, how on the transmission mechanism must be looked at. The first is to estimate, what monetary policy should be used and then estimate how long and how it will affect the economy.

The transmission mechanism is a tricky tool. According to Boivin, et. al. (2010), the relationship between fund rate and output growth can change in time. Their research discovered that in period 1962:1 to 1973:3 the correlation between those two variables was negative. In later period from 1984:1 to 2008:4, the correlation was totally opposite than before. It means, there was positive effect between the fund rate and growth of output and expenditure.

3.2.1 Monetary transmission channels

In a work of Boivin, et. al. (2010) the channels of monetary transmission are divided into two major groups and several subgroups as follows:

- Neoclassical channels
    - Investment based channels
        - Direct interest rate channels
        - Tobin's Q
    - Consumption based channels
        - Wealth effect
        - Intertemporal substitution effect
    - International trade based channels
        - Exchange rate channel

- Non-neoclassical channels
    - Effects on credit supply from government interventions in credit markets
    - Bank-based channel
    - Balance sheet channel

3.2.2 Money and credit view

This section describes transmission mechanism in money and credit view in greater detail. The first part will be focused on money view and it will describe interest rate channel and exchange rate channel. The second part, credit view will focus mainly on bank-lending channel. Theoretical background is based on Mishkin (1995) and Boivin, et. al. (2010).

Money view

The term money view originates in literature about classification of the financial market price introduced by Taylor. It is based on role of interest rate channel, which influences movement of monetary aggregates. This model is defined by two variables – money and bonds. Both of them are imperfect substitutes. The main role of interest rate is to adjust these two variables into market equilibrium as IS-LM model describes. Taking sticky wages and rational expectation into consideration, shocks in monetary policy lead to growth of interest rate and therefore, increase in cost of capital. This increase causes decline in investments, decrease in aggregate demand and also in output. Furthermore, the effect of interest rate channel is affecting spending of consumers on durables and housing.

Monetary transmission is also affected by exchange rate, which has a key role on net export. Taking flexible exchange rate into consideration, an appreciation of domestic currency will increase imports and decrease exports. The real interest rate in domestic country can be raised by contractionary monetary policy shock. According to Mundell-Fleming model, the movement in capital flows causes effect of interest rate upon exchange rate. Hence an increase in interest rate triggers a capital inflow and an appreciation of the domestic currency. This leads to more expensive domestic goods, a decrease in export and an increase in import. All these steps resulting in a decrease of AD and output.

Credit view

This part describes how imperfect information has principal effect on monetary policy channel. Bernanke and Gertler (1995) claim that, an external finance premium is created by agencies on the credit market, because of problems with imperfect information. This premium arises as a difference between internal funds as retained earnings and external funds represented by issued debt and equity. Resulting in effect of this channel to magnify the impact of monetary policy on real spending.

Another channel of monetary transmission is a bank lending channel. This channel is connected with bank loans as a main source of financing of firms. Any change in monetary policy will either increase or decrease amount of bank loans on credit market. This model suggests that central bank drains reserves and banking deposits as a result of tightening of monetary policy.

3.3 Monetary policy and output

There were many research papers focused on impact of monetary policy and real output. Lots of them used Granger causality as their main methodology how to evaluate the impact. It is necessary to say, that Granger causality is not proper philosophical causality as it seems, but it is rather a statistical causality. Author is aware of this situation and word "causality" will be used further in this thesis as a Granger sense type.

Granger causality is defined as time series Y, which stands for money causes output X relative to time series vector U (universe), which includes both X and Y variables only in case that prediction of X(t) is constructed under U(s) at all cases that s<t are more suitable for predictions that all variables of U(s) omitting Y(s) at all cases that s<t (Granger, 1969) The equation for testing betas to be equal zero to fulfil previous definition is as follows:

$$TS(x)t = const + \sum_{i=1}^{j} \alpha_i TS(x)_{t-1} + \sum_{i=1}^{j} \beta_i TS(y)_{t-1} + \sum_{i=1}^{j} \gamma_i TS(z)_{t-1} \quad (2)$$

For purpose of this thesis it is also necessary to add variable Z, which stands for lag distribution as an essential part for further research.

The first author, who tried to conduct tests for Granger causality between money and income correlation was Sims, a Nobel Prize winner in Economic science. Sims

(1972) used post war data from the US and his findings confirmed his hypothesis that there is a unidirectional causality between money and output. Also his research rejected hypothesis that there would be unidirectional causality from output to money.

Later, Sims (1980) modified his concept, because further tests revealed that other variables such as logs of interest rate and price level are diminishing the causal relationship. Therefore, his finding shows, that it is essential to specify if observed time series contains trend or the trend is removed from observation.

Since the day, Sims' research paper was published, there were many other studies, which have tried to repeat his research using data from the UK. Research study of Goodhart and Gowland (1976) found opposite results than Sims. Their research tested bivariate causality between output and monetary aggregates. Output was represented by nominal GDP and monetary aggregate by M1. The testing period was from 1958:1 to 1971:3. Findings of their paper have revealed unidirectional causality from output to M1.

Putnam and Wilford (1978) constructed their model as monetary approach with relationship to the balance of payment. The model is based that US is the reserve currency country and the UK is nonreserve currency country. Their model has many implications as follows:

- The reserve currency country has direct control over monetary base. Other countries don't have control over their money supply. Hence, monetary expansion in US M1 granger causes UK M1.
- This expansion will lead to increase in nominal incomes in all countries and so US M1 granger causes UK income.
- The reserve currency country is able to affect nominal income and also price level. The other countries have to accept new prices and nominal incomes as a work of market. Therefore, UK M1 does not granger cause UK income and furthermore the UK is not able to use their money stock for stabilization.

It is necessary to note, that these implications are valid just for fixed exchange rate period only.

Cuddington (1981) notes, that there should be granger cause from interest rate to output, because of effect on investments, savings, consumption in private sector. His propositions are:

- The UK interest rate granger causes UK output
- The UK interest rate granger causes UK M1

- The UK interest rate is not granger caused by any other variable

Other research by Eichenbaum and Singelton (1986) indicates that if trend is part of observation dataset, then the results are changed in case that trend is removed from time series. It is caused, because time series including trend tend to be non stationary and hence they are more prone for statistical errors.

Czech study by Tomšík (2005) confirms finding of Eichenbaum and Singelton (1986). There could be a problem with significance of model if input data are in nominal form and non-stationary. Tomšík suggest to use input data in real values as real GDP, real monetary aggregates and real interest rate. Then the input data should be tested by ADF test for stationarity.

3.4 Liquidity trap

In last few years, mainly because the crisis, the expression liquidity trap became often discussed topic. There are many different definitions, as each author is trying to explain it in its own way. For example, Taylor and Weerapaana (2012) said, that interest rates, which are near or equal to zero are not affected by increase in the money supply in the way, that interest rate would lower even more. Economists Miles and Scott (2012) have different explanation. When there is a large output gap in combination with low level of inflation or deflation in the same moment, then this phenomenon is considered as liquidity trap.

Because it is very difficult to lower interest rate to negative numbers, central banks have to find different solution for this situation. One of the best suitable solution is to enhance the economy by quantitative easing. There are three scenarios how quantitative easing could be used to bring positive growth in the economy (Taylor and Werapaana, 2012).

1. Expectation channel – The private sector has to be convinced by central bank, that economy is going to improve and inflation is going to increase.
2. Increase in monetary base – Increase of significant amount of money in the economy by the central bank should motivate private sector to invest in loans and other non-monetary assets.
3. Acquisitions of financial assets – Central bank might use open market operations in higher scale to motivate investors. As United Kingdom increased money by aiming on government bonds, the investors started to sell government bonds (safe investments) and purchasing investment with higher risk. On the other hand, ECB and FED used direct way. Both were directly buying assets with higher risk.

According to Svensson (2003), the best way how to fight against liquidity trap is the first channel – the expectation channel. The central bank has to convince private sector, about their expectation development of RIR. This step should lead the private sector to believe in potential inflation. Hence the RIR would decrease and the economy should arise from recession. This option seems easy and straight forward, but also Svensson confirmed, that the opposite is true. Influencing the public trust is more difficult than it seems. There is also a negative aspect of this option and that is lost of credibility.

Krugman (2008) also argues that central banks with high credibility as ECB would have it more difficult to change private expectations. It means that expansionary policy in connection with high increase in monetary base wouldn't change future expectation about increase in prices. Then the public is assuming that prices would soon go back to steady state near present intensity. Fender (2012), Scott (2012) and also Krugman (2008) see expansion in fiscal policy as more effective tool how to fight against liquidity trap.

3.5 European integration

3.5.1 The OCA Theory

The optimum currency area theory has been published in 60s of 20th century by economist Robert Mundell. This theory examines relationships between states, regions and currencies and it is trying to find benefits and costs of forming a monetary union.

Conditions for forming the OCA

There are several conditions, which have to be met by potential members of optimum currency area. Lacina (2007) states these conditions:

- Factor mobility
- Financial market integration
- Price and wage flexibility
- Variability of real exchange rate
- Openness and size of the economy
- Diversification of production and consumption
- Structural similarity of GDP
- Similar rate of inflation

- Fiscal integration
- Level of political integration

When applying these criteria on optimal currency area, there can arise two possible problems. The first one is inconclusiveness, different criteria could lead to different conclusions about forming the monetary union. The second one is incompatibility, which means that some criteria are contradictory between each other.

Benefits and costs of common currency

The benefits and costs have to be take into consideration before forming monetary union as well, because it is expected that there is no state, which would fulfil all the conditions. Kučerová (2005) names many costs connected with common currency:

- Loss of exchange rate
- Loss of monetary policy
- Loss of fiscal policy
- Growth of price level
- Microeconomical costs

On the other hand, Lacina (2007) argues with benefits like:

- Elimination of transactional costs
- Elimination of exchange rate risk
- Price stability and transparency
- Public finance
- Further economical integration
- Better position for monetary union in the World monetary system

The list of benefits and costs is huge and there are many others, which are not listed in this chapter. It depends on each state and its specification connected with economy. In case of comparing the benefits and costs, the long-term viewpoint has to be taken into consideration. For fulfilling the OCA theory there should be always more benefits than costs, before forming the monetary union.

3.5.2 BREXIT

As Rosecrance (1977) mentions, the economic interdependence between the UK and the UK is separated into two groups. The first one is vertical interdependence, which measures how changes of factor prices in one state will affect other state. The horizontal interdependence measures impact of transactions among states.

The report of Bank of England (2015) shows, that 44 per cent of export from UK went to the EU and 53 per cent of imports went from EU. The report also continuous with share foreign direct investment, their inflows and outflows. Almost 44 per cent overseas assets from the UK are held in the EU. Assets, which are held by businesses attributable and overseas residents in the UK are equal to 46.4 per cent. The report also estimates impact on UK economy connected with membership in the EU to have positive effect +20 per cent of GDP to a negative –5 per cent. The studies, which are focusing just on benefits and costs of a Brexit are in range from +1.6 per cent to a negative -9.6 per cent of GDP.

Rasmussen (2015) says that post-Brexit UK would be exposed to market conditions forced by the EU members like, France and Germany. Both of them would like to rise their market share in financial services. There are many states that are more and more tired of demanding behaviour of UK and hence they are willing to inflict punitive externalities upon UK. Furthermore, the UK would have to sign new trade agreements with third countries by itself. The outcome of these negotiations is unpredictable.

If the UK would leave the EU, it might bring some cost saving, because the UK is a net contributor to the budget of EU, but there are also some complications. The UK wouldn't be able to reclaim the whole sum of money. It would depend on the ability to negotiate. There are other states like Switzerland or Norway, which have to send some contribution payments to the EU's budget and hence the same thing is expected from the UK if they leave the EU. Another problem connected with this issue is that even the UK is net contributor for structural funds in EU's budget, there are still regions like Scotland, Northern Ireland and Wales, that would require compensation payments (Stenbaek nad Jensen, 2015).

Lazowski (2016) comments, that the biggest potential benefit of Brexit would be possibility to roll back legislation. But this is only one sided view. This roll back in disentangling EU legislation from national one is connected with huge transaction costs. Lazowski also continuous that many studies show, that the UK is one of the

most deregulated member of the EU. Therefore, this reregulation would not bring such benefits, as it is expected.

To conclude this section, researches on further European integration show that the level of interdependence between the EU and the UK is high. Also comparing the benefits and costs of Brexit and what should it bring are uncertain. Furthermore, leaving the EU would leave the UK weak against externalities connected with Brexit. Under arguments and studies focused on this theme, it is expected that most actors would advocate for UK to stay as a member of EU.

3.6 Central banks

As Mankiw (2008) explains, central banks don't have straight influence over real interest rate and monetary base. They have ability to use instruments, which steer the economy. These instruments are consisting of open market operations, minimal interest rates, minimal reserves and foreign exchange market. Central banks are able to adjust quantity of money on the market via selling and purchasing bonds. Hence if there is a need to increase amount of money on the market, central bank can buy bonds. If there is a need to create restrictive policy, central bank can do just a reverse steps and that is to offer government bonds to the public. The other most used instrument is minimal interest rates, which enables central banks to lend money for given minimal price for given period of time to commercial banks.

There is also a problem with high independence of central banks, which could lead to mistakes. These mistakes are connected with pursuing of inflation target (mainly lowering the inflation). If bankers are concerned just about lowering the inflation, there is a danger of rising unemployment and negative effect on GDP. If this situation would be real, this policy would lead to deeper recession or even to create one. So to become central bank with credibility of their actions, there is a need for an important attribute, which is accountability. (Taylor & Weerapala, 2012)

3.6.1 European Central Bank

The origin of European Central Bank (ECB) has been discussed in 1969 in Hague, where discussion about single currency market was held. The ECB was established in 1998 in the Treaty of Amsterdam. The main inspiration for ECB was German Bundesbank. The two most important objectives for the ECB are price stability and true independence. The euro area is consists of 19 states right now, where the ECB is their main authority in terms of monetary policy. The ECB is also cooperating with

other member states, who still haven't adopted Euro and maintain sovereign of their central banks. All together they make up European System of Central Banks.

The organization of decision making bodies in ECB is consists of the Executive Board, which is responsible for running and implementation of monetary policy. The Executive Board has six members – the President of the Bank, the Vice-President and other four members. The second body is the Governing Council, which is formed from members of the Executive Board and next 19 members for each central bank in the euro area. All these members create the main decision-making body in ECB. Their main responsibility is to state monetary policy and take care of short-term interest rate. The third body is the General council. Its responsibility is to deal with transitional issues of adopting euro and also advisory function. Their members are the President and the Vice-President all together with 28 governors from each central bank in the EU.

The price stability as a main goal of ECB is to maintain inflation rate below 2%. The inflation is measured by Harmonised Index of Consumer Prices. This method and value is used in further analysis in sub-chapter Inflation targeting.

3.6.2 Bank of England

The Bank of England is central bank in the United Kingdom and has been established in 1694. In the year 1997 the British parliament gave operational independence to the central bank with clear goal, which is price stability. In 1998 Bank of England received another power, control of interest rates. Even though, the government still have possibility to coordinate central bank, how they should move with interest rate in extreme cases and national interest.

The highest decision making body of the Bank of England is Monetary Policy Committee (MPC), which is consists of 9 members including governor. Every member has one vote, when they are deciding about interest rate. The meetings of MPC are taking place every month. Reports from these meetings are published two weeks after the voting. MPC also publishes quarterly inflation reports, which informs about predictions of inflation growth.

The main goal of their monetary policy is to maintain price stability and low level of inflation. These goals should lead to achievement of general economical goals as growth of economic output and level of employment. The inflation target is set by ministry of finance every year. Right now the target is set to be 2% This inflation level is used in sub-chapter Inflation targeting as targeted inflation for creation of

research model. There is no goal to achieve the lowest level of inflation, because low inflation is same bad as high inflation. Therefore, if inflation level is higher or lower by more than 1% from the targeted inflation, the Governor must write open letter to ministry of finance and explain reasons, why the target hasn't been met.
The official bank rate is interest rate, which central bank offers to commercial banks for over night deposits. This feature enables to Bank of England act as a lender of last resort. Changes in Bank rate affect interest rates on interbank market and in connection with transmission mechanism also influence economical output. Since March 2009 the bank rate has been set to level of 0,5%. According to Anderson (2013) the monetary policy is becoming ineffective when the interest rate is negative. Commercial banks would have to pay for deposits of cash in central banks.

4 Empirical Analysis

This chapter of the thesis is divided into four main parts. The first part describes testing of GDP and monetary aggregates M2 for structural breaks by Chow test. Testing of the GDP leads to the analysis of emerging crisis and detecting its peak. Before the crisis the GDP time-series have upward-sloping trend. When the crisis emerges the trend is changing its position and slope. Therefore, the detected quarter with the peak of the crisis is omitted from the observation, so there is no misleading information to corrupt the model. The time-series is divided into two parts – before crisis and after crisis. This distribution of the time-series is used in all further testing for granger causality.

This part is followed by a test for structural break in monetary aggregate M2 so the model can show, how fast the ECB and Bank of England reacted on the emerging crisis and if the steps were the same or different.

The next subchapter is describing inflation targeting of CBs as next possibility of using their monetary policy. The results compare set inflation targets with actual price level changes in observed period. According the findings, it is stated if CBs fulfilled their inflation targets.

After those findings, the thesis focuses on calculation and description of few monetary rules. These monetary rules are used for determining optimal level of short-term interest rate to stimulate monetary policy. The findings are compared with actual development of interest rates offered by the ECB and Bank of England at the same period of time.

The fourth part describes vector auto regression in Granger causality. At the beginning of this part, the analysis of input data used for calculation and testing is discussed. The input data consists of GDP, monetary aggregates M1 and M2 and Real Interest Rate (RIR). The Granger causality should reveal causal relationship between monetary aggregates and GDP and also between RIR and GDP. The results show causal causality as none, one-sided or both-sided causality. To create more significant finding of VAR model, this thesis is using lagged variables. As described at the beginning of this chapter, the tests of Granger causality are divided into two parts: before crisis and after crisis. Before crisis is using up to eight lags and after crisis is using just up to six lags, because of not sufficient amount of observation in this testing period.

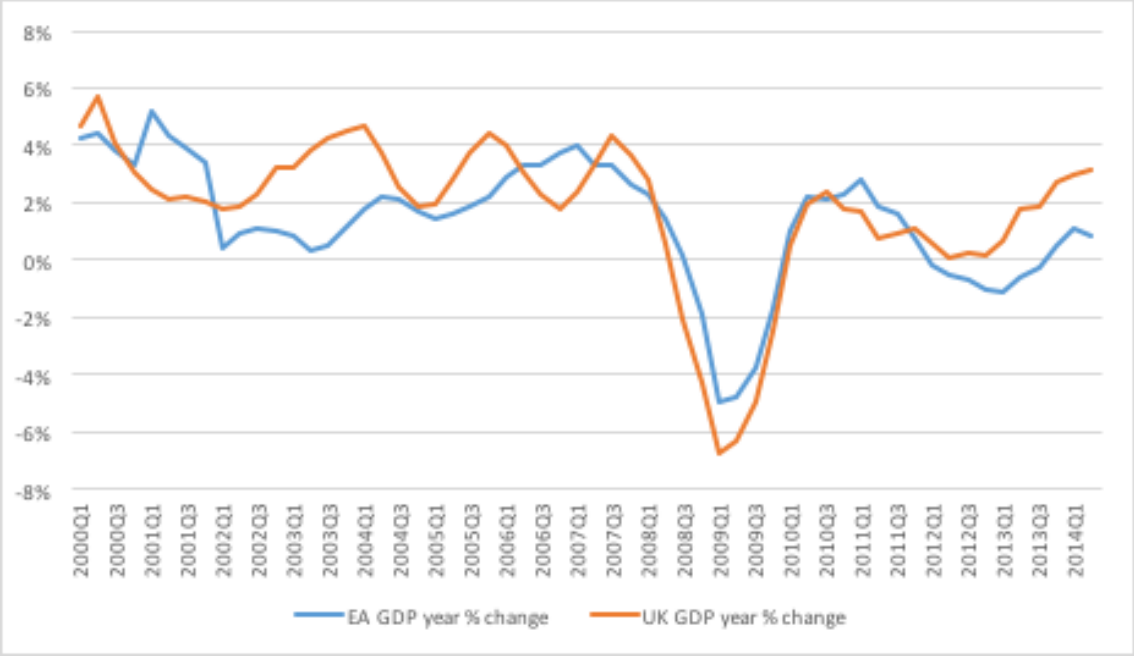
4.1 Structural breaks

If any unexpected shift of macroeconomic data connected with change of intercept or trend revels in observed period, we are speaking about a structural break. For the testing for structural breaks in linear model the Chow test is used. Because this thesis is using also linear model based on Ordinary least squares, the Chow test is also used. For purpose of this thesis the level of significance is set to 5%. The null hypothesis is stated as - There is no structural break. Using this test, it is possible to either reject or not to reject the null hypothesis.

4.1.1 Structural break in GDP

A Figure 1 shows yearly percentage changes of GDP from previous period both in the euro area and the United Kingdom. This chart reveals significant fall in output during economic crisis.

Figure. 1 Evolution of GDP in EA and UK. Source: Eurostat, author's calculation



As Figure 1 shows, the blue line describes development of seasonally adjusted GDP for the euro area and the orange line represents seasonally adjusted data of GDP for the United Kingdom. There is no discussion, that both economies were hit by the same crisis during the same period. It is not clear, when the peak of the crisis

emerges, but it is somewhere between 2008 Q3 and 2009Q1. Therefore, for more clear and accurate results the Chow tests has been used for both time-series.

Results of the Chow test discovered followings:

Table. 1 Results of Chow tests for structural breaks in GDP Time-series. Source: Eurostat, author's calculation.

OLS Model	Structural break	p-value
EA GDP	2008 Q4	1.694e-46
UK GDP	2008 Q4	1.429e-155

The Chow test for both observations for the EA and the UK has rejected null hypothesis at the same quarter – 2008 Q4. Graphs with results of the Chow test is in Appendix A at the end of this thesis. These results means, that both economies were hit by the same crisis at the same time. For higher significance, both these extremes are removed from future testing of all time-series models. Therefore, observations for the EA and the UK are distributed according to Table 2.

Figure. 2 Real GDP in EA and UK, Source: Eurostat, author's calculation.

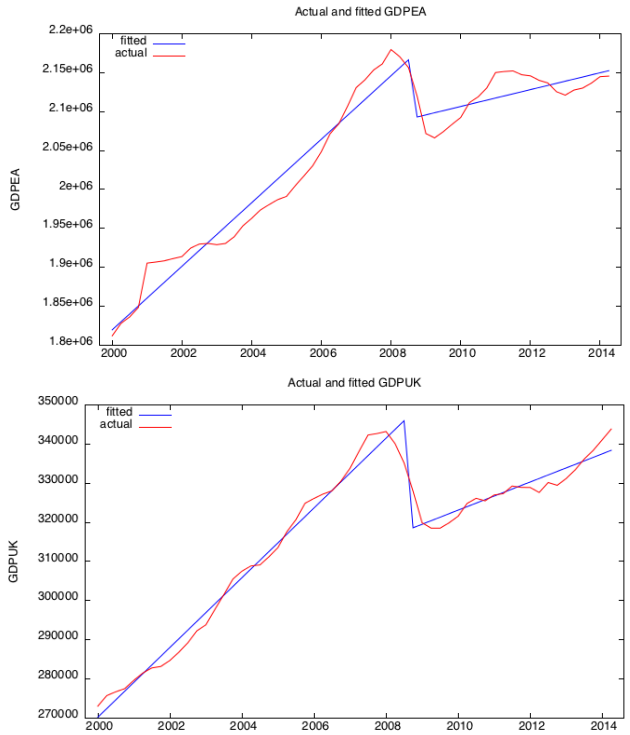


Table. 2 Distribution of GDP Time-series. Source: Eurostat, author's calculation

Time-series	Before crisis	After crisis
EA	2000 Q1 - 2008 Q3	2009 Q1 - 2014 Q2
UK	2000 Q1 - 2008 Q3	2009 Q1 - 2014 Q2

According to distribution of observations of time-series in Table 2 it makes 35 observations for the EA and also for the UK in period before crisis. For the period after crisis it makes 22 observations for each economy. Because the period after crisis has less observation than period before crisis it makes it less accurate for causal relationship, but all the tests are applied for both time-series and commented as well.

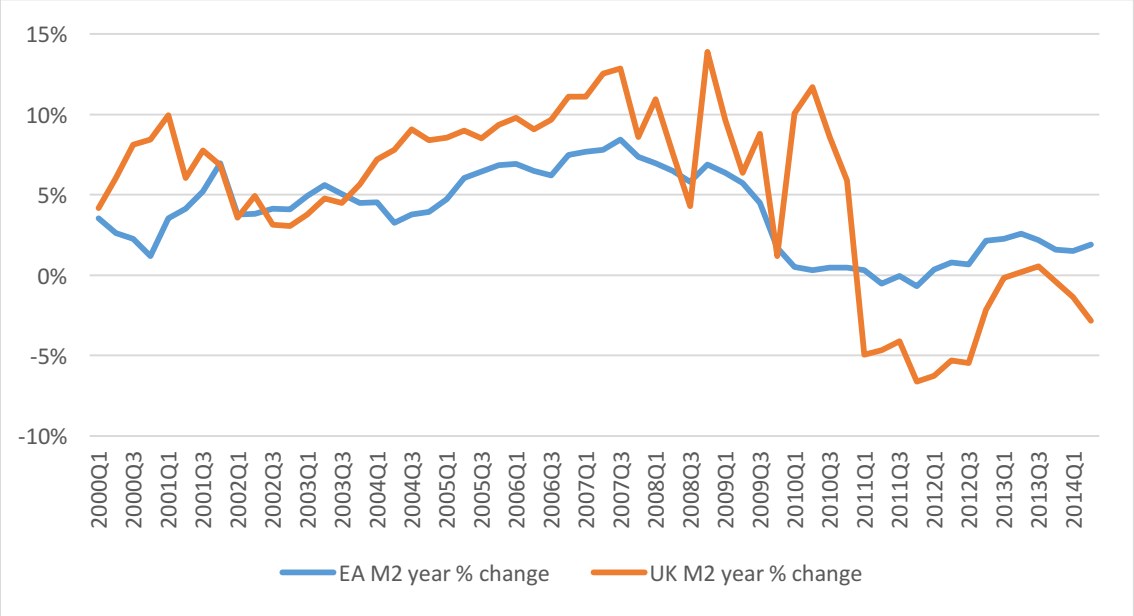
4.1.2 Structural break in M2

For the testing of structural breaks this thesis uses seasonally adjusted data of monetary aggregates M2. M2 is used, because it contains monetary aggregate M1 plus market deposits and saving deposits. M1 includes just cash, checks and demand deposits. Hence, there is little chance that there would be any structural break in M1 aggregate.

Central banks have possibility to lower inflation pressures by selling their bonds, because they will drain money from the economy. This statement is fitting to quantitative theory of money that states that amount of money in economy is proportional to price level.

A Figure 3 describes development of these data for both the EA and the UK. Again the blue line represents development of M2 for the EA and the orange line shows development of M2 for the UK. As Figure 2 shows, the development before the crisis was almost the same in the EA and the UK, but after the crisis Bank of England tried to increase their money in two waves.

Figure. 3 Evolution of M2 in EA and UK. Source: Eurostat, Bank of England database, author's calculation



Again for more accurate results, the Chow test is used for structural changes. Results are noted in Table 3 and at the first look it looks like that both CBs reacted on emerging crisis in some way. Let's discover more details about these findings.

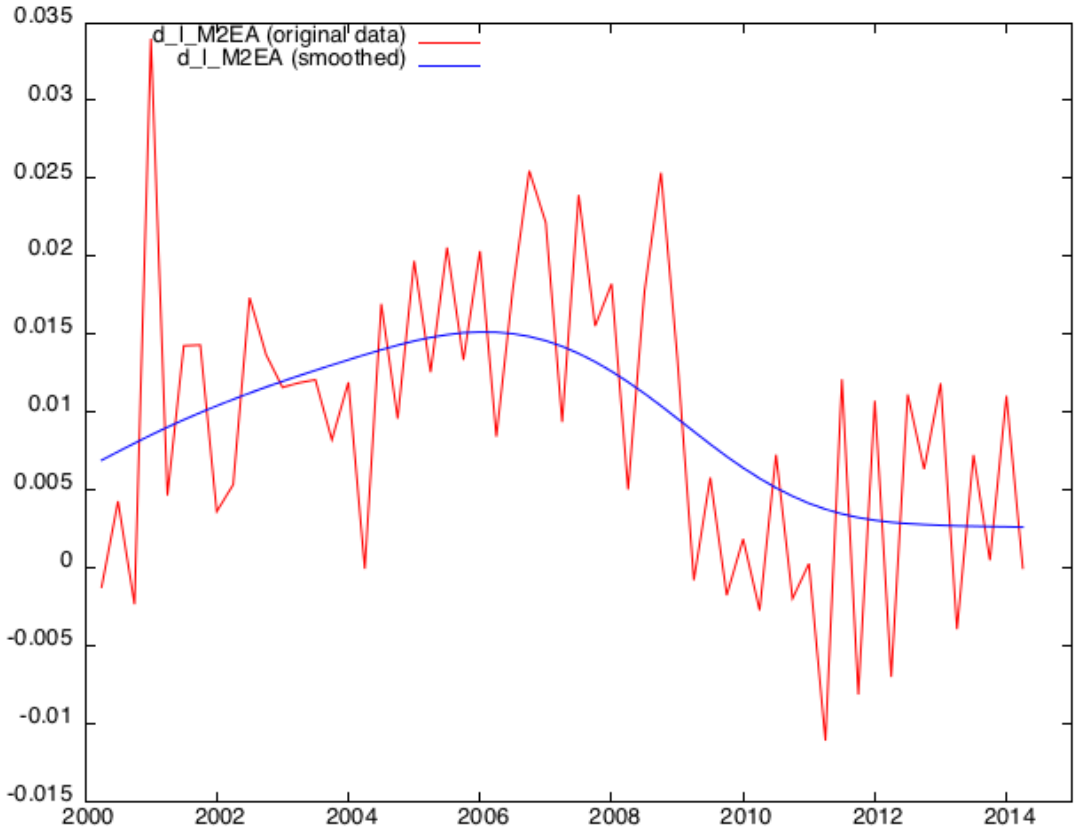
Table. 3 Results of Chow tests for structural breaks in M2 Time-series. Source: Eurostat, author's calculation.

OLS Model	Structural break	p-value
EA M2	2009 Q2	1.3178e-05
UK M2	2010 Q2	0.0009412

According to results of the Chow test with European data, there was a structural break in the second quarter of 2009. This result shows a quick reaction on arising crisis.

For higher accuracy, how ECB reacted and what was the trend of monetary aggregate M2, the graph with Hodrick-Prescott filter and trend results for structural change is shown in Figure 4. Since the point of structural change 2009:2 the tempo of growths of monetary base has lowered.

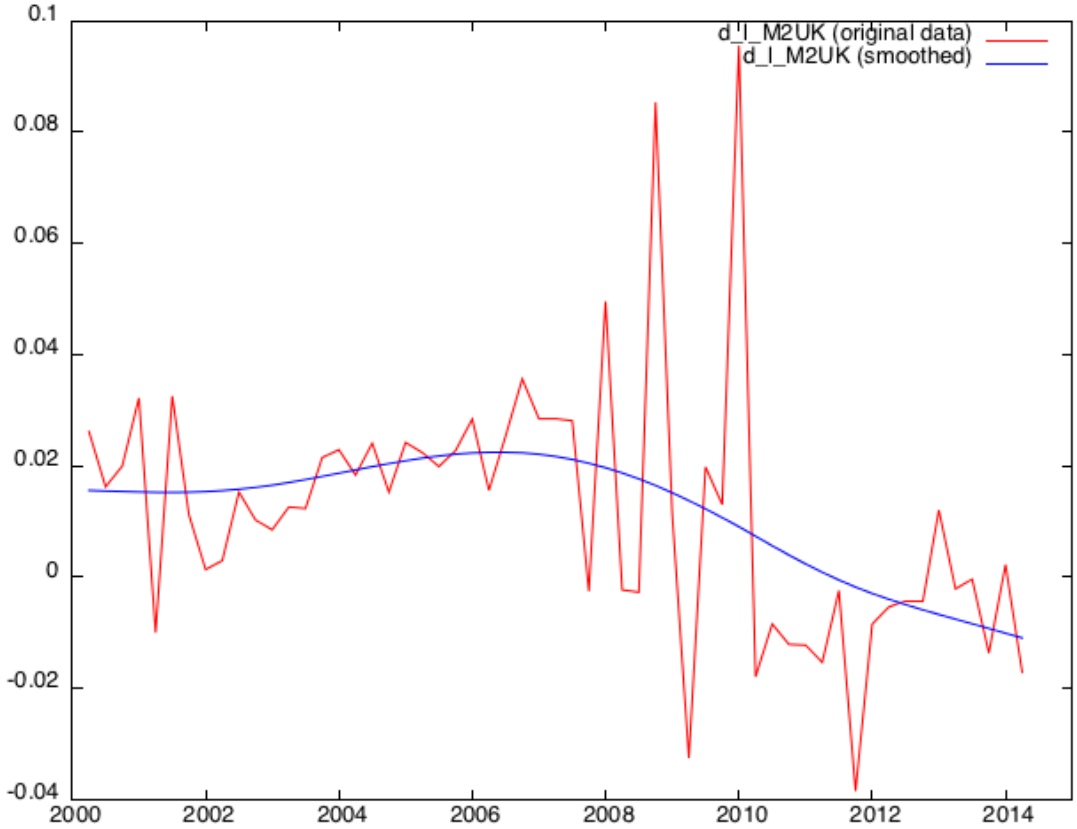
Figure. 4 Hodrick-Prescott filter on M2 in EA, Source: Eurostat, author's calculation.



The Chow tests shows that structural change in UK emerged later in the second quarter of 2010. This means that it took more time to BoE to react on the crisis.

If we look closely to results in Figure 5. It is obvious that Bank of England tried to increase monetary base right away, when the crisis hit the United Kingdom, which is totally opposite to the ECB. This finding is obvious if we compare both trend lines in Hodrick-Prescot filters of M2 in EA and UK.

Figure. 5 Hodrick-Prescott filter on M2 in UK, Source: Bank of England database, author's calculation.



4.1.3 Summary

As the results of tests for structural breaks in GDP revealed, both the EA and the UK were hit by the same crisis at the same time. The crisis had similar result – both economies experienced a serious drop in their economic performance. This impact had very similar scale in the EA and in the UK. Hence, there is no noticeable variance in the conditions, how the markets were hit.

Variance could be found in steps how the ECB and Bank of England responded to the crisis. The Bank of England increased monetary base by quantitative easing to boost economic growth. The ECB responded in an opposite way. Their goal was to lower inflation so they lowered monetary base.

4.2 Inflation targeting

A lot of studies confirmed that idea of inflation targeting is one of the best method of monetary policy. The studies propose that inflation targeting will lead to higher living standards, promote economic growth and stabilize price level in a long-lasting way.

4.2.1 Reasons for inflation targeting

According to ECB (2004) the way how to reach high level of output activity and also high level of employment is based on price stability. The ECB has established five main reasons, which confirms this claim.

- Inhabitants are able to more simple recognize relative price changes, because there is no effect of price level fluctuation. Inhabitants have better information so they should be able to construct better decisions for their consumption. All these steps should lead to higher efficiency in allocating resources to increase economy potential productivity.

- Because the growth of price level is stable it leads to lower risk of unexpected inflation. Hence inflation risk premium will not be required for investments. If the risk premium will not be demanded it should lead also to enhancement in investments and development in given area or country.

- If the price level will be stable, it will lead to lower inflation hedging.

- With stable growth in price level is connected also theory about defence against tax and also welfare incentives, which could mislead economic behaviour. These incentives are often connected with fear from unpredicted inflation or deflation.

- Stable price level encourages social stability and cohesion, because it omits wealth redistribution, which could be originated in unexpected price level change.

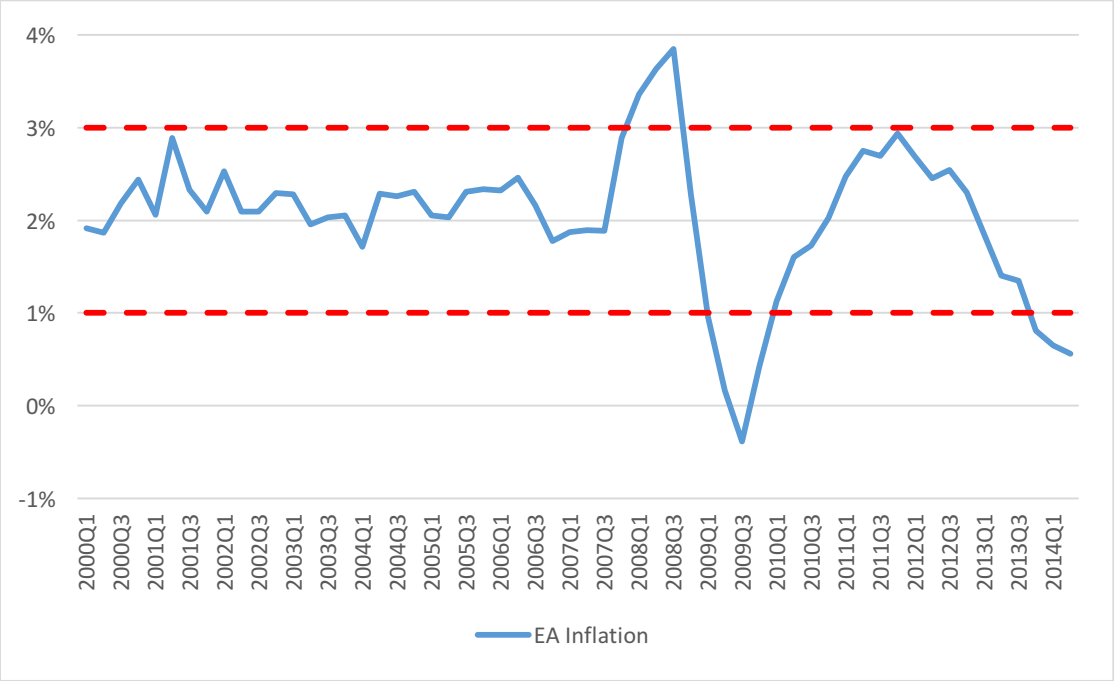
4.2.2 EA inflation targeting

The ECB is considered as a central bank with main objective connected with price stability. The origin of this strategy could be found in Bundesbank, which was model

for creating the ECB. The ECB considers positive correlation of economic output with price level stability and employment. Inflation target for the ECB is measured by Harmonised Index of Consumer Prices (HICP) and the targeted inflation is set to be 2%.

According to Figure 6, which describes ability of the ECB to follow their target inflation level, it could be considered that the ECB is successfully fulfilling their primary goal even in the time of crisis. There was just a small gap between targeted and actual inflation, but it was just for a short amount of time and later the ECB was able to get back to their target.

Figure. 6 Development of inflation in EA. Source: Eurostat

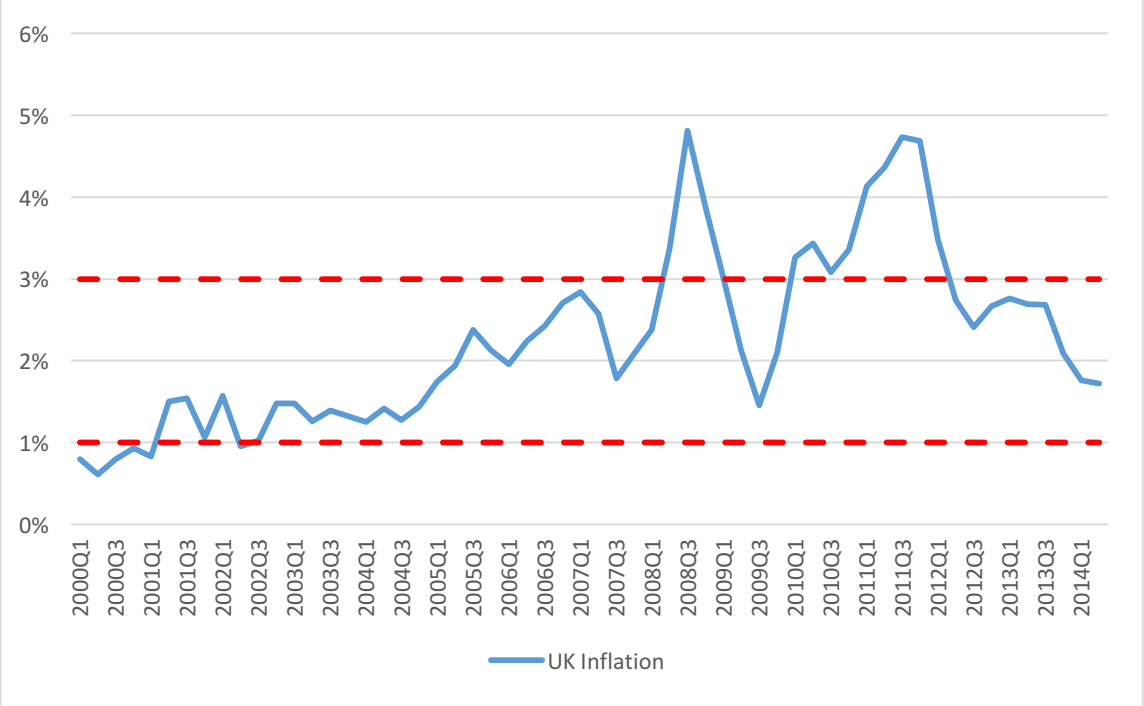


4.2.3 UK inflation targeting

The Bank of England is also following inflation targeting, because of the same reasons as the ECB. They also stated, that if there will be difference higher than +/- 1% from targeted inflation, the Governor has to write open letter and explain why this situated occurred. The Bank of England is measuring their inflation target the same way as the ECB – by the HICP and also their target inflation is set to 2%.

As Figure 7 shows, Bank of England is not fulfilling its own target as good as the ECB. The graph could be divided into two parts – before crisis and after crisis. Before crisis the Bank of England didn't have problem to follow their targeted inflation, but soon as the crisis hit the UK, the actual inflation started to be higher than targeted. This phenomenon is closely connected with quantitative easing described in previous part of this thesis. Nevertheless, at the end of observed period the inflation targeting met its goal again.

Figure. 7 Development of inflation in UK. Source: Eurostat



4.2.4 Summary

According to the obtained results, it can be stated that the ECB followed their inflation targeting much better than the Bank of England. Even if there was a small deviation at the beginning of the crisis, inflation got back to normal quickly. On the other hand, the Bank of England had much more problems to maintain their goal since the crisis hit. They managed to get back to their target inflation in the middle of the year 2012.

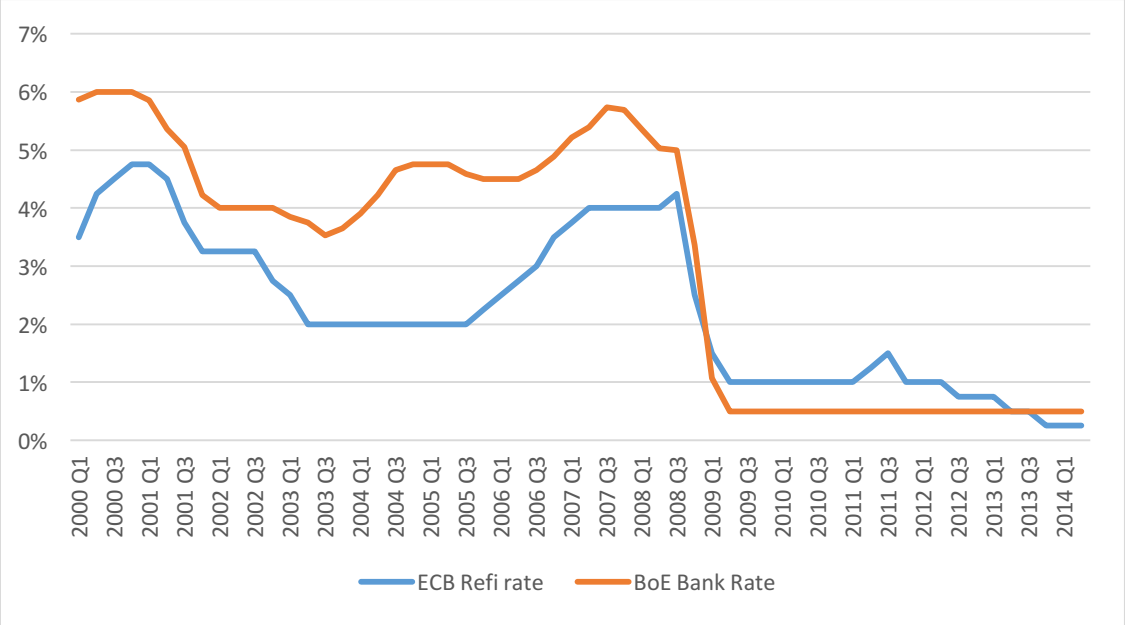
4.3 Monetary rules

Economists are trying to analyse and find easy way how to use short-term interest rate as a tool to steer monetary policy. The time during crisis was great opportunity for them to find out if there is some universal monetary rule, which could be followed to predict future development of short-term interest rates. This part of the thesis will focus on few selected rules and their predicative abilities.

4.3.1 Short-term interest rates development

The Figure 8 shows how the ECB and Bank of England used their short-term interest rates over the observed period.

Figure. 8 Development of short-term interest rates in EA and UK. Source: Eurostat, Bank of England database



On the figure it is obvious that there was a big fluctuation of the short-term interest rate in case the ECB and Bank of England. For the the ECB the short-term interest rate fluctuated between values 4.75% to 0.25% and in case of the UK from 6% to 0.5%. Also it has to be noted that 2009Q2 Bank of England has set their Bank rate to 0.5% a haven't moved it since then.

4.3.2 Taylor rule

Taylor was searching for a way how to steer short-term interest rare to stimulate economic growth. The main part of his research was focused on USA, but also during his research he observed G7 countries. Therefore, this rule can be specified and applied also for countries other than USA. His rule is closely connected with inflation and real inflation, which was discussed in previous part. According to this rule CBs should react with increasing short-term interest rate if the price level and real income are higher than target and on the other hand CBs should decrease short-term interest rate if it is below target. Taylor also believed in a steady state. Hence he added coefficients into his policy, which would to this steady state. His rule became very popular, because it was easy to calculate and easy to use. Many CBs started to use this rule in their monetary policy.

Taylor rule is calculated with formula mentioned below:

$$r = gy + h(p - p^*) + r^f \quad (3)$$

Variables in this formula can be interpreted as:

- r – short-term interest rate
- g – Taylor's coefficient set to 0.5
- h – Taylor's coefficient set to 0.5
- p^* – Taylor's coefficient set to 2%
- r^f – Taylor's coefficient set to 2%
- y – output gap
- p – inflation rate for 4 quarters

For estimating the inflation rate (p) Taylor used the Implicit Price Deflator. This method is also used in this thesis.

Now it is necessary to estimate output gap correctly. According to Taylor, output gap should be calculated as follows:

$$Output\ gap = \frac{(y - y^*)}{y^*} \quad (4)$$

Again variables in this formula stands for:

- y – actual GDP
- y^* - trend of real GDP

According to inflation report by the CNB it is possible to estimate the trend by Hodrick-Prescott filter. Result of this calculation is used further in this thesis.

Figure. 9 Taylor rule applied on EA, Source: Eurostat, author's calculation

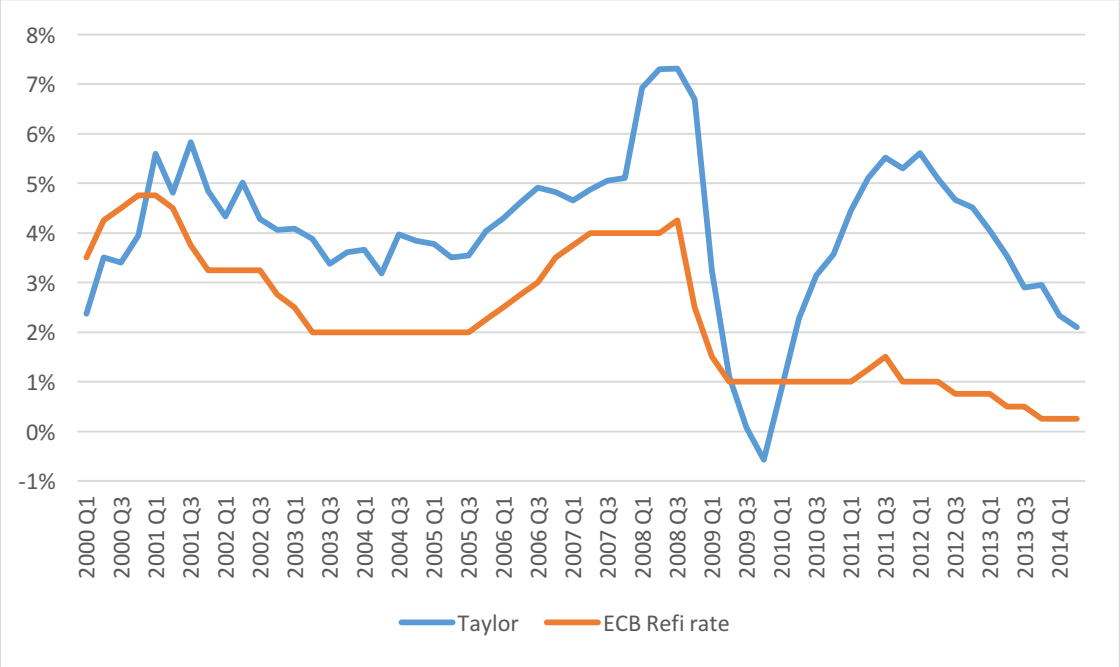
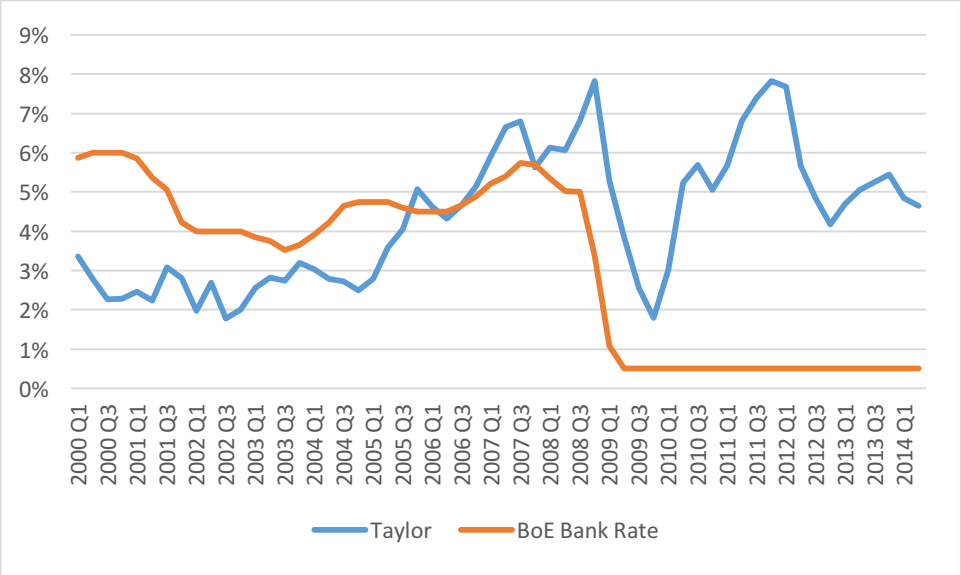


Figure 9 represents development of ECB Refi rate and calculated Taylor rule. Overall fit cannot be considered as good one but even as a bad one. In period before crisis Taylor rule corresponds closely. In this figure could be observer the two bumps at the beginning of observer period and in 2008 before the crisis. After the crisis this model is loosing its interpretative value, because it suggests to increase short-term interest rate. Nevertheless, the ECB did just opposite thing.

Figure. 10 Taylor rule applied on UK, Source: Bank of England database, author's calculation



Compered Figure 10 with Figure 9 it is more than obvious that Bank of England doesn't set their short-term interest rate according to Taylor rule. The overall fit is very bad. Only one section of this figure could be considered as a small fit a that is the time at the beginning of the crisis. At this point Taylor rule suggest to decrease interest rate. This step was performed by the Bank of England but since that time the short-term interest rate stayed fixed for the rest of the observer period.

Taylor rule was criticized for several reasons by many economists. As Svensson (2009) comments, using Taylor rule as a simple tool would be nice, there are some major problems. For example, there is a problem with possibility to add some extra variables into the model. Because of this, the model is missing some important variables and therefore, it is loosing its explanatory power. Next problem is connected with opportunities of CBs to react and modify the rule. Last but not least, there were published many academic studies, but still there is no CB, which would be dedicated to this one simple monetary rule.

4.3.3 Mankiw rule

Because of the fact, that there are many critics of simple Taylor rule, there were other economists trying to find other instrument rule, which would add missing elements to the formula and therefore, make the new rule more reliable.

As a one instrument rule, which is trying to add other aspects to the account, is Mankiw rule. This rule is calculated as:

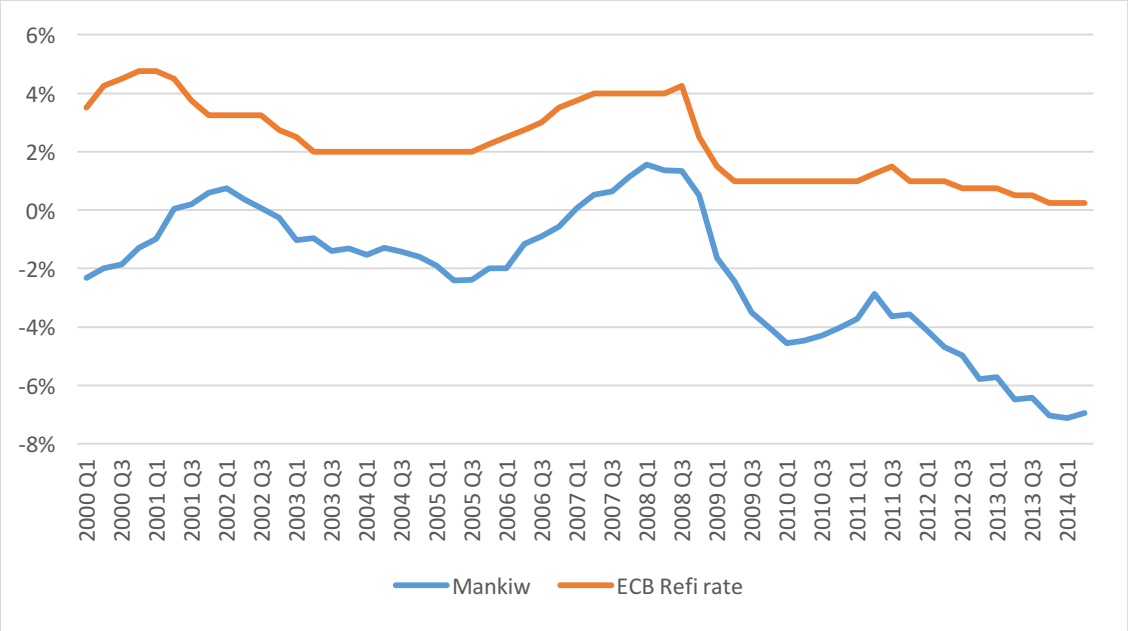
$$r = 8.5 + 1.4(\pi - u) \quad (5)$$

Variables in this formula stands for:

- r – short-term interest rate
- 8.5 – Mankiw's coefficient
- 1,4 – Mankiw's coefficient
- π - inflation without food and energy (core inflation)
- u – seasonally adjusted unemployment

Mankiw's coefficients are calculated for period of 90's in USA, hence it is not expected that the overall fit of this rule will be applicable on data in observer period in this thesis. Nevertheless, this rule will be calculated as well.

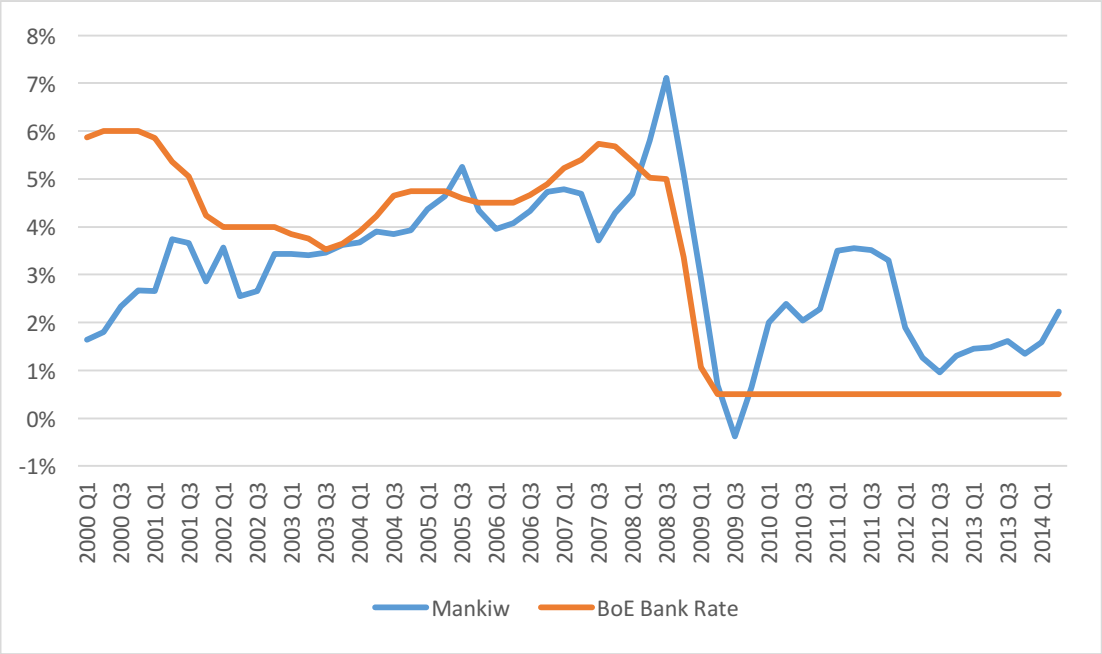
Figure. 11 Mankiw rule applied on EA, Source: Eurostat, author's calculation



As predicted, the overall fit of this Figure 11 is very bad and Mankiw rule doesn't correspond with short-term interest rate. Mankiw rule is suggesting negative inter-

est rate in the most cases in this observed time period. This outcome has been expected, because this rule was prepared in 90's in USA as mentioned in previous paragraph.

Figure. 12 Mankiw rule applied on UK, Source: Bank of England database, author's calculation



Mankiw rule applied on time-series of the UK has surprisingly fitted much better than in case of the EA. This Figure 12 could be divided into three parts. The first one 2000Q1 – 2003Q2, when Mankiw rule suggests lower interest rate than it is offered by Bank of England. Then since 2003Q3 the fit is pretty good until the point after crisis when the Bank rate has been fixed to 0.5% in 2009Q2. This result is surprising and it wasn't expected, as for the reason mentioned in EA case.

4.3.4 Galí rule

There is one more rule connected with monetary instruments and establishing the right level of short-term interest rate and that is Galí rule. Galí found his inspiration in Taylor rule, which he modified. This rule is using unemployment gap and not output gap. The whole formula can be found below:

$$r = r^* + \pi^* + 1.5(\pi_t^p - \pi^*) - 2(u_t - u^*) \quad (6)$$

Variables in this equation stands for:

- r – short-term interest rate
- r^* - equilibrium interest rate, which Galí set to be 2%
- π^* - target inflation
- π^p_t – actual inflation, calculated as IPD
- u^* - average unemployment
- u_t – targeted unemployment

The rest variables and numbers are coefficients used by Taylor. According to Galí (2010), the targeted unemployment for the EA was stated as 8.5% and for the UK it was stated as 7% in period 1999-20009. Because observed period in this thesis is closely connected with period used by Galí, the same coefficients are used.

Figure. 13 Galí rule applied on EA, Source: Eurostat, author's calculation

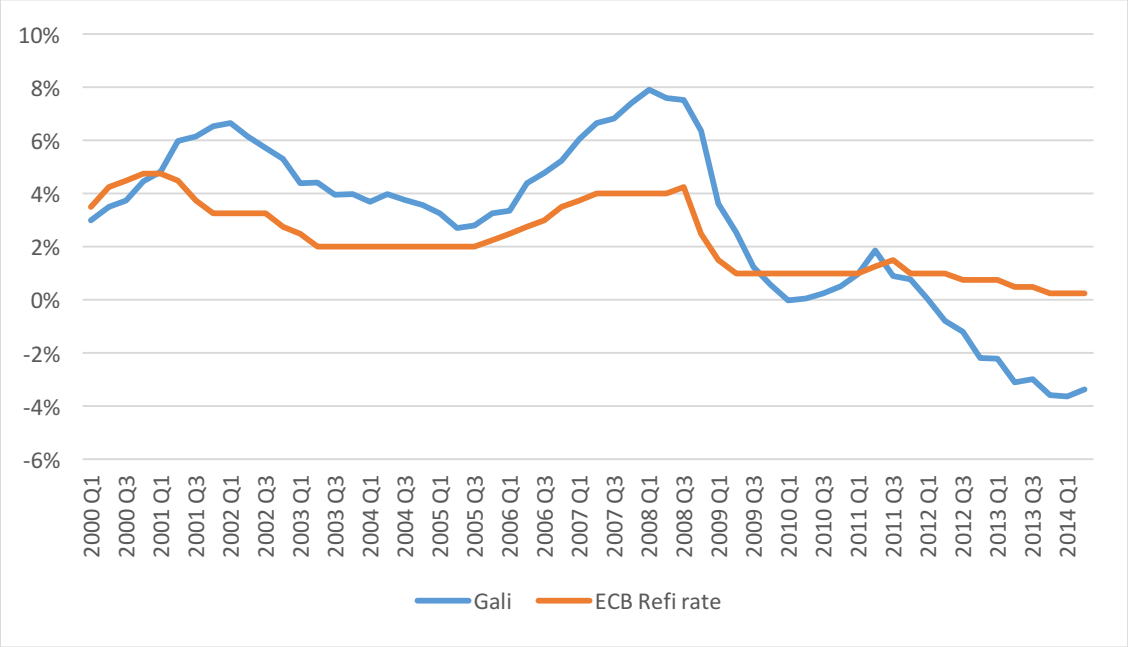
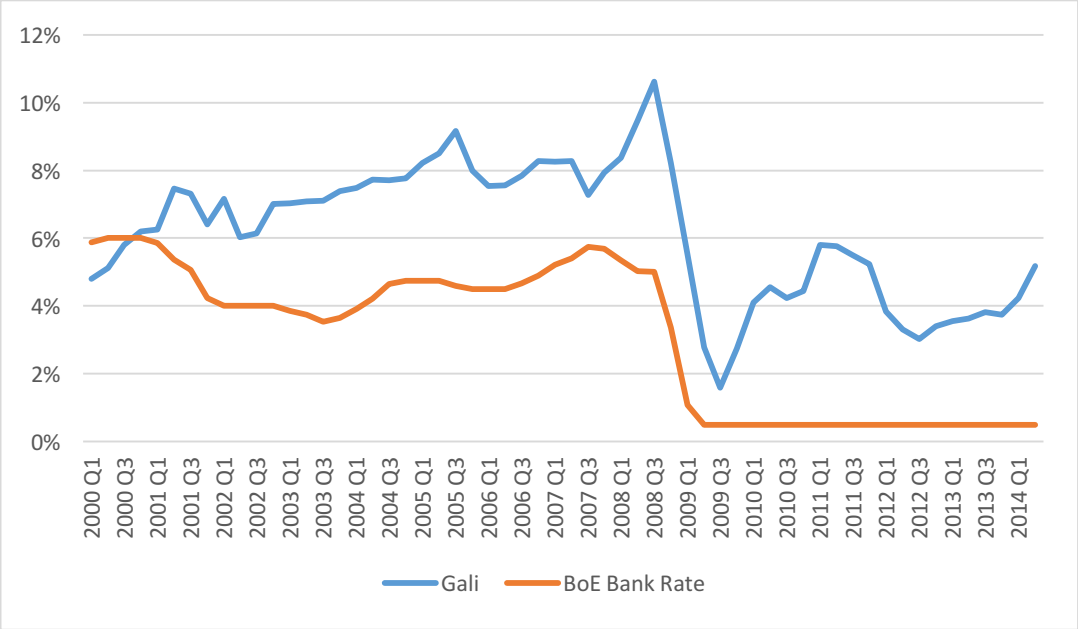


Figure 13 displays calculated Galí rule and its fit to actual ECB Refi rate. Since 2001 Galí rule suggests higher interest rate than the actual one, but it is closely correlated as it can be seen on the two bumps on the chart. After the year 2011 this rule became unusable as guideline for steering the policy. This situation is linked with higher unemployment after the year 2011.

Figure. 14 Galí rule applied on UK, Source: Bank of England database, author's calculation



As Figure 14 shows, there is similar case as for the EA. Galí rule for the UK area suggests higher short-term interest rate than actual set by Bank of England. Even if there are similar movements up and down, the overall fit is not good. One thing is totally different from previous case of the EA and that is the after crisis period. In this case Galí rule suggests to set higher interest rate than the actual one, even if in the case of the EA suggested negative one. This situation can be explained by the same reason as before. The EA had problem with increasing unemployment, but this is not the case for the UK. Actual unemployment was just for few tenth of percent higher than targeted in the UK.

4.3.5 Summary

Testing monetary rules for their actual fit revealed many surprising conclusions. All of them offer sophisticated help and suggestions of how to implement monetary policy connected with changes of the real interest rate. However, it has been proven that there are some rules, which fit better for the EA and some for the UK. Even though all the rules should be used to gain all possible information obtainable.

In the case of the EA it can be stated that using the Taylor rule and the Galí rule could be beneficial, but using the Mankiw rule resulted in no overall good fit. On the side of the UK it is totally opposite. The best fit to predict short-term interest rate showed up to be the Mankiw rule, followed by the Galí rule. The worst fit had the Taylor rule,

which could be stated as unusable for the UK. This can be explained by information that the UK is more focused on their unemployment rate than inflation rate.

All the rules had one similar problem. They can be used in time of ideal condition for the economy, but if any unpredicted shock occurs, all of them are loosing their predicative power. Hence it wouldn't be clever for any central bank to follow blindly any of those rules.

For better understanding Figures 15 and 16 containing all monetary rules and real interest rates for each country are added into this summary.

Figure. 15 Galí rule applied on EA, Source: Eurostat, author's calculation

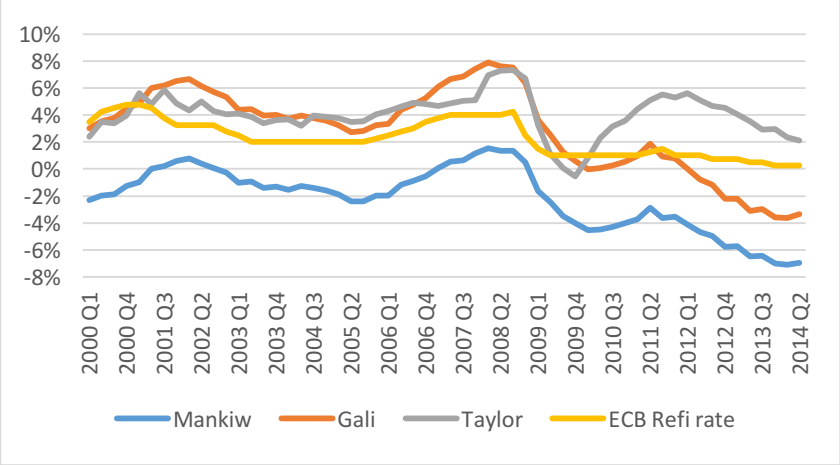
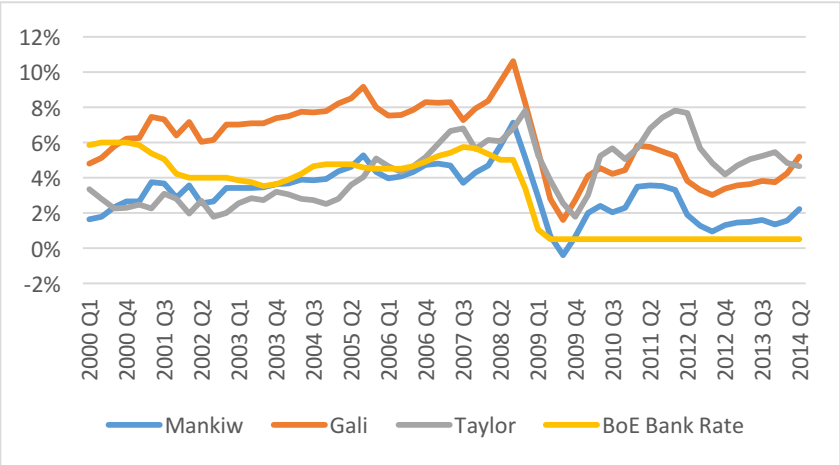


Figure. 16 Galí rule applied on UK, Source: Bank of England database, author's calculation



4.4 Granger causality

4.4.1 Input data and their testing

For Granger causality testing, it is necessary to obtain correct data to get significant model. Data used further in this thesis consists of GDP, monetary aggregates M1 and M2 and real interest rate (RIR). All data were obtained from statistical databases (Eurostat, ECB, Bank of England) in nominal form. Because data are influenced by inflation, they had to be deflated to their real values. For the deflation HICP was used. Also as Tomšík (2005) says, all data have to be stationary for significant results.

In first part of empirical analysis in this thesis, data were tested for structural breaks to clarify effect of the crises. For higher accuracy of this model, data were divided into two parts, before crisis and after crises. Hence, two time-series were specified for further testing. Both TS for the EA and the UK have the same distribution. Before crisis data are covered in period from 2000Q1 – 2000Q3 and after crises data are part of period from 2009Q1 – 2014Q2.

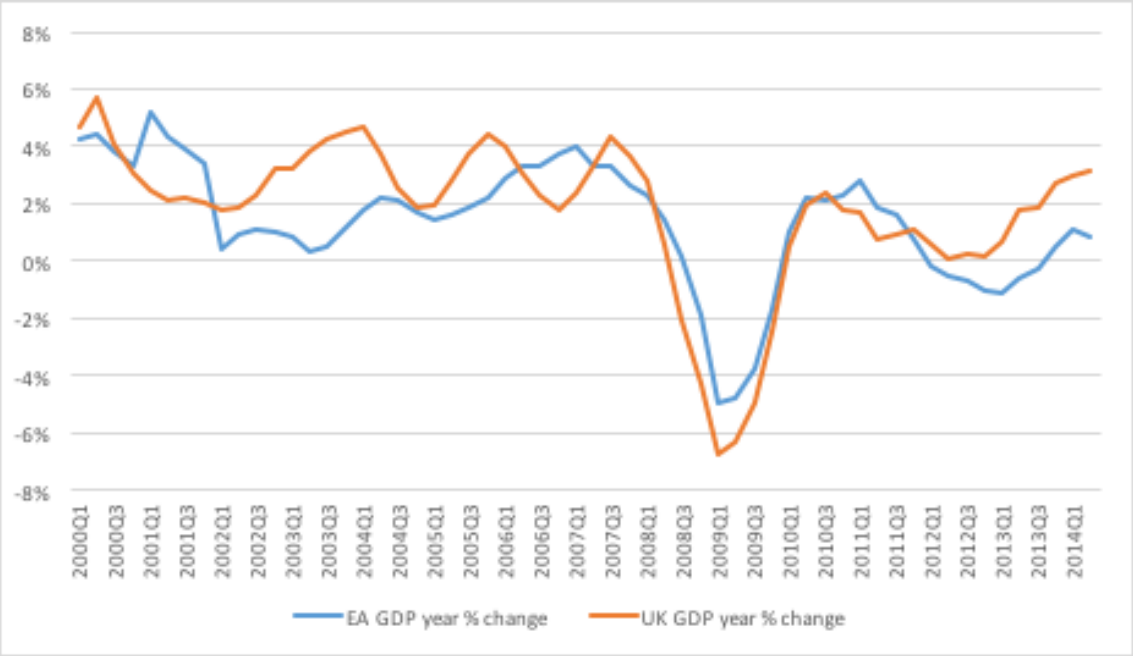
For data stationarity testing, the ADF test was used. All specifications for all the tests used for variables are commented below. Also all correlograms for each variable are listed in Appendix B in this thesis.

GDP

Gross domestic product has upward-sloping trend, which is effected by two main reasons. The first reason is real growth and the second reason is inflation. As mentioned before for further testing it is necessary to use real GDP, which is not influenced by the increase in price level. According to ADF test, the results suggest that all GDP variables are integrated at degree one. So then the real GDP is transformed into base 10 logarithms and level 1 differences to obtain stationarity. After the data were tested again and results of ADF tests say that data are stationary and therefore, they are suitable for later testing.

Results in form of correlograms are added into Appendix B. Also development of GDP of the EA and the UK in form of annual percentage growth is displayed on Figure 17.

Figure. 17 Annual percentage changes in Real GDP. Source: Eurostat, author's calculation



Monetary aggregates M1 and M2

Money supply data in form of M1 and M2 were obtained in databases of the ECB and Bank of England in nominal form. These data are under effect of inflation as GDP in previous paragraph. Hence it is necessary to convert these data by HICP 2005 into the real values. Data were then tested by ADF test for unit roots. The results suggest that the dataset in non-stationary. Again the data are converted into form of 10 bases logarithms and their first differences as in previous case of GDP. Then the real M1 and real M2 were tested again with ADF test. Results shows that stationarity was obtained by those steps.

Correlograms of tested real M1 and real M2 variables are listed in Appendix B. Figures 18 and 19 show annual growth of real M1 and M2 in form of percentage change.

Figure. 18 Annual percentage changes in Real M1. Source: ECB, Bank of Enland database, author's calculation

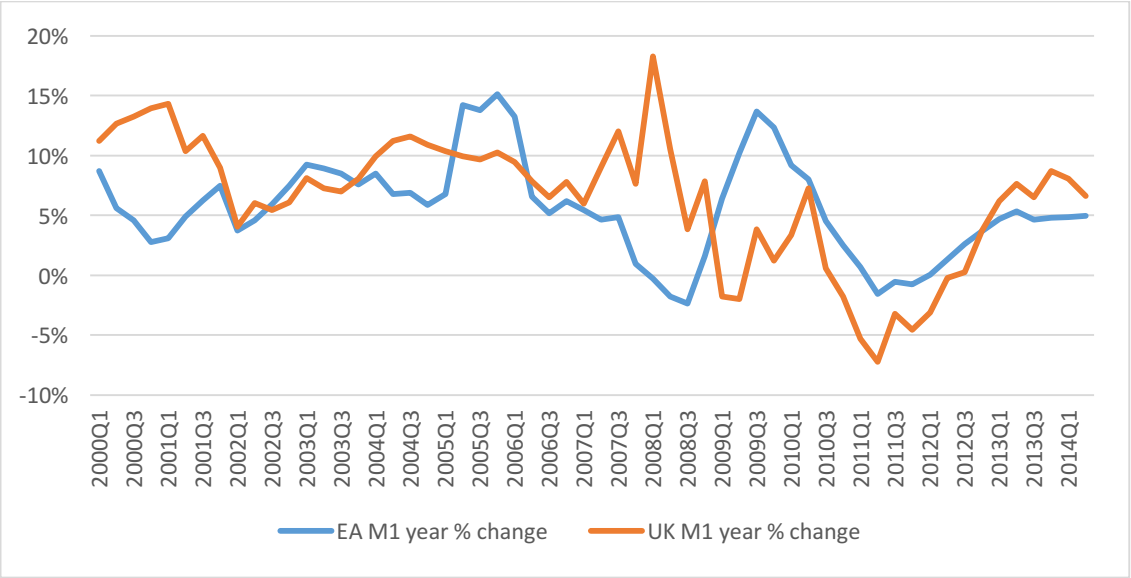
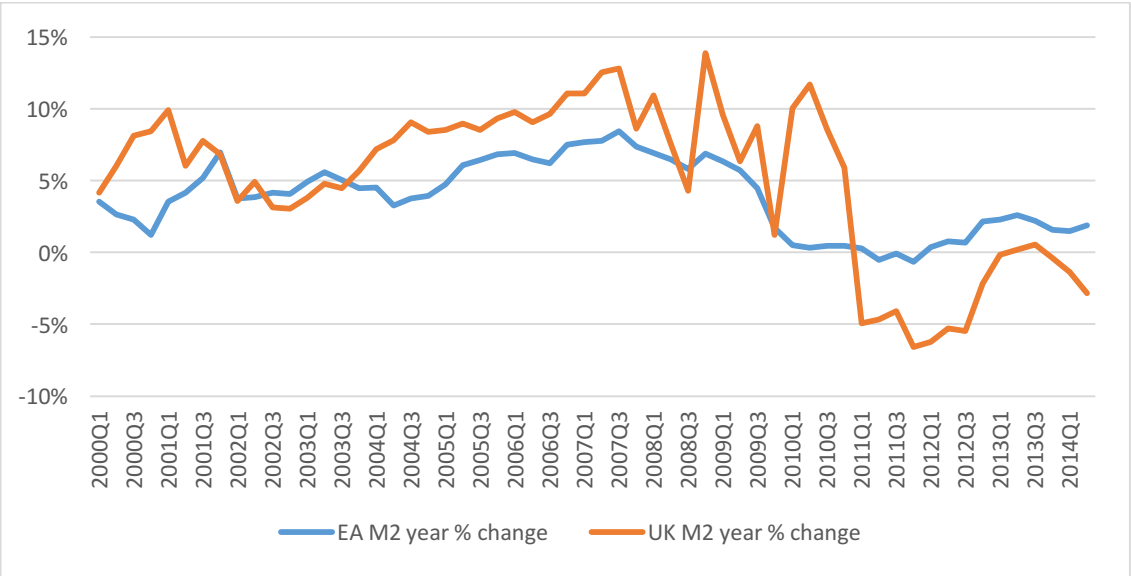


Figure. 19 Annual percentage changes in Real M2. Source: ECB, Bank of Enland database, author's calculation



RIR

Real interest rate used in further analysis in this thesis was calculated according to equation below:

$$RIR = \left(\frac{100+R}{100+i} - 1\right) \times 100 \quad (7)$$

Variables in this formula stands for:

- R – nominal interest rate in %
- i – real inflation

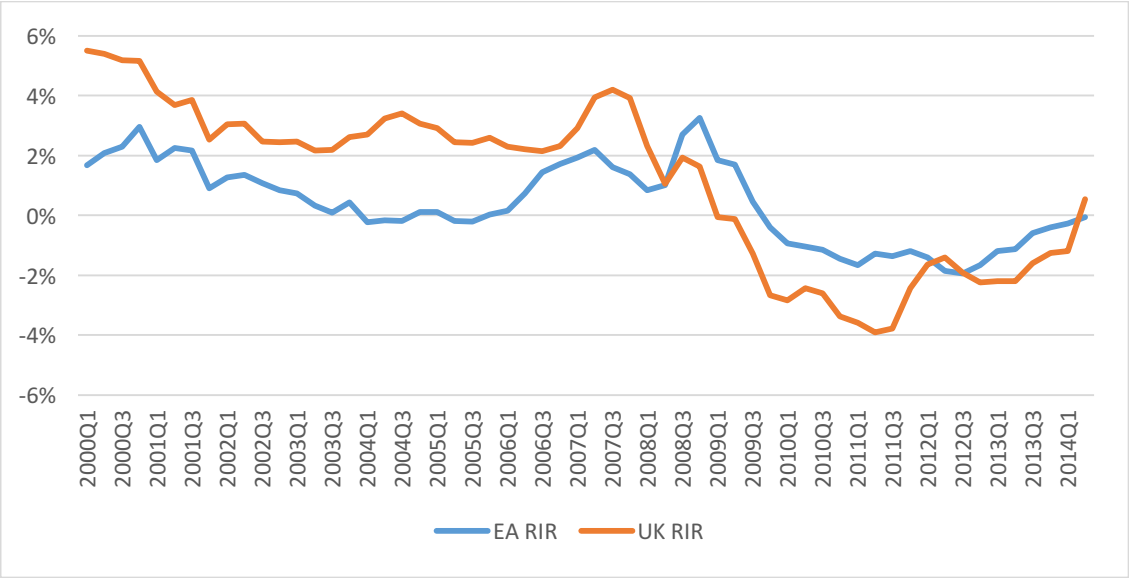
As for nominal interest rate in this formula 3-month EURIBOR has been chosen for the EA and for the UK the 3-month LIBOR has been chosen. Real inflation has been calculated by HICP.

Even though that CBs are not able to affect EURIBOR and LIBOR, they are closely linked with short-term interest rates published by the ECB and Bank of England. Hence it can be stated that these data can be used as an instruments of monetary policy.

Like in all cases before, RIR dataset has been tested by ADF test for unit roots. The whole dataset had to be converted to first differences to get stationarity.

Correlograms of tested dataset can be found in the Appendix B at the end of this thesis. The development of RIR in the EA and the UK is shown in Figure 20.

Figure. 20 Development of RIR in EA and UK. Source: ECB, Bank of Enland database, author's calculation



4.4.2 Testing for Granger causality between real GDP and real M1

Since all data and variables are according to ADF test stationary, it is possible to perform granger causality testing between real GDP and M1 in this part of the thesis. The granger causality is tested as follows:

$$Real\ GDP_t = const + \sum_{i=1}^{j} \alpha_i Real\ GDP_{t-1} + \sum_{i=1}^{j} \beta_i\ Real\ M1_{t-1} \quad (8)$$

$$Real\ GDP_t = const + \sum_{i=1}^{j} \alpha_i Real\ M1_{t-1} + \sum_{i=1}^{j} \beta_i\ Real\ GDP_{t-1} \quad (9)$$

The null hypothesis is tested in form of coefficients α and β and if these coefficients are equal to zero in this equation. The level of significance was set to be 5%. The result of p-value obtained from testing will decide if the null hypothesis is rejected or not rejected. The particular null hypothesis is always written in related tables.

In the EA before crisis period the granger causality revealed positive granger cause between real money supply M1 and real GDP in two lags in total. On the other side of equation, the testing didn't reveal any relationship between GDP grange cause real M1. The positive grange cause has been revealed in 4th and 5th lags listed in Table 4.

Table. 4 Selected results of Granger causality between real GDP and real M1 in EA in before crisis period. Source: author's calculation.

EA - M1 - before crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
3	M1 does not granger cause GDP	0.088084	0.9659	Do not reject
	GDP does not granger cause M1	0.26584	0.8493	Do not reject
4	M1 does not granger cause GDP	3.2805	0.0308	Reject
	GDP does not granger cause M1	0.76268	0.5613	Do not reject
5	M1 does not granger cause GDP	2.9368	0.0413	Reject
	GDP does not granger cause M1	0.63145	0.6783	Do not reject
6	M1 does not granger cause GDP	0.99178	0.4653	Do not reject
	GDP does not granger cause M1	0.70323	0.6518	Do not reject

These results are quite unexpected because it would mean that just by increasing the money supply in form of M1 would lead to higher GDP. As Sims (1980) mentioned, he obtained similar results, where past performance of M1 helped to forecast GDP in the future. This phenomenon was affected by nominal values of GDP and M1 in their log levels in Sims research. The solution for this situation was to add nominal interest rate into the model.

In the after crisis period the tested dataset found positive bidirectional causality between real M1 and real GDP in two out of six lags and positive granger cause between real money supply and real GDP in three out of six lags. As Table 5 shows, quantitative easing in case of money supply M1 could be positive option for the EA to handle the crisis.

Table. 5 Results of Granger causality between real GDP and real M1 in EA in after crisis period. Source: author's calculation.

EA - M1 - after crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
1	M1 does not granger cause GDP	3.1503	0.0938	Do not reject
	GDP does not granger cause M1	8.1740	0.0109	Reject
2	M1 does not granger cause GDP	3.5788	0.0455	Reject
	GDP does not granger cause M1	5.7446	0.0151	Reject
3	M1 does not granger cause GDP	9.3459	0.0023	Reject
	GDP does not granger cause M1	6.1559	0.0103	Reject
4	M1 does not granger cause GDP	5.6260	0.0187	Reject
	GDP does not granger cause M1	1.2794	0.3542	Do not reject
5	M1 does not granger cause GDP	29.092	0.0011	Reject
	GDP does not granger cause M1	2.4243	0.1767	Do not reject
6	M1 does not granger cause GDP	133.06	0.0075	Reject
	GDP does not granger cause M1	1.6703	0.4207	Do not reject

In the case of the UK, the positive granger cause between real money supply M1 and real GDP has been found also. This casual relationship is observed in six out of eight lags. Therefore, it means that simple increase in money in form of M1 has positive effect on GDP development.

Table. 6 Results of Granger causality between real GDP and real M1 in UK in before crisis period. Source: author's calculation.

UK - M1 - before crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
1	M1 does not granger cause GDP	1.7686	0.1936	Do not reject
	GDP does not granger cause M1	3.5852	0.0680	Do not reject
2	M1 does not granger cause GDP	6.1283	0.0064	Reject
	GDP does not granger cause M1	2.6447	0.0894	Do not reject
3	M1 does not granger cause GDP	3.8188	0.1601	Do not reject
	GDP does not granger cause M1	2.2434	0.1091	Do not reject
4	M1 does not granger cause GDP	3.3309	0.0292	Reject
	GDP does not granger cause M1	2.6510	0.0577	Do not reject
5	M1 does not granger cause GDP	1.1318	0.3793	Reject
	GDP does not granger cause M1	1.6030	0.2098	Do not reject
6	M1 does not granger cause GDP	2.8945	0.0444	Reject
	GDP does not granger cause M1	1.1682	0.3733	Do not reject
7	M1 does not granger cause GDP	4.6815	0.0097	Reject
	GDP does not granger cause M1	1.7727	0.1830	Do not reject
8	M1 does not granger cause GDP	5.0216	0.0132	Reject
	GDP does not granger cause M1	1.3809	0.3191	Do not reject

In the after crisis period in case of the UK, just two bidirectional relationships were found in first two lags. I wouldn't add any significance to this result, because it seems to be just irregular relationship.

Table. 7 Selected results of Granger causality between real GDP and real M1 in UK in after crisis period. Source: author's calculation.

UK - M1 - after crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
1	M1 does not granger cause GDP	4.4074	0.0110	Reject
	GDP does not granger cause M1	4.1730	0.0269	Reject
2	M1 does not granger cause GDP	6.1577	0.0121	Reject
	GDP does not granger cause M1	4.8705	0.0248	Reject

Complete results of all Granger cause testing for the EA and the UK and both for before and after crisis are noted in Appendix C at the end of this thesis.

4.4.3 Testing for Granger causality between real GDP and real M2

The equations for testing granger causality between real GDP and real money supply M2 have following form:

$$Real\ GDP_t = const + \sum_{i=1}^{j} \alpha_i Real\ GDP_{t-1} + \sum_{i=1}^{j} \beta_i\ Real\ M2_{t-1} \quad (10)$$

$$Real\ GDP_t = const + \sum_{i=1}^{j} \alpha_i Real\ M2_{t-1} + \sum_{i=1}^{j} \beta_i\ Real\ GDP_{t-1} \quad (11)$$

Testing for relationship between real GDP and real M2 in the euro area seems to have positive granger cause in first three lags in observed period before crisis and also in first two lags in after crisis period. According to obtained results it can be stated that increase in M2 has positive influence for growth in GDP in short period of time.

Table. 8 Selected results of Granger causality between real GDP and real M2 in EA in before crisis period. Source: author's calculation.

EA - M2 - before crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
1	M2 does not granger cause GDP	9.4165	0.0045	Reject
	GDP does not granger cause M2	0.049294	0.8258	Do not reject
2	M2 does not granger cause GDP	5.7899	0.0081	Reject
	GDP does not granger cause M2	0.046986	0.9542	Do not reject
3	M2 does not granger cause GDP	3.5580	0.0292	Reject
	GDP does not granger cause M2	1.7931	0.1754	Do not reject

Table. 9 Selected results of Granger causality between real GDP and real M2 in EA in after crisis period. Source: author's calculation.

EA - M2 - after crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
1	M2 does not granger cause GDP	4.7104	0.0444	Reject
	GDP does not granger cause M2	1.1806	0.2924	Do not reject
2	M2 does not granger cause GDP	2.8245	0.0332	Reject
	GDP does not granger cause M2	1.8608	0.1920	Do not reject

While testing casual relationship between real output and real money supply M2 in the UK, results find just two significant results in before crisis period in 6th and 8th lag observation. It seems that quantitative easing in form of money M2 doesn't have

such an effect like in the EA. Positive relationship in late lags observation could also mean, that market in the UK is waiting for reaction of the EA market.

Table. 10 Selected results of Granger causality between real GDP and real M2 in UK in before crisis period. Source: author's calculation.

UK - M2 – before crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
6	M2 does not granger cause GDP	2.5320	0.0476	Reject
	GDP does not granger cause M2	0.89717	0.5218	Do not reject
7	M2 does not granger cause GDP	1.8624	0.1642	Do not reject
	GDP does not granger cause M2	1.7444	0.1895	Do not reject
8	M2 does not granger cause GDP	2.8040	0.0329	Reject
	GDP does not granger cause M2	1.2502	0.3709	Do not reject

More significant results were obtained in after crisis observation, where positive relationship between real GDP and real M2 found four significance grange causes in 3rd to 6th lags. This results shows, that quantitative easing in form of money supply M2 in the UK had higher effect than in the EA.

Table. 11 Selected results of Granger causality between real GDP and real M2 in UK in after crisis period. Source: author's calculation.

UK - M2 - after crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
3	M2 does not granger cause GDP	6.3350	0.0094	Reject
	GDP does not granger cause M2	0.89065	0.4762	Do not reject
4	M2 does not granger cause GDP	3.4883	0.0425	Reject
	GDP does not granger cause M2	0.59492	0.6765	Do not reject
5	M2 does not granger cause GDP	4.0470	0.0156	Reject
	GDP does not granger cause M2	0.41874	0.8193	Do not reject
6	M2 does not granger cause GDP	33.920	0.0289	Reject
	GDP does not granger cause M2	0.38129	0.8481	Do not reject

All results of Granger cause of real GDP and real M2 can be found in their full form in Appendix C at the end of this thesis.

4.4.4 Testing for Granger causality between real GDP and RIR

Equation for Granger causality between real GDP and real interest rate is tested based on formulas below:

$$Real\ GDP_t = const + \sum_{i=1}^{j} \alpha_i Real\ GDP_{t-1} + \sum_{i=1}^{j} \beta_i\ RIR_{t-1} \quad (12)$$

$$Real\ GDP_t = const + \sum_{i=1}^{j} \alpha_i\ RIR_{t-1} + \sum_{i=1}^{j} \beta_i\ Real\ GDP_{t-1} \quad (13)$$

Selected results obtained from Granger causality testing for the euro area are listed in Table 12 below. Results show that there is a positive relationship between real GDP and RIR in first four lags in observed period before crisis. It means, that real interest rate has crucial effect on GDP growth. Other for lags in this model didn't show any significant relationship. Complete results are listed at the end of the thesis in Appendix C.

Table. 12 Selected results of Granger causality between real GDP and RIR in EA in before crisis period. Source: author's calculation.

EA - RIR - before crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
1	RIR does not granger cause GDP	15.550	0.0004	Reject
	GDP does not granger cause RIR	0.15610	0.6956	Do not reject
2	RIR does not granger cause GDP	9.3289	0.0008	Reject
	GDP does not granger cause RIR	0.68552	0.5124	Do not reject
3	RIR does not granger cause GDP	5.4081	0.0055	Reject
	GDP does not granger cause RIR	0.50529	0.6823	Do not reject
4	RIR does not granger cause GDP	2.9781	0.0429	Reject
	GDP does not granger cause RIR	0.13814	0.9663	Do not reject

Situation after crisis has totally opposite results than dataset before crisis. The dataset didn't show any casual relationship between real GDP and RIR. Therefore, it can be stated that interest rate is loosing its power as monetary instrument, when its value is close to zero.

According to results of Granger causality in Table 13 between variables for the UK dataset model, the positive relationship can be found in two lags in before crisis period. More accurate, the null hypothesis was rejected in 4th and 6th lag of the model. Because the development of RIR in the UK was similar with development in the EA,

it is possible to state that the UK market is waiting for reaction of the euro area market.

Table. 13 Selected results of Granger causality between real GDP and RIR in UK in before crisis period. Source: author's calculation.

UK - RIR - before crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
4	RIR does not granger cause GDP	1.6526	0.0085	Reject
	GDP does not granger cause RIR	0.63106	0.6458	Do not reject
5	RIR does not granger cause GDP	1.1413	0.3749	Do not reject
	GDP does not granger cause RIR	1.8481	0.1541	Do not reject
6	RIR does not granger cause GDP	1.7269	0.0127	Reject
	GDP does not granger cause RIR	2.1228	0.1111	Do not reject

Situation after crisis is totally the same as in case of the euro area. According to results obtained from Granger causality testing, there was no significant relationship between real GDP and RIR. Hence RIR fails in situations, when some external shocks hit the economy and there is a need for help to recover from this shock. All the other results connected with this model are listed at the end of the thesis in Appendix C.

4.4.5 Summary

In this part of the thesis casual relationship between real output, money supply in form of M1 and M2 and real interest rate was tested.

Testing for Granger causality shows that there is a connection between money supply and GDP. More specifically, quantitative easing looks like it could be a good tool to boost the economy. The euro area and the United Kingdom's GDP reacted similarly on increases both in M1 and M2. But closer look on numbers suggests that during the after crisis period in the UK the significant increase in M2 had higher effect than in case of the EA.

Results also indicate that RIR has a positive effect on growth of GDP in periods with normal conditions and no unexpected situations.

In case of the euro area the RIR had positive influence in the first four quarters and in later observations no other null hypothesis has been rejected. In the United Kingdom the first significant causality was found in fourth lag and then in sixth lag. Because the development of real interest rate was similar between the EA and the UK,

it is possible that markets first react to situation in the euro area and after that they react on situation in the United Kingdom.

Results from observations after the crisis didn't show any significant Granger-type causality between real output and real interest rate. This situation is closely connected with low levels of both short-term interest rates. This confirms fear of many economists from liquidity trap. Also as many studies describe, monetary policy is becoming ineffective in situations like this and it is very difficult to escape from this liquidity trap.

5 Conclusion

The diploma thesis "*Comparison of Monetary Policy of European Central Bank and Bank of England*" examined the effect of monetary policy strategies upon economic performance in the euro area and in the United Kingdom from several different angles. This thesis should provide answers to following research questions:

4. *What are the main differences between the euro area and the UK economy responsiveness to the monetary policy?*
5. *Do the euro area and the UK conduct similar tools of monetary policy?*
6. *Did the euro area and the UK used the same strategies to handle the situation during crisis and after crisis?*

As the results of this thesis show, both central banks were performing almost the same monetary regime before the crisis hit the market. This policy was inflation targeting. After the crisis emerged to the European market, the ECB kept the growth of price level stable, except for one short period of time. The Bank of England increased monetary base in order to decrease the unemployment and hence the inflation in the UK that have risen over the inflation target. This finding supports Philips theory about balance between unemployment and inflation.

This thesis also tried to verify if monetary rules could be used as guidelines for central banks, how to steer their short-term interest rates. The main disadvantage of monetary rules is that they are using economic data from the past and so central banks could just compare how markets responded on different steps in the past years. Results identified that the Taylor rule is more suitable for the EA and the Mankiw rule fits better for the UK situation. This finding was expected since the Mankiw rule is considering unemployment in its calculation and the Bank of England is more concerned about unemployment than the ECB. Nevertheless, all the monetary rules fail with their interpretation value after the crisis.

Research of responsiveness to changes in monetary aggregates M1 and M2 shows, that quantitative easing could be used as a tool to boost economy in the euro area. Positive causal relationship in sense of Granger causality was confirmed even in the after crisis period. On the other hand, short-term interest rate was effective just in period before the crisis. After the crisis there has been no impact of this monetary instrument.

Similar results have been obtained in time-series testing of the United Kingdoms's dataset. Quantitative easing seems to be an effective tool how to regulate economy.

Also short-term interest rate granger causes growth of GDP in the before crisis period. After the crisis period, no impact of this monetary instrument has been confirmed.

As Krugman (2010) stated, the situation of low level real interest rate seems to drag advanced countries into the liquidity trap, where monetary policy is becoming ineffective. The RIR is in such a low level that even another decrease wouldn't motivate consumers to spend more money.

According to findings of Granger causality testing, the responsiveness of the monetary policy strategy to changes in monetary aggregates M1 and M2 and changes in short-term interest rates shows, that both economies reacted to these changes and there are also differences between each other.

The main difference could be found in time needed for market to react on changes performed by the central banks. Results indicate that the euro area market is reacting almost immediately on monetary policy changes of the ECB and the UK's market is reacting with a delay almost one year on changes of the Bank of England. Therefore, it can be said that UK's market is waiting for reaction of the euro area market.

In connection with further monetary integration and upcoming referendum about BREXIT, the results imply that the monetary regime of the Bank of England can be considered as autonomous. Even though the reaction of market is taking more time and it is waiting for reaction from the ECB, it is affecting economic situation on its own market. Hence it can be said, that maintaining its own currency is still beneficial for the UK. On the other hand, results show close relationship between European and British economies and so this might be an argument why to stay as a member of the European Union

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Appendices

A Structural breaks

Figure A 1 – Chow test on GDP of EA. Source:Eurostat, author's calculation

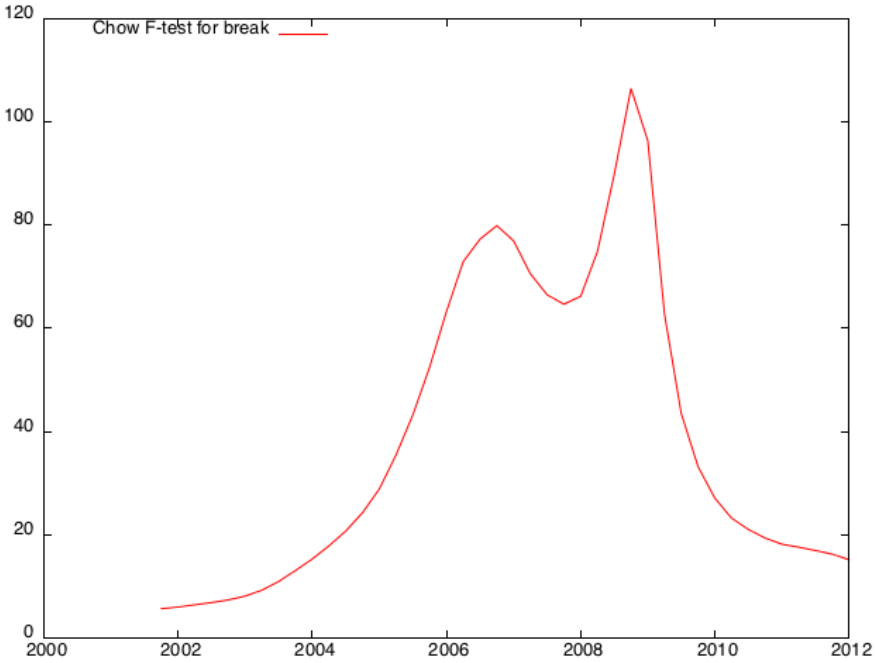
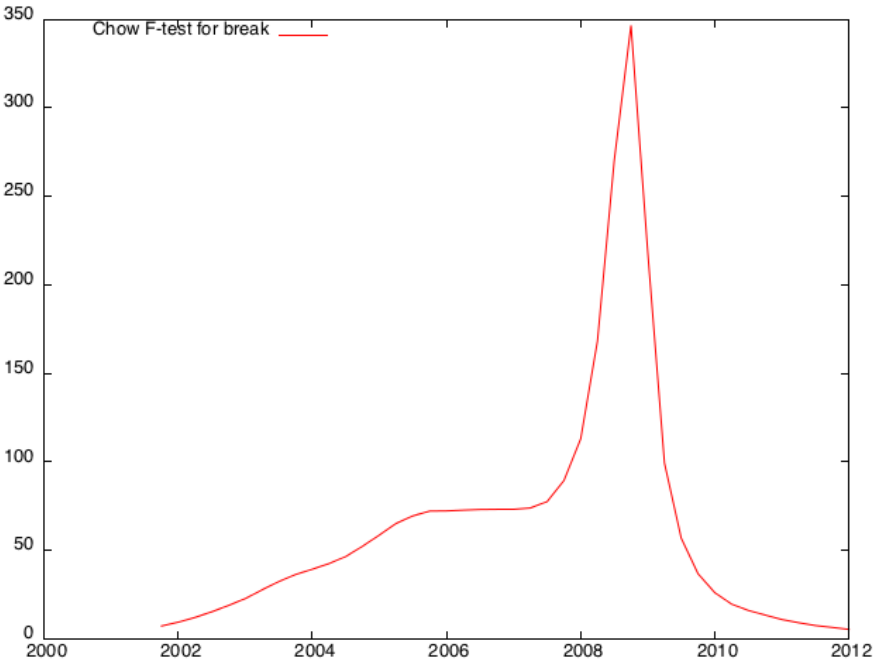


Figure A 2 – Chow test on GDP of UK. Source:Eurostat, author's calculation



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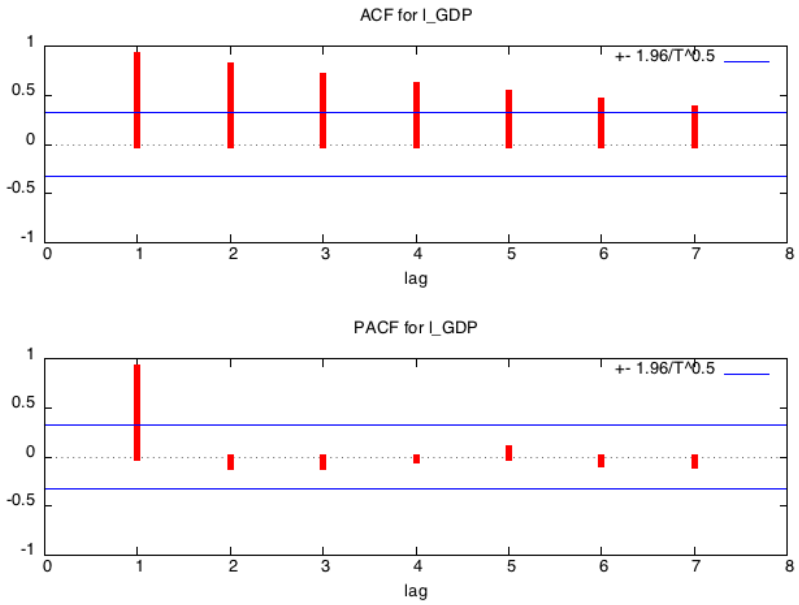
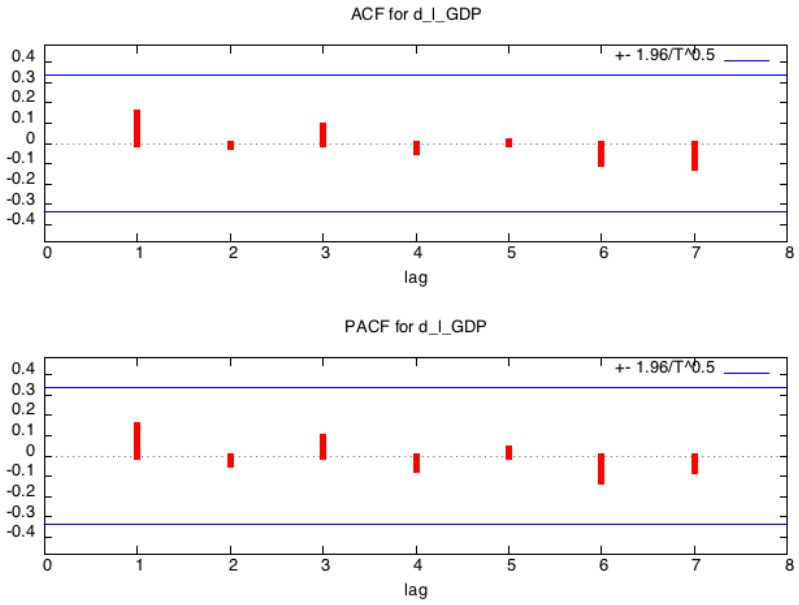
B Correlograms

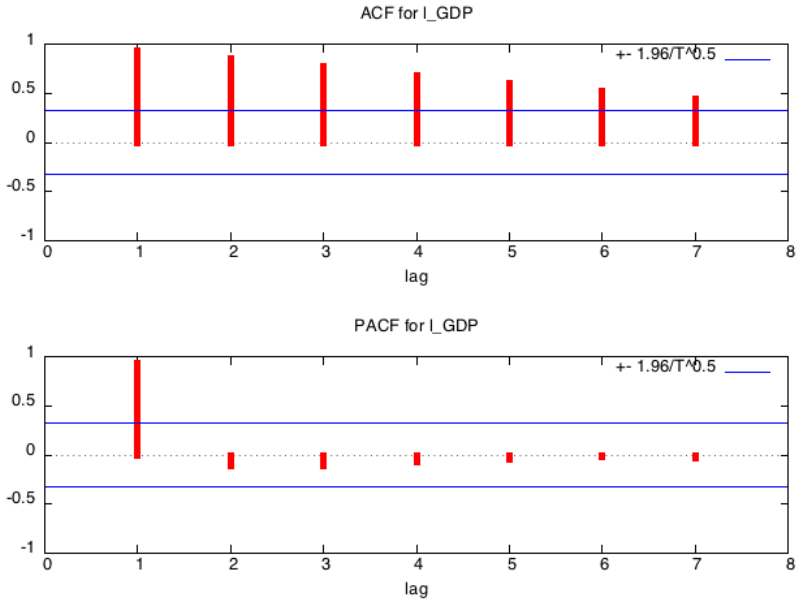
Correlogram 1 – base 10 log, EA_GDP_before_crisis. Source: Author's calculation



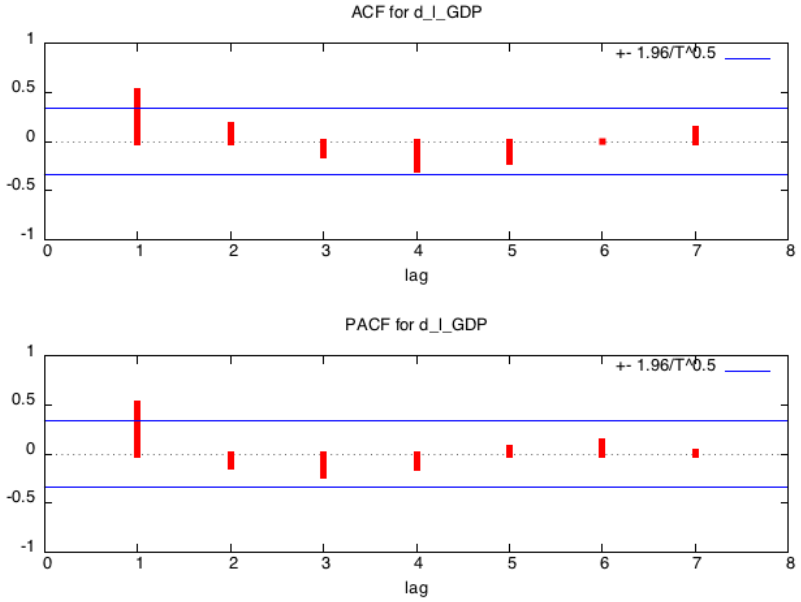
Correlogram 2 – first difference of base 10 log, EA_GDP_before_crisis. Source: Author's calculation



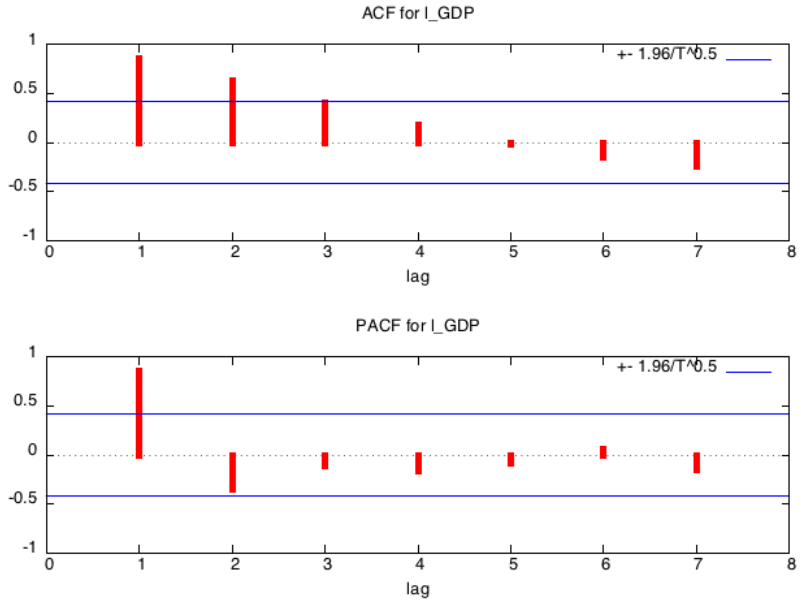
Correlogram 3 – base 10 log, UK_GDP_before_crisis. Source: Author's calculation



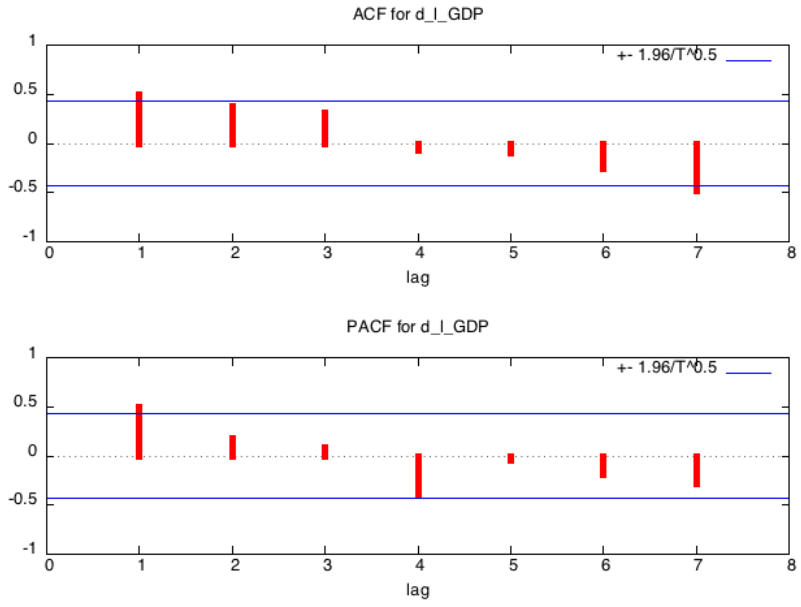
Correlogram 4 – first difference of base 10 log, UK_GDP_before_crisis. Source: Author's calculation



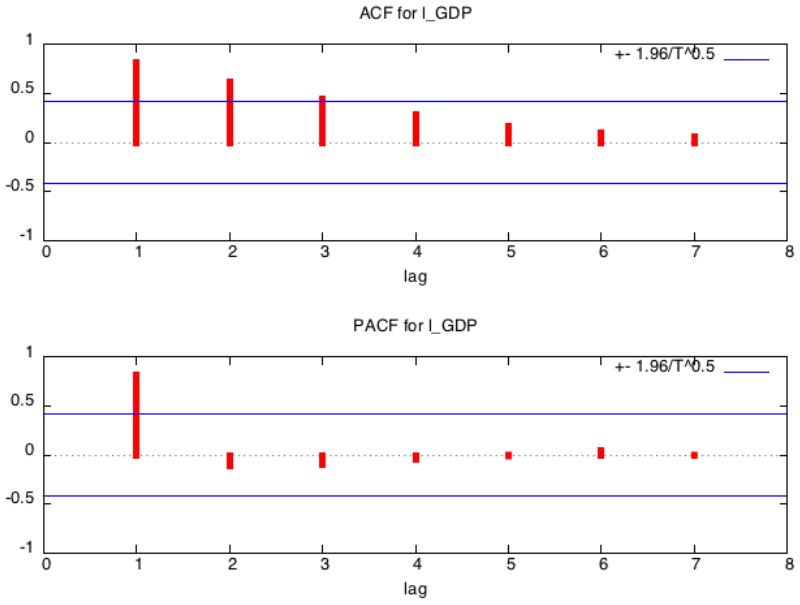
Correlogram 5 – base 10 log, EA_GDP_after_crisis. Source: Author's calculation



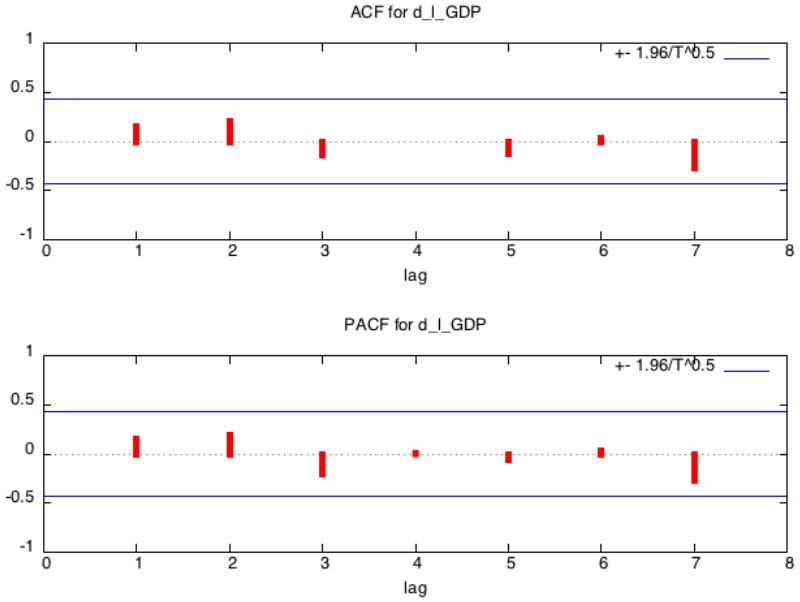
Correlogram 6 – first difference of base 10 log, EA_GDP_after_crisis. Source: Author's calculation



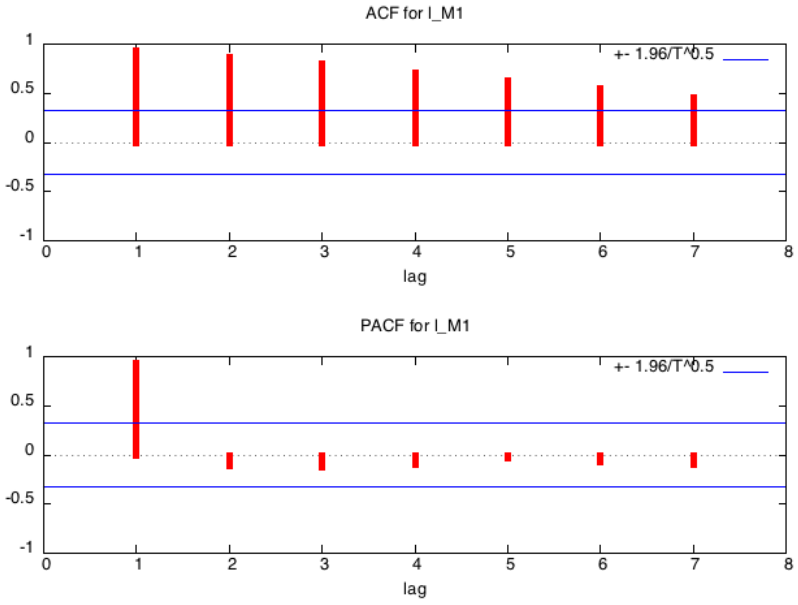
Correlogram 7 – base 10 log, UK_GDP_after_crisis. Source: Author's calculation



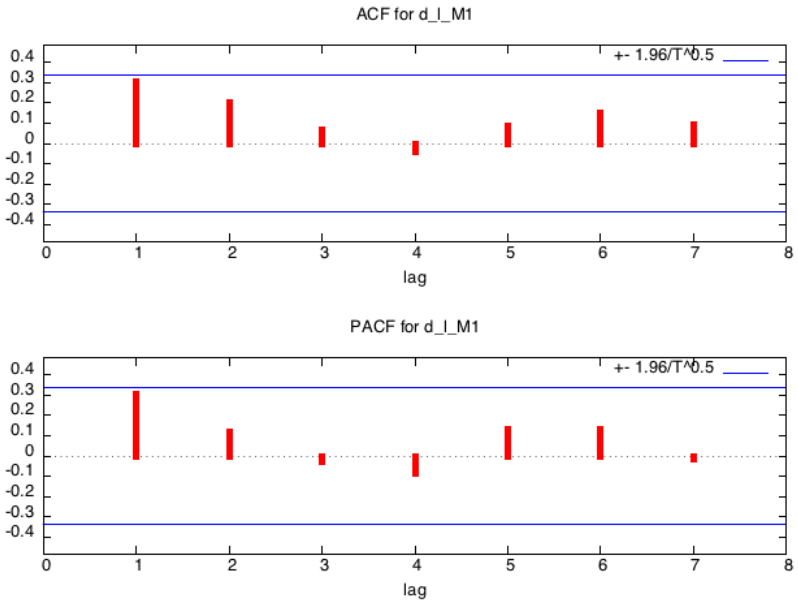
Correlogram 8 – first difference of base 10 log, UK_GDP_after_crisis. Source: Author's calculation



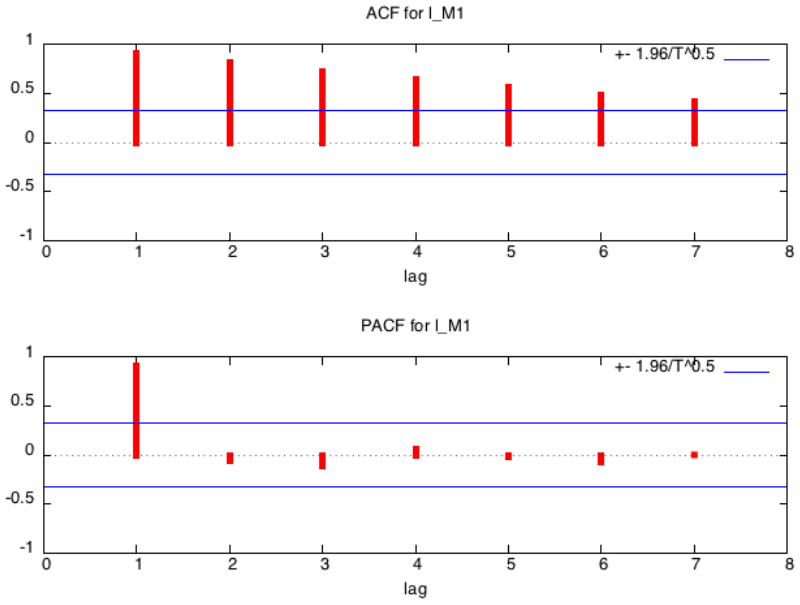
Correlogram 9 – base 10 log, EA_M1_before_crisis. Source: Author's calculation



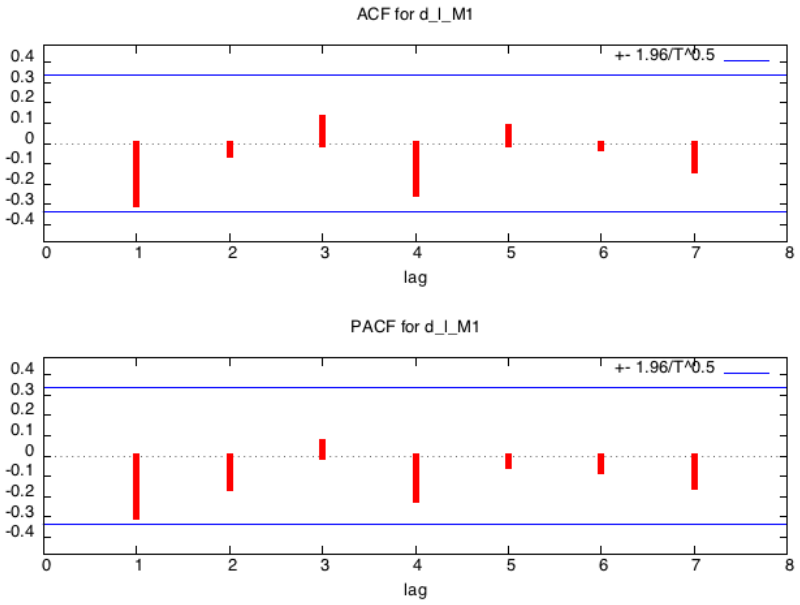
Correlogram 10 – first difference of base 10 log, EA_M1_before_crisis. Source: Author's calculation



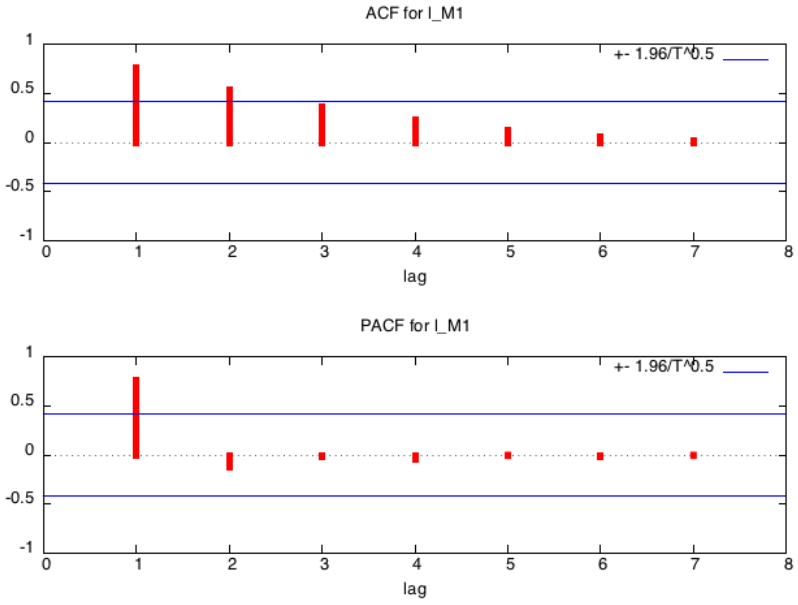
Correlogram 11 – base 10 log, UK_M1_before_crisis. Source: Author's calculation



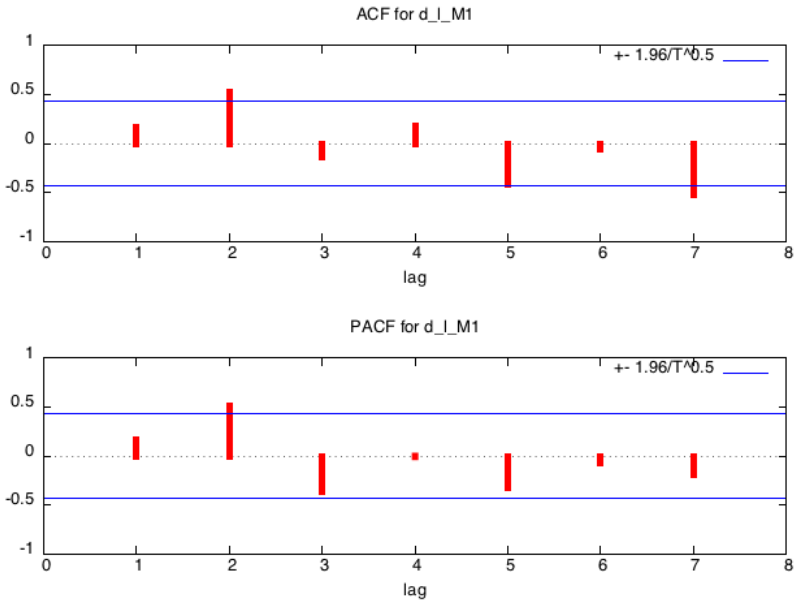
Correlogram 12 – first difference of base 10 log, UK_M1_before_crisis. Source: Author's calculation



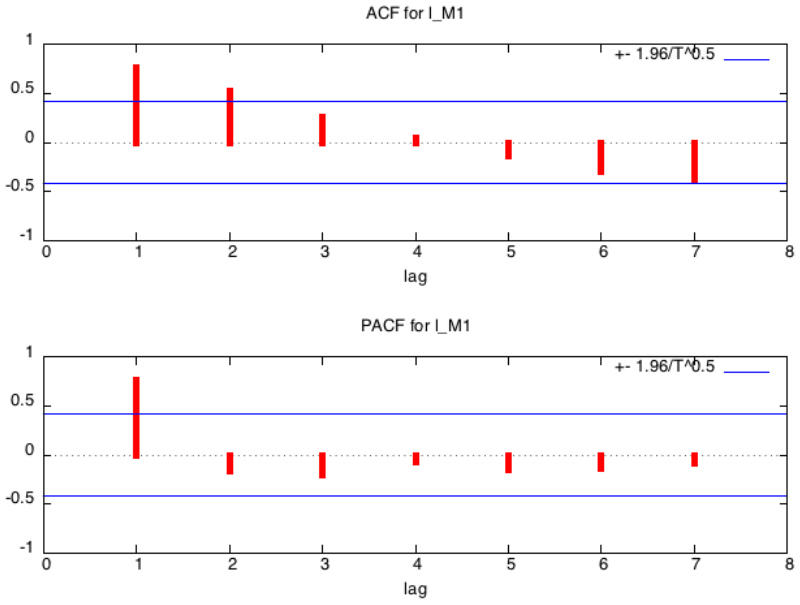
Correlogram 13 – base 10 log, EA_M1_after_crisis. Source: Author's calculation



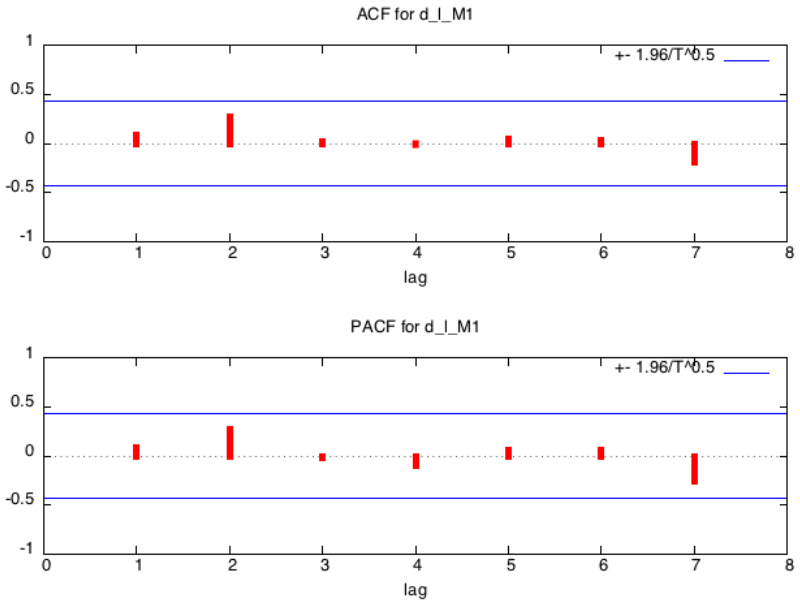
Correlogram 14 – first difference of base 10 log, EA_M1_after_crisis. Source: Author's calculation



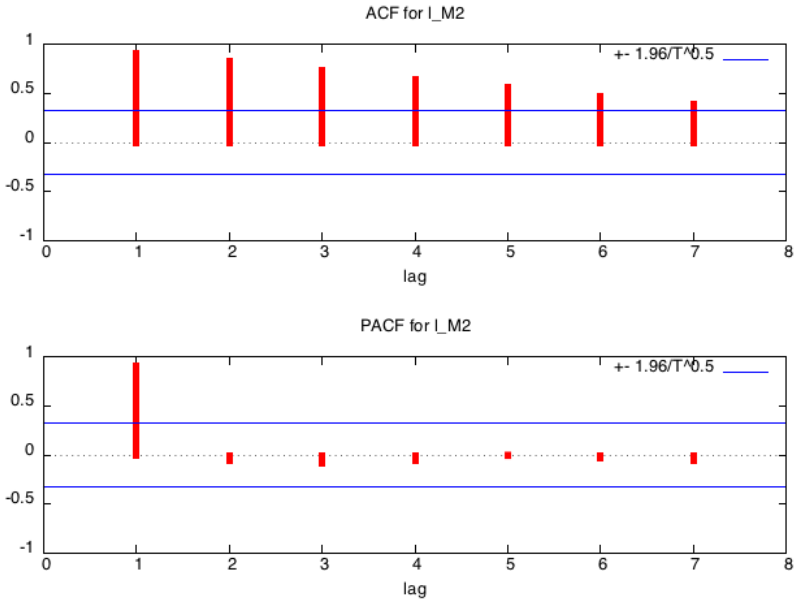
Correlogram 15 – base 10 log, UK_M1_after_crisis. Source: Author's calculation



Correlogram 16 – first difference of base 10 log, UK_M1_after_crisis. Source: Author's calculation



Correlogram 17 – base 10 log, EA_M2_before_crisis. Source: Author's calculation



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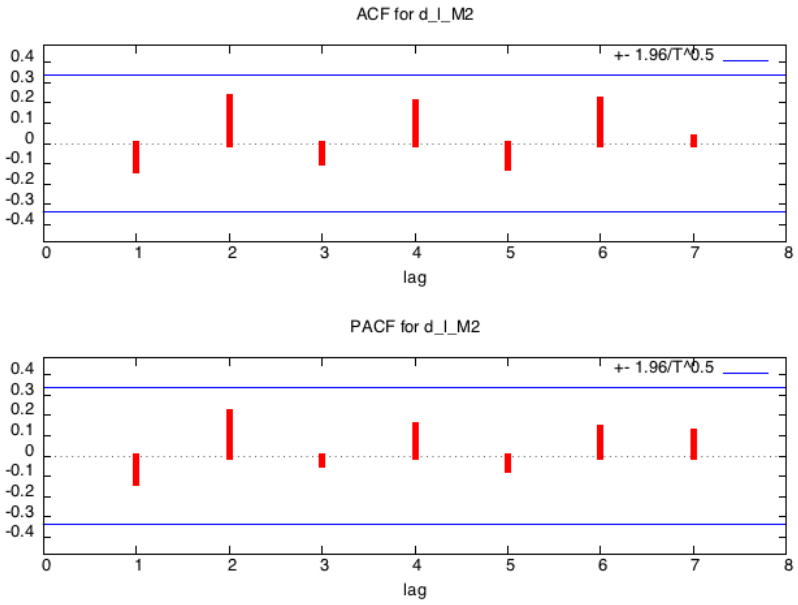
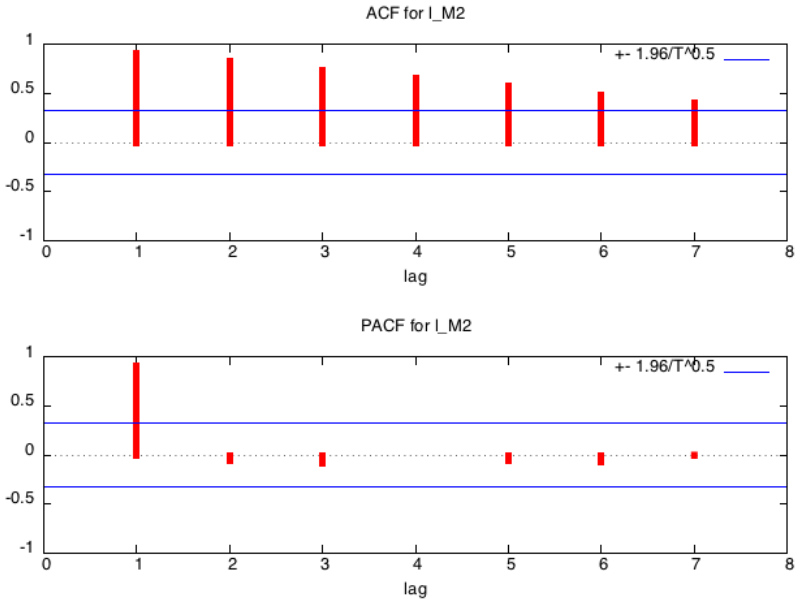
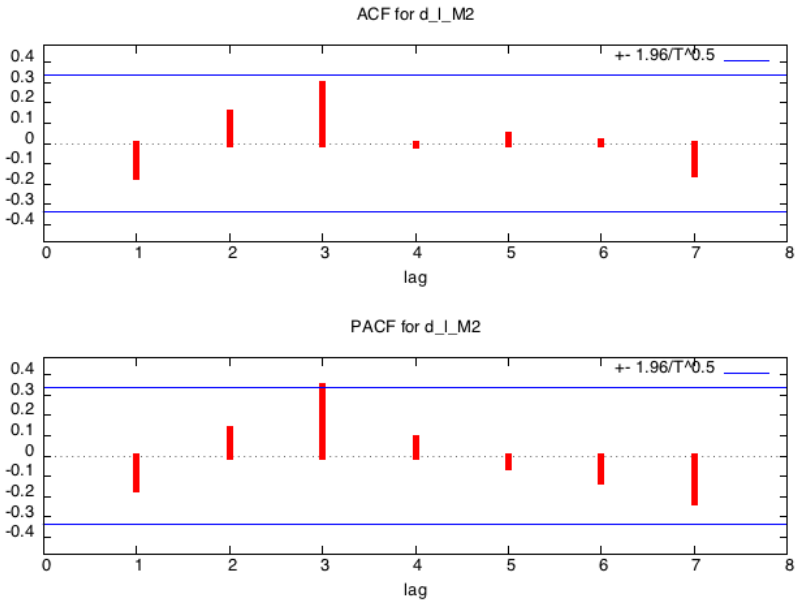


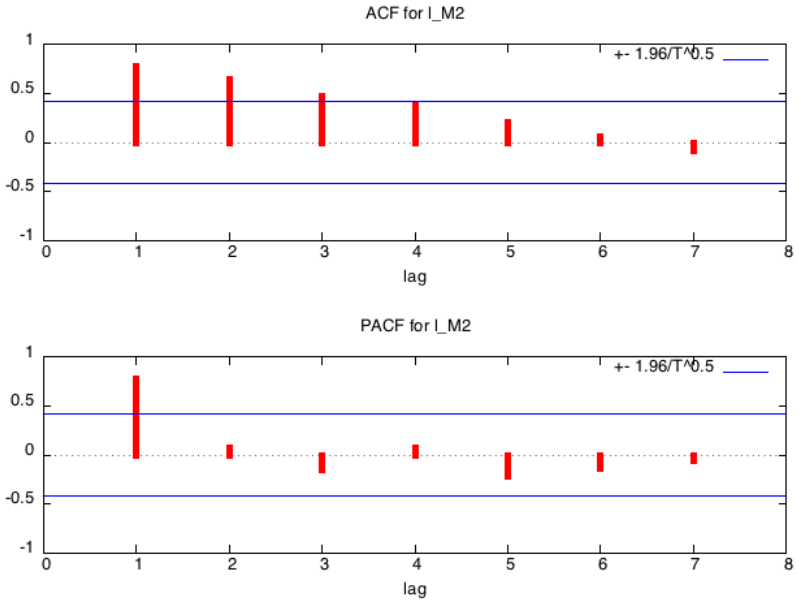
Correlogram 19 – base 10 log, UK_M2_before_crisis. Source: Author's calculation



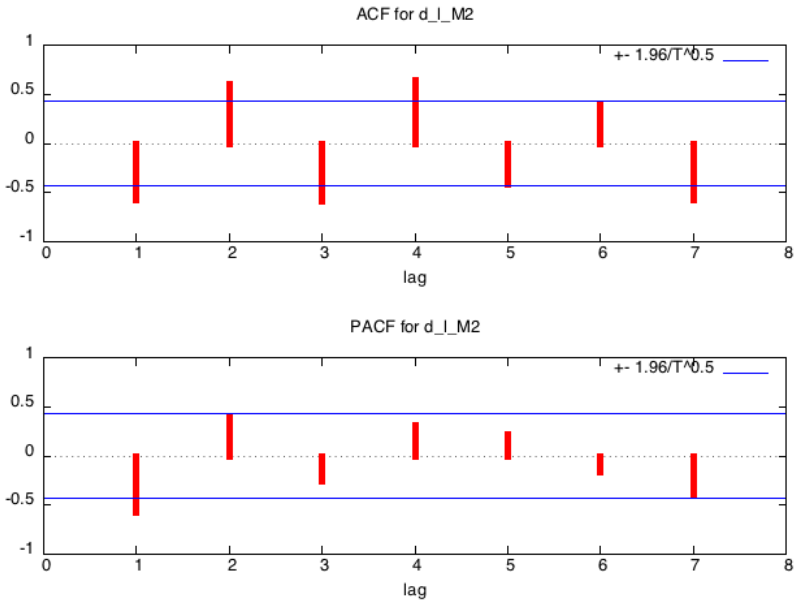
Correlogram 20 – first difference of base 10 log, UK_M2_before_crisis. Source: Author's calculation



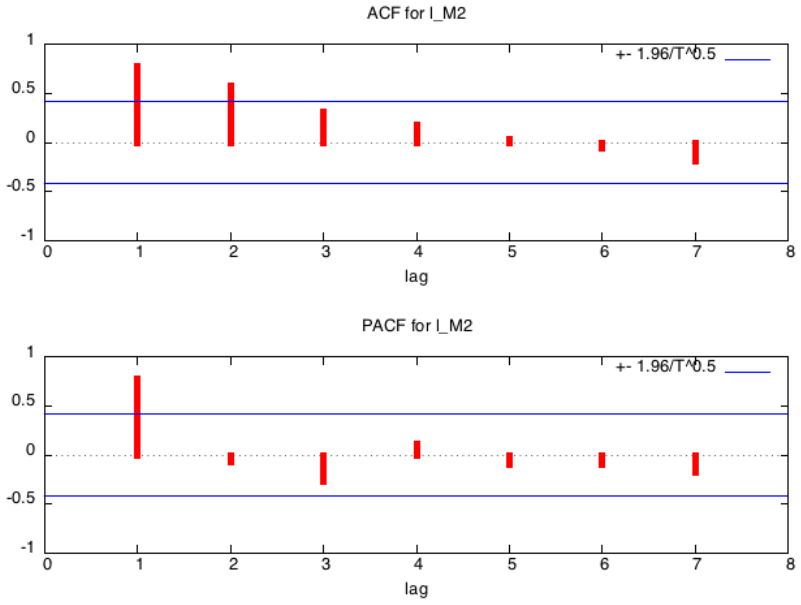
Correlogram 21 – base 10 log, EA_M2_after_crisis. Source: Author's calculation



Correlogram 22 – first difference of base 10 log, EA_M2_after_crisis. Source: Author's calculation



Correlogram 23 – base 10 log, UK_M2_after_crisis. Source: Author's calculation



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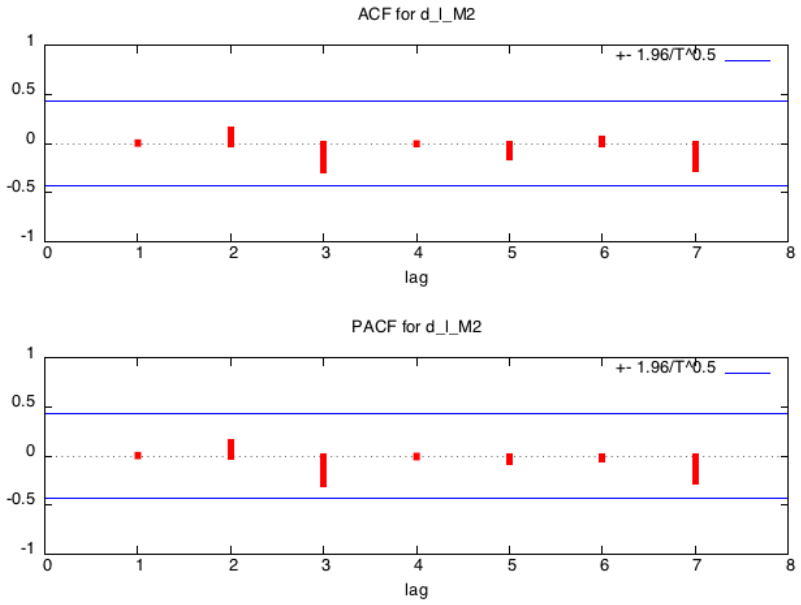
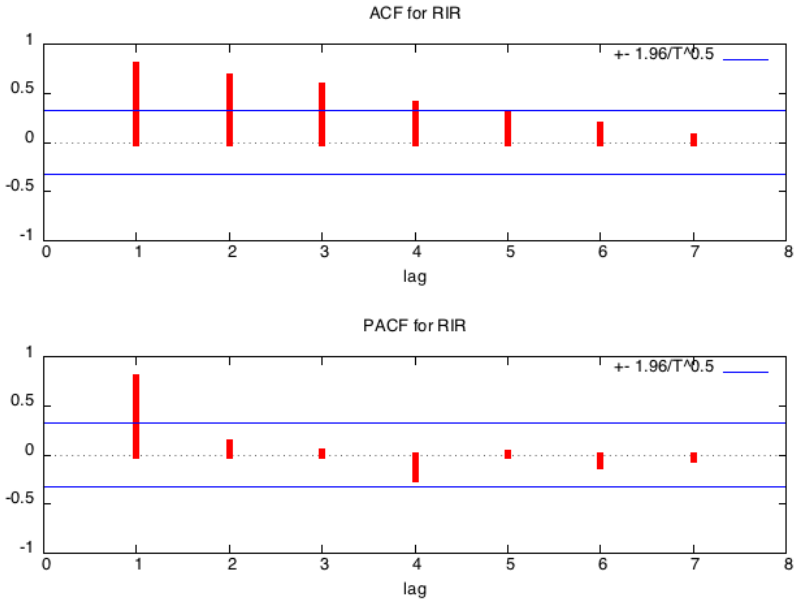
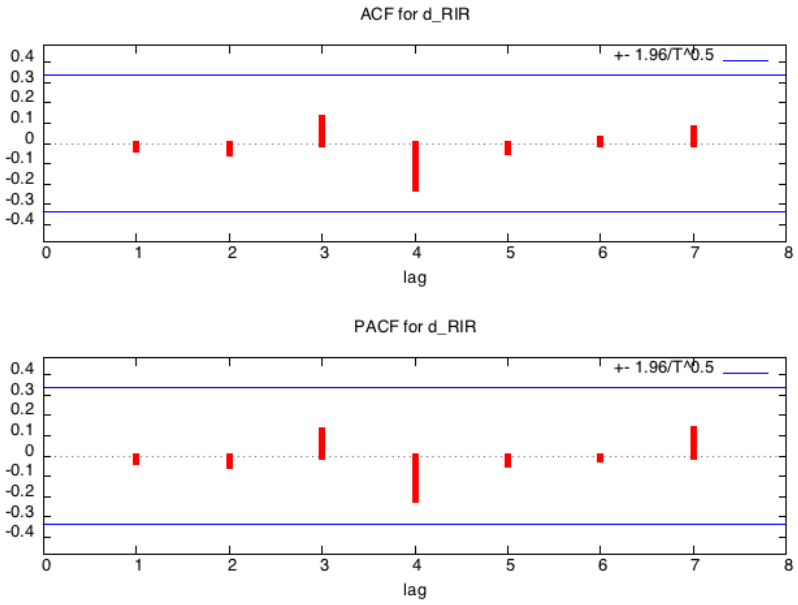


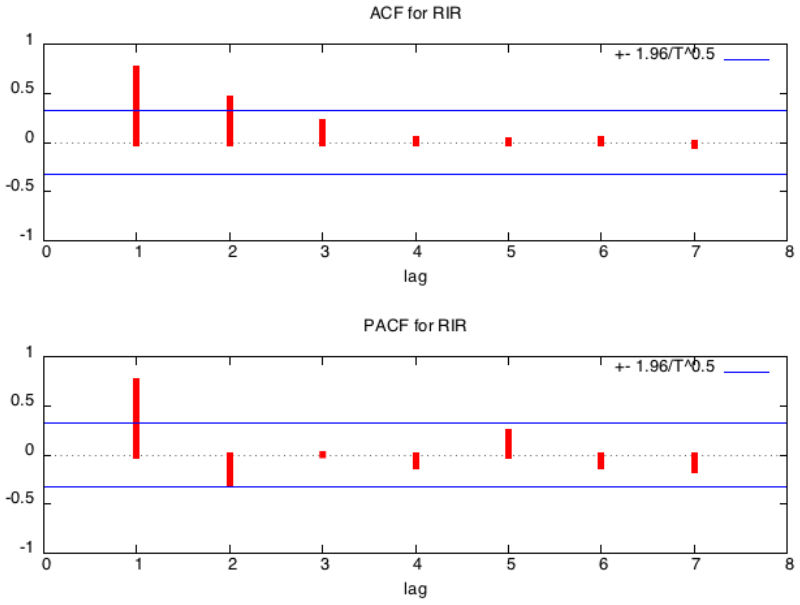
Correlogram 25 – base of EA_RIR_before_crisis. Source: Author's calculation



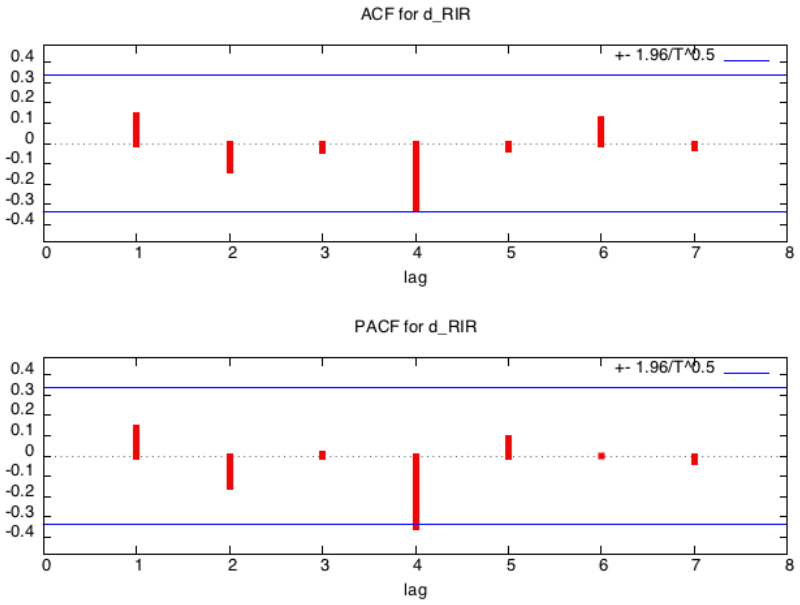
Correlogram 26 – first difference of EA_RIR_before_crisis. Source: Author's calculation



Correlogram 27 – base of UK_RIR_before_crisis. Source: Author's calculation



Correlogram 28 – first difference of UK_RIR_before_crisis. Source: Author's calculation



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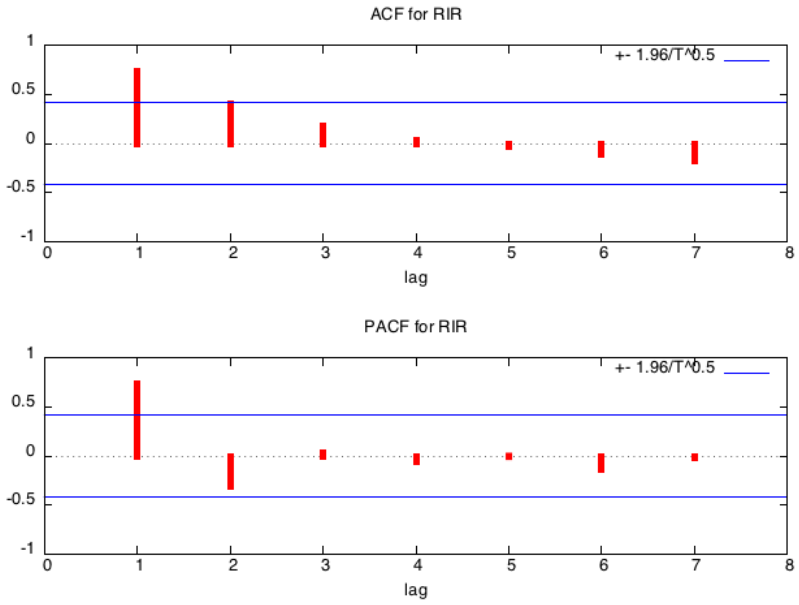
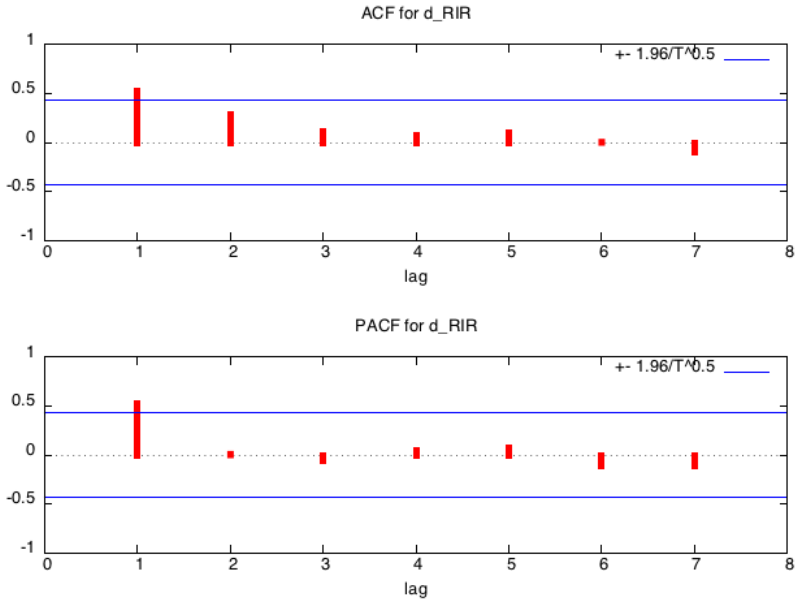


Correlogram 30 – first difference of EA_RIR_after_crisis. Source: Author's calculation



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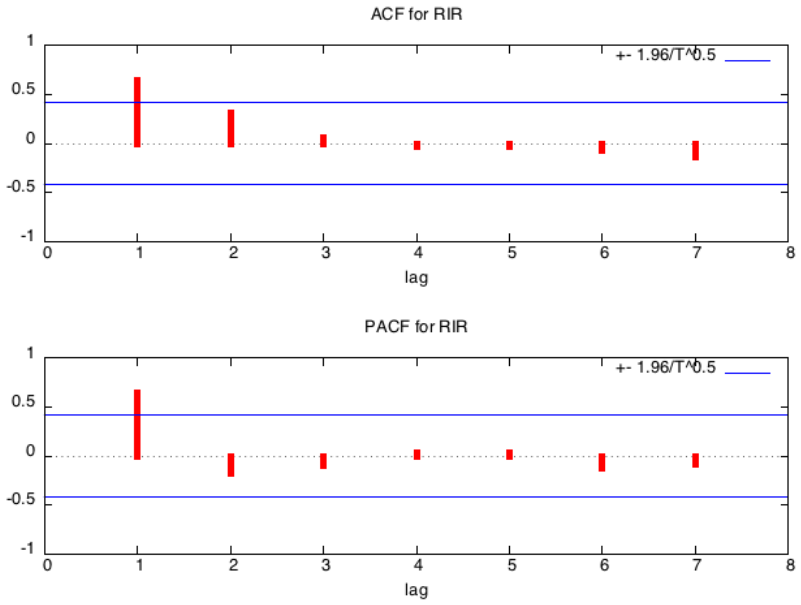
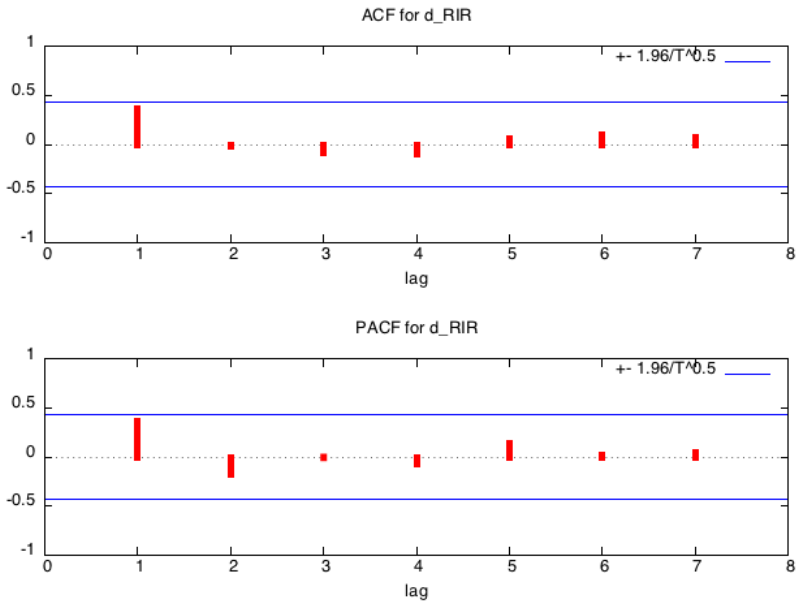


Correlogram 32 – first difference of UK_RIR_after_crisis. Source: Author's calculation



C Granger causality - results

Table C1 – Granger Causality test between real GDP and real Money Supply (M1) in EA in before crisis period. Source: Author's calculation

EA - M1 - before crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
1	M1 does not granger cause GDP	0.21672	0.6449	Do not reject
	GDP does not granger cause M1	0.46321	0.5013	Do not reject
2	M1 does not granger cause GDP	0.17604	0.8395	Do not reject
	GDP does not granger cause M1	0.30664	0.7384	Do not reject
3	M1 does not granger cause GDP	0.088084	0.9659	Do not reject
	GDP does not granger cause M1	0.26584	0.8493	Do not reject
4	M1 does not granger cause GDP	3.2805	0.0308	Reject
	GDP does not granger cause M1	0.76268	0.5613	Do not reject
5	M1 does not granger cause GDP	2.9368	0.0413	Reject
	GDP does not granger cause M1	0.63145	0.6783	Do not reject
6	M1 does not granger cause GDP	0.99178	0.4653	Do not reject
	GDP does not granger cause M1	0.70323	0.6518	Do not reject
7	M1 does not granger cause GDP	0.90174	0.5355	Do not reject
	GDP does not granger cause M1	0.73077	0.6507	Do not reject
8	M1 does not granger cause GDP	1.9915	0.1625	Do not reject
	GDP does not granger cause M1	0.75383	0.6495	Do not reject

Table C2 – Granger Causality test between real GDP and real Money Supply (M1) in EA in after crisis period. Source: Author's calculation

EA - M1 - after crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
1	M1 does not granger cause GDP	3.1503	0.0938	Do not reject
	GDP does not granger cause M1	8.1740	0.0109	Reject
2	M1 does not granger cause GDP	3.5788	0.0455	Reject
	GDP does not granger cause M1	5.7446	0.0151	Reject
3	M1 does not granger cause GDP	9.3459	0.0023	Reject
	GDP does not granger cause M1	6.1559	0.0103	Reject
4	M1 does not granger cause GDP	5.6260	0.0187	Reject
	GDP does not granger cause M1	1.2794	0.3542	Do not reject
5	M1 does not granger cause GDP	29.092	0.0011	Reject
	GDP does not granger cause M1	2.4243	0.1767	Do not reject
6	M1 does not granger cause GDP	133.06	0.0075	Reject
	GDP does not granger cause M1	1.6703	0.4207	Do not reject

Table C3 – Granger Causality test between real GDP and real Money Supply (M1) in UK in before crisis period. Source: Author's calculation

UK - M1 - before crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
1	M1 does not granger cause GDP	1.7686	0.1936	Do not reject
	GDP does not granger cause M1	3.5852	0.0680	Do not reject
2	M1 does not granger cause GDP	6.1283	0.0064	Reject
	GDP does not granger cause M1	2.6447	0.0894	Do not reject
3	M1 does not granger cause GDP	3.8188	0.1601	Do not reject
	GDP does not granger cause M1	2.2434	0.1091	Do not reject
4	M1 does not granger cause GDP	3.3309	0.0292	Reject
	GDP does not granger cause M1	2.6510	0.0577	Do not reject
5	M1 does not granger cause GDP	1.1318	0.3793	Reject
	GDP does not granger cause M1	1.6030	0.2098	Do not reject
6	M1 does not granger cause GDP	2.8945	0.0444	Reject
	GDP does not granger cause M1	1.1682	0.3733	Do not reject
7	M1 does not granger cause GDP	4.6815	0.0097	Reject
	GDP does not granger cause M1	1.7727	0.1830	Do not reject
8	M1 does not granger cause GDP	5.0216	0.0132	Reject
	GDP does not granger cause M1	1.3809	0.3191	Do not reject

Table C4 – Granger Causality test between real GDP and real Money Supply (M1) in UK in after crisis period. Source: Author's calculation

UK - M1 - after crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
1	M1 does not granger cause GDP	4.4074	0.0110	Reject
	GDP does not granger cause M1	4.1730	0.0269	Reject
2	M1 does not granger cause GDP	6.1577	0.0121	Reject
	GDP does not granger cause M1	4.8705	0.0248	Reject
3	M1 does not granger cause GDP	3.0965	0.0715	Do not reject
	GDP does not granger cause M1	2.6607	0.1000	Do not reject
4	M1 does not granger cause GDP	1.7598	0.2300	Do not reject
	GDP does not granger cause M1	1.7349	0.2350	Do not reject
5	M1 does not granger cause GDP	2.9332	0.1313	Do not reject
	GDP does not granger cause M1	3.7979	0.0847	Do not reject
6	M1 does not granger cause GDP	1.7135	0.4133	Do not reject
	GDP does not granger cause M1	4.9826	0.1766	Do not reject

Table C5 – Granger Causality test between real GDP and real Money Supply (M2) in EA in before crisis period. Source: Author's calculation

EA - M2 - before crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
1	M2 does not granger cause GDP	9.4165	0.0045	Reject
	GDP does not granger cause M2	0.049294	0.8258	Do not reject
2	M2 does not granger cause GDP	5.7899	0.0081	Reject
	GDP does not granger cause M2	0.046986	0.9542	Do not reject
3	M2 does not granger cause GDP	3.5580	0.0292	Reject
	GDP does not granger cause M2	1.7931	0.1754	Do not reject
4	M2 does not granger cause GDP	1.6145	0.2078	Do not reject
	GDP does not granger cause M2	0.078053	0.9882	Do not reject
5	M2 does not granger cause GDP	2.0068	0.1264	Do not reject
	GDP does not granger cause M2	0.27353	0.9217	Do not reject
6	M2 does not granger cause GDP	0.82063	0.5710	Do not reject
	GDP does not granger cause M2	0.27219	0.9414	Do not reject
7	M2 does not granger cause GDP	0.65448	0.7056	Do not reject
	GDP does not granger cause M2	0.80998	0.5957	Do not reject
8	M2 does not granger cause GDP	1.2453	0.3730	Do not reject
	GDP does not granger cause M2	0.46134	0.8552	Do not reject

Table C6 – Granger Causality test between real GDP and real Money Supply (M2) in EA in after crisis period. Source: Author's calculation

EA - M2 - after crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
1	M2 does not granger cause GDP	4.7104	0.0444	Reject
	GDP does not granger cause M2	1.1806	0.2924	Do not reject
2	M2 does not granger cause GDP	2.8245	0.0332	Reject
	GDP does not granger cause M2	1.8608	0.1920	Do not reject
3	M2 does not granger cause GDP	1.4954	0.2699	Do not reject
	GDP does not granger cause M2	2.3846	0.1249	Do not reject
4	M2 does not granger cause GDP	1.0687	0.4318	Do not reject
	GDP does not granger cause M2	3.3551	0.0682	Do not reject
5	M2 does not granger cause GDP	2.2058	0.2028	Do not reject
	GDP does not granger cause M2	2.8834	0.1350	Do not reject
6	M2 does not granger cause GDP	2.7289	0.2923	Do not reject
	GDP does not granger cause M2	1.7947	0.4002	Do not reject

Table C7 – Granger Causality test between real GDP and real Money Supply (M2) in UK in before crisis period. Source: Author's calculation

UK - M2 - before crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
1	M2 does not granger cause GDP	1.0532	0.3130	Do not reject
	GDP does not granger cause M2	0.89651	0.3513	Do not reject
2	M2 does not granger cause GDP	0.80984	0.4554	Do not reject
	GDP does not granger cause M2	0.46624	0.6323	Do not reject
3	M2 does not granger cause GDP	3.5580	0.7229	Do not reject
	GDP does not granger cause M2	0.67504	0.5758	Do not reject
4	M2 does not granger cause GDP	0.23805	0.9137	Do not reject
	GDP does not granger cause M2	0.47413	0.7542	Do not reject
5	M2 does not granger cause GDP	0.76668	0.5857	Do not reject
	GDP does not granger cause M2	0.83237	0.5435	Do not reject
6	M2 does not granger cause GDP	2.5320	0.0476	Reject
	GDP does not granger cause M2	0.89717	0.5218	Do not reject
7	M2 does not granger cause GDP	1.8624	0.1642	Do not reject
	GDP does not granger cause M2	1.7444	0.1895	Do not reject
8	M2 does not granger cause GDP	2.8040	0.0329	Reject
	GDP does not granger cause M2	1.2502	0.3709	Do not reject

Table C8 – Granger Causality test between real GDP and real Money Supply (M2) in UK in after crisis period. Source: Author's calculation

EA - M2 - after crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
1	M2 does not granger cause GDP	0.069358	0.7954	Do not reject
	GDP does not granger cause M2	2.1659	0.1594	Do not reject
2	M2 does not granger cause GDP	0.28453	0.7566	Do not reject
	GDP does not granger cause M2	1.3615	0.2882	Do not reject
3	M2 does not granger cause GDP	6.3350	0.0094	Reject
	GDP does not granger cause M2	0.89065	0.4762	Do not reject
4	M2 does not granger cause GDP	3.4883	0.0425	Reject
	GDP does not granger cause M2	0.59492	0.6765	Do not reject
5	M2 does not granger cause GDP	4.0470	0.0156	Reject
	GDP does not granger cause M2	0.41874	0.8193	Do not reject
6	M2 does not granger cause GDP	33.920	0.0289	Reject
	GDP does not granger cause M2	0.38129	0.8481	Do not reject

Table C9 – Granger Causality test between real GDP and real interest rate (RIR) in EA in before crisis period. Source: Author's calculation

EA - RIR - before crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
1	RIR does not granger cause GDP	15.550	0.0004	Reject
	GDP does not granger cause RIR	0.15610	0.6956	Do not reject
2	RIR does not granger cause GDP	9.3289	0.0008	Reject
	GDP does not granger cause RIR	0.68552	0.5124	Do not reject
3	RIR does not granger cause GDP	5.4081	0.0055	Reject
	GDP does not granger cause RIR	0.50529	0.6823	Do not reject
4	RIR does not granger cause GDP	2.9781	0.0429	Reject
	GDP does not granger cause RIR	0.13814	0.9663	Do not reject
5	RIR does not granger cause GDP	2.0650	0.1175	Do not reject
	GDP does not granger cause RIR	0.10664	0.9894	Do not reject
6	RIR does not granger cause GDP	1.8079	0.1648	Do not reject
	GDP does not granger cause RIR	0.12675	0.9911	Do not reject
7	RIR does not granger cause GDP	1.8977	0.1573	Do not reject
	GDP does not granger cause RIR	0.26875	0.9548	Do not reject
8	RIR does not granger cause GDP	0.25525	0.9662	Do not reject
	GDP does not granger cause RIR	0.73806	0.6604	Do not reject

Table C10 – Granger Causality test between real GDP and real interest rate (RIR) in EA in after crisis period. Source: Author's calculation

EA - RIR - after crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
1	RIR does not granger cause GDP	2.3120	0.1468	Do not reject
	GDP does not granger cause RIR	0.98170	0.3357	Do not reject
2	RIR does not granger cause GDP	0.56715	0.5796	Do not reject
	GDP does not granger cause RIR	3.0439	0.0799	Do not reject
3	RIR does not granger cause GDP	1.1769	0.3628	Do not reject
	GDP does not granger cause RIR	1.7790	0.2092	Do not reject
4	RIR does not granger cause GDP	0.65184	0.6417	Do not reject
	GDP does not granger cause RIR	1.6100	0.2623	Do not reject
5	RIR does not granger cause GDP	0.65438	0.6735	Do not reject
	GDP does not granger cause RIR	2.1338	0.2126	Do not reject
6	RIR does not granger cause GDP	0.74532	0.6701	Do not reject
	GDP does not granger cause RIR	1.8603	0.3901	Do not reject

Table C11 – Granger Causality test between real GDP and real interest rate (RIR) in UK in before crisis period. Source: Author's calculation

UK - RIR - before crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
1	RIR does not granger cause GDP	2.3972	0.1320	Do not reject
	GDP does not granger cause RIR	0.054776	0.8165	Do not reject
2	RIR does not granger cause GDP	1.5825	0.2239	Do not reject
	GDP does not granger cause RIR	0.14518	0.8655	Do not reject
3	RIR does not granger cause GDP	1.3495	0.2820	Do not reject
	GDP does not granger cause RIR	1.2620	0.3097	Do not reject
4	RIR does not granger cause GDP	1.6526	0.0085	Reject
	GDP does not granger cause RIR	0.63106	0.6458	Do not reject
5	RIR does not granger cause GDP	1.1413	0.3749	Do not reject
	GDP does not granger cause RIR	1.8481	0.1541	Do not reject
6	RIR does not granger cause GDP	1.7269	0.0127	Reject
	GDP does not granger cause RIR	2.1228	0.1111	Do not reject
7	RIR does not granger cause GDP	1.2475	0.3510	Do not reject
	GDP does not granger cause RIR	2.8173	0.0553	Do not reject
8	RIR does not granger cause GDP	0.98633	0.5023	Do not reject
	GDP does not granger cause RIR	1.3926	0.3149	Do not reject

Table C12 – Granger Causality test between real GDP and real interest rate (RIR) in UK in after crisis period. Source: Author's calculation

UK - RIR - after crisis				
Lag	**Null hypothesis**	**F-statistics**	**p-value**	**Decision**
1	RIR does not granger cause GDP	0.52035	0.4805	Do not reject
	GDP does not granger cause RIR	0.13098	0.7219	Do not reject
2	RIR does not granger cause GDP	2.4173	0.1254	Do not reject
	GDP does not granger cause RIR	0.18851	0.8303	Do not reject
3	RIR does not granger cause GDP	1.4730	0.2755	Do not reject
	GDP does not granger cause RIR	0.94170	0.4536	Do not reject
4	RIR does not granger cause GDP	1.2043	0.3799	Do not reject
	GDP does not granger cause RIR	2.0086	0.1862	Do not reject
5	RIR does not granger cause GDP	1.1207	0.4518	Do not reject
	GDP does not granger cause RIR	1.4933	0.3353	Do not reject
6	RIR does not granger cause GDP	0.75765	0.6651	Do not reject
	GDP does not granger cause RIR	0.49684	0.7856	Do not reject