Czech University of Life Sciences Prague
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Diploma Thesis

Central banks at times of financial crisis: Fed vs ECB

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DIPLOMA THESIS ASSIGNMENT

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Economics and Management

Thesis title

Central banks at times of financial crisis: Fed vs ECB

Objectives of thesis

The primary goal is to identify and compare the anti-crisis measures of the FED and the European Central Bank, and to evaluate their impact on the development of basic macroeconomic indicators in the EU and the United States.

Methodology

Two broad methods of reasoning as the deductive and inductive approaches will be applied. Graphical and numerical methods will be used to compare effects of anti-crisis measures on the basis of macroeconomic aggregates, such as basic statistical methods, prognosis, regression methods and comparison methods.

The proposed extent of the thesis
60 pages

Keywords
financial crisis, FED, European Central Bank, monetary policy, interest rate, reserve requirements, open market operations

Recommended information sources

Blinder, A. S.: Central Banking in Theory and Practice. Massachusetts Institute of Technology, 1998. ISBN 0-262-02439-X
Lloyd, T. B.: Money, Banking and Financial Markets. Thomson Learning, 2006. ISBN 0-324-32282-8
Mankiw, N. G.: Principles of Macroeconomics. Cengage Learning, 7e, 2014. ISBN-13:978-1-285-16591-2

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Prague on 27. 03. 2016

Decleration

I declare that I have worked on my diploma thesis titled Central banks at times of financial crisis: Fed vs ECB by myself and I have used only the sources mentioned at the end of the thesis. As the author of the diploma thesis, I declare that the thesis does not break copyrights of any third person.

In Prague on 28th March, 2016 _____

Anna Marcoňová

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I would like to thank to Ing. Petr Procházka, Msc, Ph.D. for his helpfulness, flexibility and moral support during my work on this thesis.

Centrální banky v době finanční krize: Fed vs ECB

Souhrn

Finanční krize 2007-2008, známá také jako globální finanční krize, byla nejhorší finanční krizí od Velké hospodářské krize ve třicátých letech minulého století. Krize začala ve Spojených státech, ale rychle se rozšířila po celém světě. Některé z největších světových finančních institucí padly, některé byly zachráněny státními záchrannými balíčky.

Obvykle je velice těžké, ba nemožné, finanční krizi předpovědět , protože jsou-li zpozorovány některé znaky přicházející krize, je většinou už příliš pozdě. Z tohoto důvodu by pozornost měla být zaměřena na včasné a přesné protikrizové opatření, které mohou zmírnit následky finanční krize a pomoci návratu ekonomiky do stavu před krizí. Tato diplomová práce se zabývá tím, co se dělo v průběhu krize a to ne pouze následky krize, ale především jak reagovaly některé ekonomické instituce. Pozornost je zaměřena na centrální banky, konkrétně na Federální rezervní systém a Evropskou centrální banku a kroky, které podnikly během globální finanční krize. Finanční krize je v této práci zkoumána z pohledu monetární politiky. Tato diplomová práce analyzuje jak nástroje monetární politiky, prováděné centrálními bankami, ovlivnily vývoj základních makroekonomických ukazatelů, především pak cenové hladiny.

Klíčová slova:

finanční krize, FED, Evropská centrální banka, monetární politika, úroková míra, cenová hladina, povinné minimální rezervy, operace na volném trhu

Central banks at times of financial crisis: Fed vs ECB

Summary

The financial crisis of 2007-2008, also known as Global Financial Crisis, was the worst financial crisis since the Great Depression in 1930s. It started in the United States, but it quickly expanded around the world. Some of the world's largest financial institutions have collapsed, some have been saved by the government's rescue packages.

It is usually very hard, even impossible to predict a financial crisis, because when some characteristics of upcoming crisis are spotted, it is already too late. Therefore, the attention should be focused on early and accurate anti-crisis measures, that can moderate the consequences of the financial crisis, and helping economy to return to pre-crisis level. This thesis is focused on what happened during the crisis, not only the consequences of the crisis, but primarily how an economic institutions reacted. The attention is directed to the central banks, namely the Federal Reserve System and the European Central Bank and their steps taken during the global financial crisis. The financial crisis is researched from a monetary policy point of view. This diploma thesis analyses how monetary policy tools performed by the central banks affected the development of the basic macroeconomic indicators, primarily the price level.

Keywords:

financial crisis, FED, European Central Bank, monetary policy, interest rate, price level, reserve requirements, open market operations

Table of Contents

1. Introduction

The financial crisis of 2007-2008, also known as Global Financial Crisis, was the worst financial crisis since the Great Depression in 1930s. It started in the United States, but it quickly expanded around the world. Some of the world's largest financial institutions have collapsed, some have been saved by the government's rescue packages.

As the global financial crisis significantly affected our lifes, the importance of having a solid understanding of crises in general and especially the financial crisis of 2007-08 is obvious. It is usually very hard, even impossible to predict a financial crisis, because when some characteristics of upcoming crisis are spotted, it is already too late. Therefore, the attention should be focused on early and accurate anti-crisis measures, that can moderate the consequences of the financial crisis, and helping economy to return to pre-crisis level. This thesis is focused on what happened during the crisis, not only the consequences of the crisis, but primarily how an economic institutions reacted. The attention will be directed to the central banks, namely the Federal Reserve System and the European Central Bank and their steps taken during the global financial crisis.

The diploma thesis is structured into 8 chapters. It begins with introduction, goals of the diploma thesis and methodology. Two main parts are literature review and analytical part, my own research. The literature review provides an analysis of the problem on the general level, basic theoretical knowledge about central banks in general and their roles, the Federal Reserve System and the European Central Bank, their structure and responsibilities. Literature review also includes the definition of monetary policy, its goals and tools, such as interest rates, reserve requirements, open market operations, foreign exchange operations. The most important part of the diploma thesis is analytical part, meaning my own research. This practical part provides a detailed definition of Global Financial Crisis, its inception and causes. The financial crisis is researched from a monetary policy point of view. The practical part analyses how monetary policy tools performed by the central banks affected the development of the basic macroeconomic indicators, mainly the price level. Regarding

inflation, there are many factors that determine the price level and these factors are not under the control of central banks. The practical part covers only central bank's monetary policy tools that influence the price level and other monetary policy goals.

The last parts of this diploma thesis are results and discussion where the outcomes of the research and recommendations will be provided. This diploma thesis also includes conclusion, references and supplement with some additional calculations.

2. Objectives and methodology

2.1 Objectives

The diploma thesis is a case study focused on anti-crisis measures used by central banks during the financial crisis of 2007-2008 in the United States and the European Union. The primary goal of the diploma thesis is to identify and compare the anti-crisis measures of the Federal Reserve System and the European Central Bank, and to evaluate their impact on the development of the price level in the European Union and the United States.

Since it is more suitable to the topic, an alternative to research hypothesis was chosen, which is the research question. After comparing the anti-crisis measures of the Federal Reserve System and the European Central Bank, the results and conclusion of the thesis will answer the research questions:

"Which central bank was more successful in influencing the development of basic economic indicators during the financial crisis of 2007-2008? The Federal Reserve System or the European Central Bank?"

"Which central bank had a larger impact on the development of the price level during the financial crisis?"

2.2 Methodology

In the diploma thesis, the graphical and the numerical methods are used to compare the effects of the anti-crisis measures on the basis of macroeconomic aggregates. Graphical methods depict the development of macroeconomic indicators. Moreover, statistical methods, prognosis, regression methods and comparison methods are used in the analytical part of the diploma thesis. Specifically, basic statistical methods such as computation of standard deviation and coefficient of variation are employed to evaluate activities of central banks that relate to interest rates. Regression methods, namely an ordinary least squared method, provides a tool for comparison of monetary policy tools and their impact on the inflation rate

changes. The development of the macroeconomic indicator was set as the dependent variable and the monetary policy tools were set as independent variables. The researcher analyzes how and in what extend the independent variables influenced dependent variable. This will be expressed and analyzed by means of flexibility. For all the analysis, data from the beginning of the year 2007 until the end of the year 2014 were included. For the inflation rate prognosis ARIMA model is used. ARIMA is a forecasting technique that projects the future values of a series based entirely on its own inertia.[1] The inflation rate prognosis will be made for the EU and the U.S. for the year 2016, thus monthly data from the beginning of the year 2007 until the end of the year 2015 will be included.

[1] Forecasting solutions [online] <http://www.forecastingsolutions.com/arima.html> [Accessed 17.2.2016]

3. Theoretical Part

3.1 The role of central banks

In almost every country, there is one major bank, which acts as a leader of monetary market. It is supervising, regulating and controlling financial institutions of the country, especially commercial banks. Such a bank is known as the central bank of the country. Most countries have some form of central bank serving as the principle authority for the nation's financial matters.[2] The central bank is a public institution . It is a non-business entity, meaning that its primary task is not to make profit. Central banks, the government authorities in charge of monetary policy, are one of the most important players in financial markets around the world. Its actions affect interest rates, the amount of credit, and the money supply, all of which have direct impacts not only on financial markets, but also on aggregate output and inflation.[3]

The central bank is nowadays primarily an agency for monetary policy, it also has important financial stability functions. It helps control and stabilize the monetary and banking system of the country. The structure of the roles and the responsibilities given, and the range of other functions are allocated vary between countries, but some general functions and responsibilities of central banks can be summarized.

- Issue notes and coins, meaning manage the production and distribution of the nation's currency.
- Promote the stability of the country's financial system

[2] Oanda.com: The role of central bank [online] <http://www.oanda.com/forex-trading/learn/intro-to-currency-trading/fundamental-analysis/central-bank> [Accessed 28.8.2015]

[3] MISHKIN, F. S.: *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.

- Implement a monetary policy that provides consistent growth, employment and price stability[4]
- Ensure stability of financial system, e.g. regulate bank lending and financial derivatives
- Lender of Last Resort to Commercial banks. If banks get into liquidity shortages then the Central Bank is able to lend the commercial bank sufficient funds to avoid the bank running short. This is a very important function as it helps maintain confidence in the banking system
- Lender of Last Resort to Government. Government borrowing is financed by selling bonds on the open market. If central bank intervene and buy some government bonds, then they can avoid 'liquidity shortages'. [5]
- Representation of the country

All activities are directed towards the central bank's primary task, thereby maintaining the monetary stability of the country. This could be accessed primarily by low inflation rate. The majority of central banks was created in the 20th century as public policy agencies for central banking functions.

3.2 Institutions and their structure

A central bank is an institution designed to oversee the banking system and regulate the quantity of money in the economy. There is a central bank in almost every country of the world, even though they are not all similar. There are some common features for all the central banks that have been mentioned in the previous chapter, on the other hand there are different approaches how these institutions work. The main differences are between a structure of central banks, in dependence on government of the given state, mandate, frequency of

[4] Oanda.com: The role of central bank [online] <http://www.oanda.com/forex-trading/learn/intro-to-currency-trading/fundamental-analysis/central-bank> [Accessed 28.8.2015]
[5] Economic help [online] <http://www.economicshelp.org/blog/3667/economics/what-is-the-function-of-a-central-bank/> [Accessed 28.8.2015]

meetings etc. What is important to know is how the Federal Reserve System and the European Central Bank work, who controls these institutions and determines their actions, what motivates their behavior, and last, but not least who holds the reins of power.

3.2.1 The Federal Reserve System

The Federal Reserve System, also known as the Federal Reserve, and informally as the Fed, is the central banking system of the United States.[6] Before the twentieth century, a major characteristic of American politics was the fear of centralized power, so the founders of the Fed recognized that if power was too concentrated in a particular city or state, an American central bank might not have enough public support to operate effectively. That is why they decided to set up a decentralized system with 12 Federal Reserve banks spread throughout the country. The Federal Reserve banks have been established as a quasi-private institutions overseen by directors from the private sector living in that district who represent views from that region.[7]

The Federal Reserve System was created by the Federal Reserve Act on December 23, 1913 and began operating in 1914. Over time, the structure of the Federal Reserve System has been evolved, and responsibilities have become broader. The Fed is an unusual mixture of public and private elements.[8] It was created, largely in response to a series of bank failures in 1907, which convinced Congress that an institution for assuring the health of the nation's banking system is needed.

The Federal Reserve has two major responsibilities. The first is to regulate commercial banks, ensure the health of the banking system and monitor each bank's financial condition. The Fed

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[6] MISHKIN, F. S. *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.

[7] MISHKIN, F. S. *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.

[8] Federal Reserve Education [online] <https://www.federalreserveeducation.org/about-the-fed/structure-and-functions> [Accessed 29.8.2015]

is also the bank's bank, which means that it provides loans to commercial banks to maintain stability in the banking system. Moreover, it acts as a lender of last resort, meaning it is a lender to those who cannot borrow anywhere else, for instance financially troubled banks that do not have required amount of cash.[9]

The second and more important job of the Federal Reserve is to control the quantity of money that is made available in the economy, called the money supply. The Fed ensures the setting of the money supply by policymakers in the central bank. At the Federal Reserve, monetary policy is made by the Federal Open Market Committee (FOMC). The FOMC meets about every six weeks in Washington, D.C., to discuss the condition of the economy and consider changes in monetary policy.[10] The FOMC consists of seven members of the board of governors and five of the twelve regional bank presidents. All twelve presidents of regional bank attend meetings of the FOMC, even though only five has a right to vote. The one who always gets a vote is the president of New York Fed, since New York is the traditional financial center of the U.S. economy. Through the decisions of the FOMC, the Fed has the power to increase or decrease the number of dollars in the economy.[11]

The Structure of the Federal Reserve System

The Federal Reserve System include the following entities: the Federal Reserve banks, the Board of Governors of the Federal Reserve System, the Federal Open Market Committee (FOMC), the Federal Advisory Council, and around 4,800 member commercial banks.[12]

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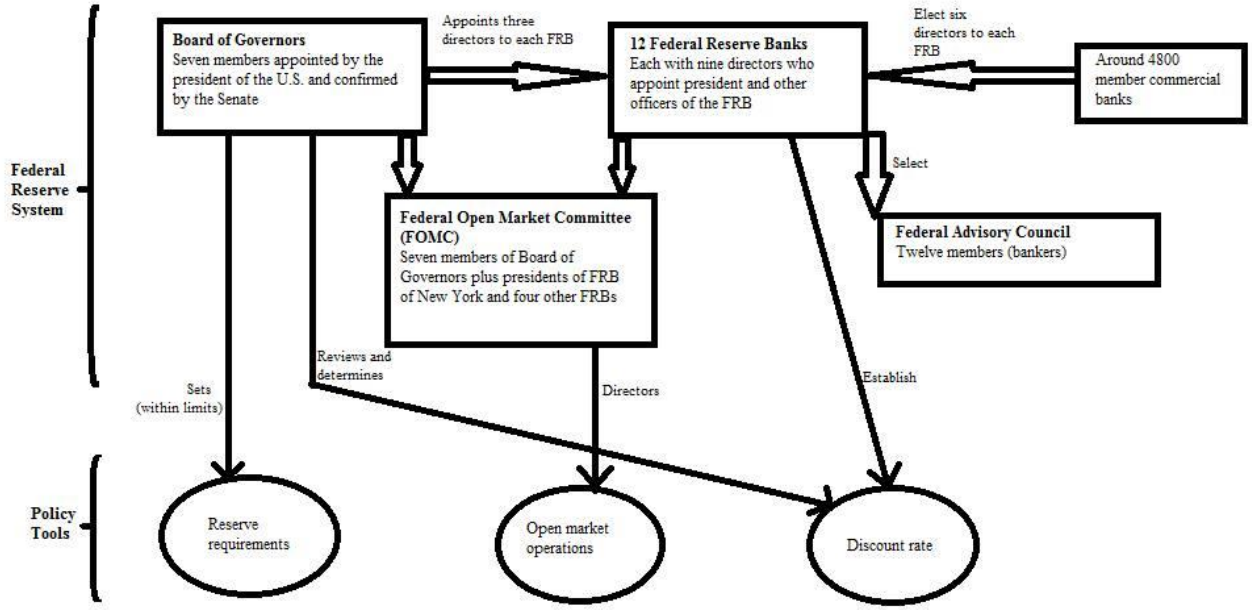
[9] MISHKIN, F. S. *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.

[10] MANKIW, N. G.: *Principles of Macroeconomics*. Cengage Learning, 7e, 2014. ISBN-13:978-1-285-16591-2

[11] MANKIW, N. G.: *Principles of Macroeconomics*. Cengage Learning, 7e, 2014. ISBN-13:978-1-285-16591-2

[12] Federal Reserve Education [online] <https://www.federalreserveeducation.org/about-the-fed/structure-and-functions> [Accessed 29.8.2015]

Figure 1: Formal structure and allocation of policy tools in the Federal Reserve



Source: Mishkin, F.: The Economics of Money, Banking and Financial Markets

Federal Reserve Banks are located in 12 districts across the United States and each of them are quasi-public, meaning part is public and part is private. The Federal Reserve banks are owned by the commercial banks in the district that are members of the Fed. These commercial banks buy stock in the Federal Reserve bank, which is a membership requirement. The member banks elect six directors for the district bank and three more are appointed by the Board of Governors. The directors could be professional bankers, prominent leaders from industry, labor, agriculture, or the consumer sector. Together, these nine directors appoint the president of the bank.[13] All member banks hold stock in Reserve Banks and receive dividends. Unlike stockholders in a public company, banks cannot sell or trade their Fed stock. Reserve Banks interact directly with the banks in their Districts through examinations and financial services and bring important regional perspectives that help the entire Federal Reserve System

[13] MISHKIN, F. S. *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.

do its job more effectively.[14] The 12 Federal Reserve banks have many functions such as issue new currency, clear checks or provide loans to commercial banks. But from the financial crisis point of view, the most important is their involvement in the monetary policy of the U.S. They decide which banks can obtain discount loans from the Fed, they establish the discount rate and above all, five of the twelve bank presidents have a vote in the Federal Open Market Committee, which directs open market operations.[15]

The Federal Reserve System is run by its ***Board of Governors***, which has seven members appointed by the president and confirmed by the Senate. The governors have fourteen-year terms, they are given long terms to provide them independence from short-term political pressures when they formulate monetary policy.[16] The most important member of the board of governors is the chairman, who is appointed by the president of the United States for a four-year term and the chairman of the Fed is currently Janet Yellen[17], who was named to the Fed job by President Barack Obama in 2014. The chairman directs the Fed staff, presides over board meetings, and testifies regularly about Fed policy in front of congressional committees.[18] In terms of monetary policy, the Board of Governors sets reserve requirements, within limits imposed by legislation, and effectively controls the discount rate. It also sets the salary of the president and other officers and reviews each Federal Reserve bank's budget. Moreover, the Board has some bank regulatory functions, it approves bank mergers and applications for new activities or supervises the activities of foreign banks in the United States.[19]

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[14] Federal Reserve Education [online] <https://www.federalreserveeducation.org/about-the-fed/structure-and-functions> [Accessed 8.9.2015]
[15] MISHKIN, F. S. *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.
[16] MANKIW, N. G.: *Principles of Macroeconomics*. Cengage Learning, 7e, 2014. ISBN-13:978-1-285-16591-2
[17] Board of Governors of the Federal Reserve System, *Board members* [online] <http://www.federalreserve.gov/aboutthefed/bios/board/yellen.htm> [Accessed 6.9.2015]
[18] MANKIW, N. G.: *Principles of Macroeconomics*. Cengage Learning, 7e, 2014. ISBN-13:978-1-285-16591-2
[19] MISHKIN, F. S. *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.

The Federal Open Market Committee is responsible for the formulation of a policy designed to promote stable prices and economic growth.[20] It consists of the president of the Federal Reserve Bank of New York, the presidents of four other Federal Reserve banks and the seven members of the Board of Governors. The chairman of the Board of Governors is also the chairman of the FOMC. Among the responsibilities of the committee is to influence the monetary base by making decisions regarding the conduct of open market operations. As for controlling the money supply, these operations are the most significant policy tool that the Fed has.[21] Therefore, the FOMC is the essential point for policymaking in the Federal Reserve System. Decisions regarding these policy tools are made in the FOMC, even though the committee does not actually set the discount rate and reserve requirements. After the decision making, the final part of the process is ensured by the Federal Reserve Bank of New York, which then actually carries out securities purchases or sales. The FOMC is an example of the interdependence built into the Fed's structure, since it combines the expertise of the Board of Governors and the 12 Reserve Banks and regional input from Reserve Bank directors and advisory groups, which brings the private sector perspective to the FOMC and provides grassroots input for monetary policy decisions.[22]

All ***national banks*** are required to be members of the Federal Reserve System and commercial banks can choose whether they want to be a member of the Fed or not. Currently, one third of commercial banks in the U.S. are members of the Federal Reserve System.

3.2.2 The European Central Bank

There is one independent central bank that oversees not just one economy, but 27 of them. It is the European Central Bank, which is located in Frankfurt, Germany. The Central Bank operates as the main central bank for all European Union members. The European Central Bank and the European System of Central Banks (ESCB) were established by the Maastricht

[20] Federal Reserve Education [online] <https://www.federalreserveeducation.org/about-the-fed/structure-and-functions> [Accessed 8.9.2015]

[21] Federal Reserve Education [online] <https://www.federalreserveeducation.org/about-the-fed/structure-and-functions> [Accessed 8.9.2015]

[22] Federal Reserve Education [online] <https://www.federalreserveeducation.org/about-the-fed/structure-and-functions> [Accessed 8.9.2015]

Treaty and began operation in January 1999.[23] The system of central banks in each country has a similar role as the Federal Reserve banks.

The ECB is not owned or supported by any individual government; rather it is a private institution, endowed with its position by the European Union.[24] The European Central Bank consists of three main bodies, which are the ***governing council***, which formulates the monetary policy; the ***executive board***, which implements the decisions of the central bank, and the ***general council***, which carries out decisions with all the national central banks of the European Union. The ECB is considered to be the most independent central bank than any other one in the world because its charter cannot be changed by legislation. It can be changed only by revision of the Maastricht Treaty, a difficult process, because all signatories would have to agree.[25]

The national central banks of all member states of the EU, also the European Central Bank are parts of the European System of Central Banks. According to Article 105 of the Maastricht Treaty "the primary objective of the ECB shall be to maintain price stability" and that "without prejudice to the objective of price stability, the ECB shall support the general economic policies in the Community". This mandate is in contrast to the U.S. Federal Reserve, which has a multiple mandate of price stability, full employment, and moderate long-term interest rates.[26] In the Maastricht Treaty, no provision of acting as a lender of last resort is included, nor does the European Central Bank have supervisory powers over European banks.

The structure of the ECB

The Governing Council is the main decision-making body of the European Central Bank. It includes six members of the Executive Board and nineteen governors of the national central

[23] FOUKAL, R.: *The European Central Bank — History, Structure, and the Decision Making Process* [online] <https://www.hitpages.com/doc/5990315441782784/1> [Accessed 20.11.2015]
[24] FOUKAL, R.: *The European Central Bank — History, Structure, and the Decision Making Process* [online] <https://www.hitpages.com/doc/5990315441782784/1> [Accessed 20.11.2015]
[25] MISHKIN, F. S. *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.
[26] DOMINGUEZ, K.: *The European Central Bank, the Euro, and Global Financial Markets*. Journal of Economic Perspectives – Volume 20, Number 4 – Fall 2006.

banks[27]. The Governing Council defines Euro Zone monetary policy and fixes the interest rates at which commercial banks can borrow from the ECB. The main responsibility of the Council is to adopt the guidelines and take the decisions necessary to ensure the continued performance of the tasks of the Euro-system.[28]

The main role of ***the Executive Board*** is to implement the monetary policy of the ECB and conduct the day-to-day business of the ECB. The board contains the President of the ECB Mario Draghi, the Vice-President and four members that are appointed on the basis of professional merit, monetary and banking experience. All members are appointed by the European Council.[29]

The General Council includes the President and Vice-President of the European Central Bank, plus the governors of the national central banks of the 28 EU Member States. The main roles of the General Council are to report on convergence, the reporting activities, collecting statistical data and working as an advisory body of the ECB.[30]

To sum up all three decisions making bodies, governing council formulates, executive board implements, and general council applies the monetary policy in the all Euro Zone states.[31]

The primary goal of the European Central Bank is price stability and all the monetary policy instruments are used with respect to this goal. The ECB does not have to report to any political body, elected or otherwise and it is not formally oversight by any EU institution. Among the elemental tasks of the ECB belong conducting foreign exchange operations, defining and

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[27] European Central Bank, *Governing Council* [online] <https://www.ecb.europa.eu/ecb/orga/decisions/govc/html/index.en.html> [Accessed 13.9.2015]

[28] European Parliament [online] <http://www.europarl.europa.eu/atyourservice/en/displayFtu.html?ftuId=FTU_1.3.11.html> [Accessed 15.9.2015]

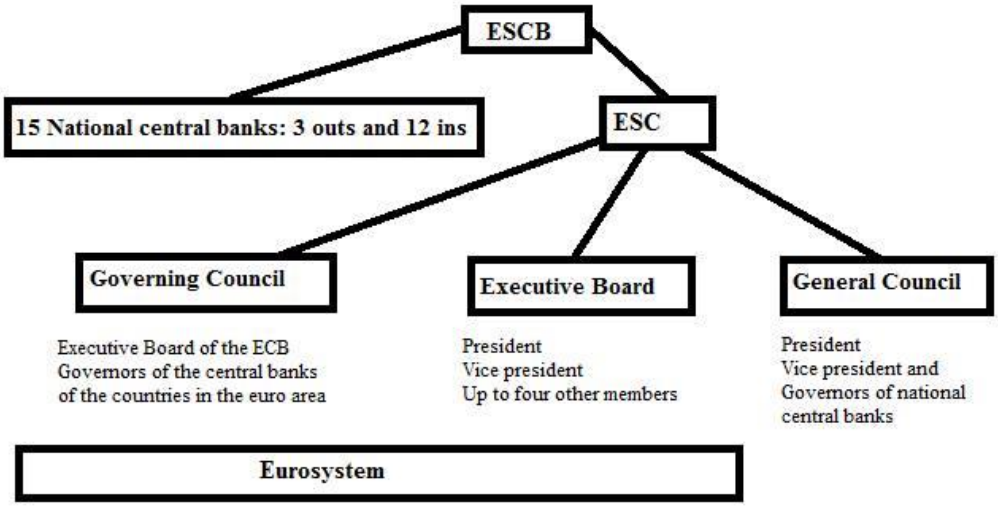
[29] European Central Bank, *Governing Council* [online] <https://www.ecb.europa.eu/ecb/orga/decisions/govc/html/index.en.html> [Accessed 13.9.2015]

[30] European Central Bank, *General Council* [online] <https://www.ecb.europa.eu/ecb/orga/decisions/genc/html/index.en.html> [Accessed 13.9.2015]

[31] FOUKAL, R.: *The European Central Bank — History, Structure, and the Decision Making Process* [online] <https://www.hitpages.com/doc/5990315441782784/1> [Accessed 20.11.2015]

implementing monetary policy, promoting the smooth operation of payment systems, holding and managing the official foreign reserves of the EU Member States.[32]

Figure 2: Structure of the European System of Central Banks



Source: The European Central Bank: Credibility, Transparency, and Centralization p.10

3.3 Financial crises

A financial crisis is defined as episodes of financial-market volatility marked by significant problems of illiquidity and insolvency among financial-market participants and/or by official intervention to contain such consequences.[33] Financial crises have different sizes and shapes, develop into different forms, and can rapidly spread across countries and continents. They often require immediate and comprehensive policy responses, call for major changes in financial sector and fiscal policies, and can necessitate the global coordination of policies.[34]

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[32] FOUKAL, R.: *The European Central Bank — History, Structure, and the Decision Making Process* [online] <https://www.hitpages.com/doc/5990315441782784/1> [Accessed 20.11.2015]

[33] BORDO, M. *Is this crisis problem growing more severe?* [online] <http://www.sfu.ca/~djacks/courses/ECON372/Papers/Bordo%20et%20al,%20Is%20the%20Crisis%20Problem%20Growing%20More%20Severe.pdf> [Accessed 23.11.2015]

[34] International Monetary Fund [online] <https://www.imf.org/external/pubs/ft/wp/2013/wp1328.pdf> [Accessed 5.11.2015]

3.3.1 Mutual characteristics

Mishkin defines a financial crisis as a major disruption in financial markets that is characterized by a sharp decline in asset prices and the failure of many financial and nonfinancial institutions. Even though financial crises have some mutual characteristics they come in different forms. The International Monetary Fund[35] defines four groups of crises: currency crises, bank crises, debt crises and sudden stop crises meaning capital account crises. Currency crisis appears after a speculative attack on the currency, raising of interest rate or selling a significant amount of forex reserves, that brings devaluation of the currency. A sudden stop is unpredicted and large drop in international capital inflows. Debt crisis happens when a country does not want to or cannot service its domestic or foreign debt. Bank crisis, including the great crisis, is a financial crisis that affects the banking activity, including bank runs that lead to fall of a financial institution.

It is usually very hard even impossible to predict a financial crisis, because when some characteristics of upcoming crisis are spotted, it is already too late. The five factors that can cause a financial or bank crisis have been defined by Mishkin. These factors are increase in interest rates, increase in uncertainty in financial markets, asset market effects on the balance sheets, meaning that a decline in a stock market can cause worsening in balance sheet of the company, thus it can increase adverse selection and moral hazard problems in financial markets and trigger a crisis. The other factors that can cause a financial crisis are problems in the banking sector and government fiscal imbalances. The decline in lending can lead to a decline in investment spending, which slows economic activity and banks may start to fail, which is called bank panic. Fears of default on the government debt can also spark a foreign exchange crisis in which the value of the domestic currency falls sharply because investors pull their money out of the country.[36]

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[35] International Monetary Fund [online] <https://www.imf.org/external/pubs/ft/wp/2013/wp1328.pdf> [Accessed 23.11.2015]

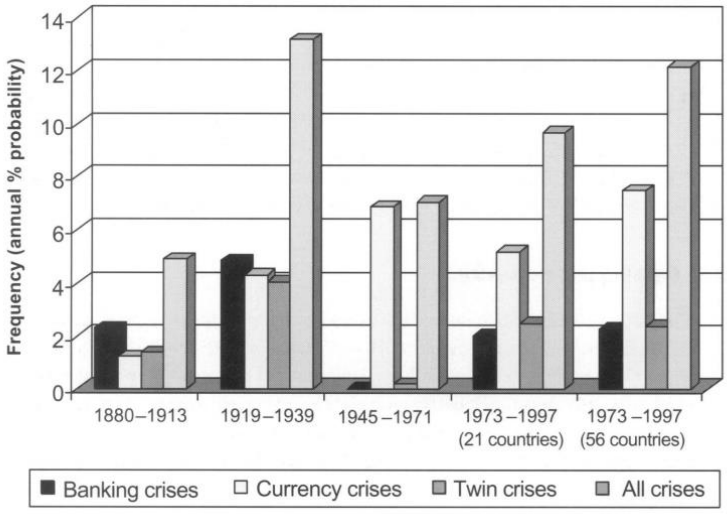
[36] MISHKIN, F. S. *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.

Financial crises are often preceded by asset and credit booms that eventually turn into busts. There are some fundamental factors detected such as macroeconomic imbalances, internal or external shocks, but sometimes financial crisis might be caused by irrational factors, which includes for instance sudden runs on the banks or a piece of information.

3.3.2 History

Financial crises have been an unfortunate part of the industry since its beginnings. Markets are apparently destined to repeat history as irrational exuberance is followed by an equally irrational despair thus periodic bouts of chaos are the inevitable result.[37] The financial crises problem has grown since 1973. The frequency of financial crises doubled since 1973 compared to 1945-1972. Annual frequency was about 12% during 1973-2001, meaning in the given countries, there was nearly one in eight chance of going through a financial crisis in the given year. On the contrary, in a period of 1945-1971 the annual frequency was only 6.5%.[38]

Figure 3: Crises frequency 1880-1997



Source: Bordo et al 2001

[37] ANDERSON, S.: *History of the past 40 years in financial crises*. [online] <http://www.ifre.com/a-history-of-the-past-40-years-in-financial-crises/21102949.fullarticle> [Accessed 26.11.2015]
[38] BORDO, M. *Is this crisis problem growing more severe?* [online] <http://www.sfu.ca/~djacks/courses/ECON372/Papers/Bordo%20et%20al,%20Is%20the%20Crisis%20Problem%20Growing%20More%20Severe.pdf> [Accessed 23.11.2015]

A brief history of financial crises[39]:

1720 South Sea bubble – The South Sea Company, set up to trade with South America, focused instead on insider dealing of government debts, with disastrous results.

1792 Panic of 1792 – The expansion of credit by the newly formed Bank of the U.S. and prompted speculation in bank stocks and government debt by prominent bankers.

1825 Latin American crisis – Excitement over the newly independent Latin America caused a speculative bubble.

1837 Cotton crisis – A sharp fall in cotton prices, bubble in a land prices and credit crunch started a recession in the United States that lasted for several years.

1873 Long depression – Boom and bust in Europe after Franco-Prussian war and railway bubble in America led into twenty years of stagnation in Great Britain.

1929 Wall Street crash – The most devastating stock market crash in the history of the U.S. After the speculative boom in 1920s, it brought 10 years of depression.

1973 Oil crisis – The collapse of the Bretton Woods system combined with an embargo imposed by Arab oil exporters.

2001 Dot-com crash – Telecom and Internet sector speculative bubble covering the period 1997-2001

2008 Subprime crisis – Borrowers were approved for loans that were not able to pay. This combined with large decline of home prices led to the worst financial crisis since the Wall Street crash.

M. Bordo states that there is little evidence that crises have grown longer or output losses have become larger, the crises might have grown more frequent, but they have not grown more severe. The data also show that crises have evolved over time. For example, currency crises were dominant during the 1980s, whereas banking crises and sudden stops became more prevalent in the 1990s and 2000s.[40]

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[39] The Economist: *Financial Crisis* <http://www.economist.com/news/essays/21600451-finance-not-merely-prone-crises-it-shaped-them-five-historical-crises-show-how-aspects-today-s-fina> [23.11.2015]

[40] International Monetary Fund [online] <https://www.imf.org/external/pubs/ft/wp/2013/wp1328.pdf> [Accessed 23.11.2015]

3.4 Monetary policy

Monetary policy is a process when the policy maker – central bank - uses its tools and instruments to achieve given goals. Monetary policy transmission mechanism denotes the way in which the operating target affects the ultimate target. Monetary policy instruments relate to the everyday realisation of monetary policy, while the planning horizon for ultimate target is usually several months or even years.[41]

We can perceive two ways of monetary policy, accommodative and tight monetary policy. Accommodative policy means that central bank lower all interest rates, thus the banks are willing to provide more loans and people want to borrow relatively cheaper money. Companies and households spend more money and velocity of money tends to increase. On the other hand tight monetary policy means that central bank increases the interest rates and banks are willing to provide fewer loans and their clients ask for fewer loans.[42] Households and companies spend less money, the velocity of money tends to decrease. Central banks apply tight policy in case of an overheated economy, low unemployment, high inflation expectation.

3.4.1 Monetary policy goals

Monetary policy is the process by which central banks control the supply of money or target inflation and interest rates to ensure price stability and general trust in the currency. The supply of money is credit, cash, checks, and money market mutual funds and the most important of these is credit, which includes loans, bonds, and mortgages.[43] According to Mishkin there are some general goals of monetary policy identical to every central bank. One

[41] JÍLEK, J.: *Money and Monetary Policy : Current Practice*. In IEEP [online]. Praha: VŠE, 2006 <http://www.ieep.cz/editor/assets/publikace/pdf/jilek_money.pdf> [Accessed 26.11.2015]

[42] MISHKIN, F. S. *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.

[43] About News [online] <http://useconomy.about.com/od/glossary/g/Monetary_policy.htm> [Accessed 28.9.2015]

of the goals is high employment, since high unemployment causes human misery and increases the crime, also results in a loss of output. The unemployment rate is not zero when the economy is at full employment due to what is called structural unemployment and frictional unemployment. Steady economic growth is another goal of monetary policy. This goal could be reached by encouraging people to save or directly encouraging firms to invest. Central banks are aware of economic and social costs of inflation, thus one of the most important goals of monetary policy is stable price level.[44] Inflation makes it harder to plan the future and also creates uncertainty that might hamper economic growth. For the same reason interest-rate stability is desirable. Another significant goals of monetary policy are stability of financial markets and stability in foreign exchange markets. A rise in the value of a given currency makes the country less competitive, on the other hand, declines in the value of the currency stimulate inflation. Some of the mentioned goals might be in conflict with each other. The goal of price stability often conflicts with the goals of interest-rate stability and high employment in the short run. For example, when the economy is expanding and unemployment is falling, both inflation and interest rates may start to rise.[45] On the contrary, many monetary policy goals such as high employment and economic growth or interest-rate stability and financial market stability are consistent with each other.

Central banks are not able to directly influence the mentioned goals, therefore they use a set of tools that indirectly affect certain goals after a period of time. These tools are open market operations, changes in reserve requirements or discount rate. To hit a goal by aiming the target is much easier and more efficient than aiming the goal directly.

3.4.2 Operating targets, intermediate targets

Monetary policy tools are instruments that are controlled directly and precisely by a central bank. On the contrary, monetary policy objectives are controlled indirectly and imprecisely

[44] MISHKIN, F. S. *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.

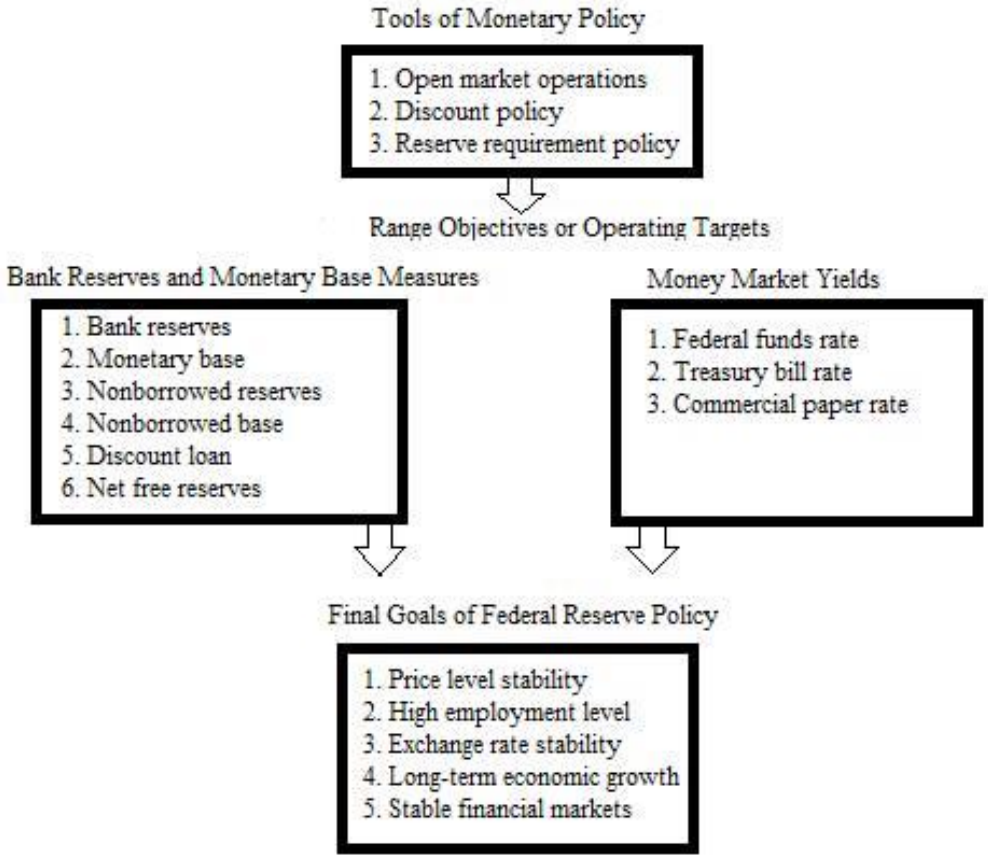
[45] MISHKIN, F. S. *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.

and their impact can be visible in one year at the earliest. The effect of changes in a central bank's portfolio of government securities or discount rate on the nation's output, employment, and price level might not be seen for at least one year.[46] Thomas states two types of monetary policy targets, operating and intermediate. Operating targets are controlled by a central bank as a part of its strategy to achieve monetary policy goals, but intermediate targets are not that easily controlled, thus a central bank attempts to control intermediate targets in its effort to achieve policy goals. The effective intermediate target must be able to control or at least strongly influence the variable. They must measurable, controllable with important influence. Operating targets generally score quite high on the measurability and controllability criteria, and respond quickly and strongly to changes in the central bank policy tools, on the other hand, intermediate targets are linked to monetary policy goals and have higher score on the importance criterion.[47]

[46] THOMAS, L. B.: *Money, Banking and Financial Markets*. Thomson South-Western 2006, 618 p. ISBN 978-0-324-17673-5

[47] THOMAS, L. B.: *Money, Banking and Financial Markets*. Thomson South-Western 2006, 618 p. ISBN 978-0-324-17673-5

Figure 4: Links in the Transmission of Fed Policy



Source: Thomas, L. B.: Money, Banking and Financial Markets

Operating targets are bank reserves, nonborrowed reserves, the nonborrowed base, the monetary base, discount loans, net free reserves, federal funds rate, treasury bill rate and commercial paper rate. Intermediate targets are monetary aggregates M1, M2, M3, bank credit and long-term interest rates, such as government bond yield, corporate bond yield, mortgage rate.[48]

[48] THOMAS, L. B.: *Money, Banking and Financial Markets*. Thomson South-Western 2006, 618 p. ISBN 978-0-324-17673-5

3.4.3 Monetary policy tools

Monetary policy is a process when the policy maker – central bank - uses its tools and instruments to achieve given goals. Monetary policy is the macroeconomic policy laid down by the central bank that involves management of money supply and interest rate and is the demand side economic policy used by the government of a country to achieve macroeconomic objectives like inflation, consumption, growth and liquidity.[49] According to Jílek, monetary policy consists in the regulation of the short-term interest rates by the central bank with a view to stabilize inflation. Monetary policy exists only in market-oriented countries, for prices in centrally planned economies are subject to direct regulation.[50]

One can say that the monetary policy tools represent the implementation of this policy and monetary policy goals are its expected results. Although, the literature shows different definitions of monetary policy, they all basically agree that it is a macroeconomic policy conducted by the monetary authority (usually the central bank) in order to ensure price stability.

Monetary policy tools are instruments that are controlled by the central bank and are linked to monetary policy goals. These tools are open market operations, discount window policy and reserve requirement policy. By far the most used instrument are open market operations.

3.4.3.1 Open market operations

Open market operation is the most important and the most influential monetary policy tool. Open market operation means selling or buying of securities by the central bank in the open market. Central banks implement this monetary policy tool to impact bank reserves, monetary aggregates, the monetary base and interest rates.

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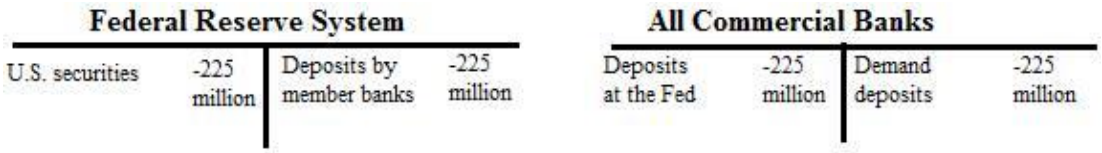
[49] The Economic Times (2015) [online] <http://economictimes.indiatimes.com/definition/monetary-policy> [Accessed 26.11.2015]

[50] JÍLEK, J.: *Money and Monetary Policy : Current Practice*. In IEEP [online]. Praha: VŠE, 2006 <http://www.ieep.cz/editor/assets/publikace/pdf/jilek_money.pdf> [Accessed 26.11.2015]

Suppose that there is high inflation and enormous aggregate expenditures, thus the central bank would sell securities in the open market. When the central bank sells $100 million of securities, reserves and the monetary base decrease by $100 million since aggregate bank deposits at the central bank decrease by $100 million.[51]

Figure 5: Central bank selling securities in the open market



Source: Thomas, L. B.: Money, Banking and Financial Markets

The beginning of usage of open market operations was in 1920s, when the Fed purchased government securities to supplement weakening earnings and to reach a steady flow of interest income. Then the Fed noticed that when the purchase was made, interest rates immediately fell. The impact of open market operations on a balance sheet is always the same, although these operations could be in common stocks, futures, municipal bonds, corporate bonds, preferably government securities.

Open market operations are divided into two categories: defensive and dynamic operations. Dynamic open market operations are intended to change the level of reserves and the monetary base, and defensive open market operations are intended to offset movements in other factors that affect reserves and the monetary base, such as changes in Treasury deposits with the Fed or float.[52]

Generally, there are two types of open market operation. First type are permanent operations, which means an outright buying or selling of government securities. The other type of open market operations is REPO operations, meaning temporary or repurchase agreement open

[51] THOMAS, L. B.: *Money, Banking and Financial Markets*. Thomson South-Western 2006, 618 p. ISBN 978-0-324-17673-5

[52] MISHKIN, F. S. *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.

market operations. These are short-term, often overnight. Most central banks focus their monetary-regulating policies and monitoring on REPO transactions, and the securities are subject to buy-back.[53]

Akhtar states that the permanent operations are outright operations in the market where dealers submit bids during auctions. Usually, treasury bills, a short-term discount securities with maximum maturity of one year, or treasury coupon securities, debt instruments with maximum maturities of two to about thirty years, are sold or bought. The temporary operations are repurchase agreements (RPs) when securities are bought from dealers who then repurchase them at a given price and date. It allows central bank to respond quickly and smoothly to reserves shortage, also transaction costs for RPs are very low. Repurchase agreements can be conducted on a term basis or on an overnight basis. Most RPs are arranged to mature within seven days. The other type of temporary open market operations is matched sale-purchase transactions (MSPs). These are usually arranged to one to seven days. In MSPs, a central bank makes a contract for sale of securities to a dealer and simultaneously a matching contract to buy them back from the dealer on a given date.[54]

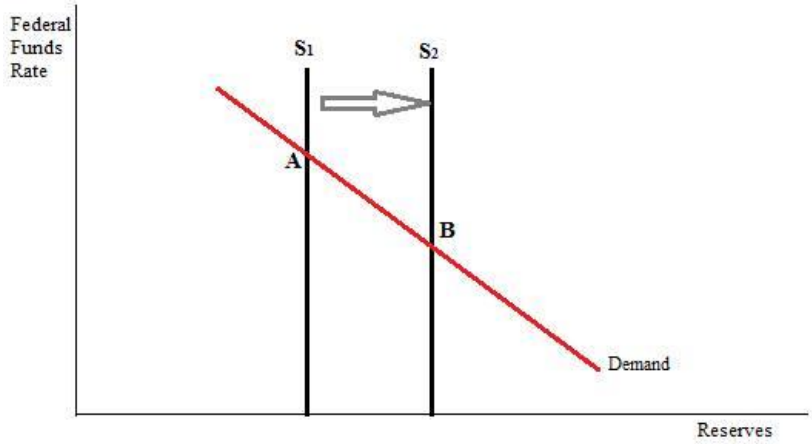
Open market operations have many advantages such as precision and flexibility.[55] Such a high level of accuracy cannot be reached by any other monetary policy tool, such as reserve requirements or discount rate. The amount by which the monetary base will be influenced is certain. When the central bank purchases $100 million of government securities, it will inject $100 million into the banking system. The open market operations influences straight money supply through reserves and the monetary base, in contrast to reserve requirements changes that influence the money supply multiplier. Open market operations are realized every day, it can easily change aim and course. The changes are not highly visible to the general public, because of enormous transactions every day it is a very flexible tool. Another advantage is that open market operations occur at the initiative of the central bank, which has absolute control

[53] CentralBanksGuide.com [online] <http://www.centralbanksguide.com/about.php> [Accessed 4.1.2016]
[54] AKHTAR, M. A.: *Understanding open market operations* [online] <https://research.stlouisfed.org/aggreg/meeks.pdf> [Accessed 14.12.2016]
[55] THOMAS, L. B.: *Money, Banking and Financial Markets*. Thomson South-Western 2006, 618 p. ISBN 978-0-324-17673-5

over the volume of operations. For example, in discount operations central bank can only encourage or discourage banks to take out loans by changing the discount rate but cannot directly control the volume of discount loans.[56] Another advantage is that open market operation can be realized very quickly without administrative delays.

The federal funds market is the market where banks with surplus of reserves lend their reserves deposit at the central bank to banks that have reserves shortage. This lending and borrowing is known as buying and selling federal funds, thus the interest rate at which federal funds are bought and sold is the federal funds rate[57] (in case of the European Union this rate is called main refinancing rate). When the Federal Reserve purchases securities in the open market, the supply of bank reserves increases and the federal funds rate falls.

Figure 6: Federal Reserve Open Market Purchases and the Federal Funds Rate



Source: Thomas, L. B.: Money, Banking and Financial Markets

3.4.3.2 Foreign exchange operations

Open market operations can also be done in other assets besides government bonds and have the exact effect on the monetary base. The example of this is central bank's foreign exchange

[56] MISHKIN, F. S. *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.
[57] THOMAS, L. B.: *Money, Banking and Financial Markets*. Thomson South-Western 2006, 618 p. ISBN 978-0-324-17673-5

intervention. Foreign exchange intervention is the action taken by a central bank in order to influence the spot exchange rate of the domestic currency to other currencies on the market.

The Fed sells or buys dollars on foreign exchange markets, which is a factor that affects the monetary base. A Federal Reserve intervention in the foreign exchange market involves a purchase or sale of assets denominated in a foreign currency. A Federal Reserve purchase of any asset, whether it is a U.S. government bond or a deposit denominated in a foreign currency, is still just an open market purchase and so leads to an equal rise in the monetary base.[58] Naturally, the sale of foreign currency leads to a decline of the monetary base. When a central bank buys a domestic currency or sells a foreign assets it leads to the same decline in international reserves of the given central bank and also the decline of the monetary base. According to Mishkin, there are two types of foreign exchange interventions made by central banks, unsterilized and sterilized. Unsterilized foreign exchange intervention is the intervention, in which a central bank allows the buy or sale of domestic currency to have an effect on the monetary base. In contrast, a foreign exchange intervention with an offsetting open market operation that leaves the monetary base unchanged is called a sterilized foreign exchange intervention.

One type of unsterilized intervention in selling dollars that brings the money supply increase. As the money supply is higher, the price level is higher and it leads to a lower expected future exchange rate. Moreover, higher real money supply causes the interest rate on dollar deposits to slide. People try to sell their dollars and it means the exchange rate falls. An unsterilized intervention in which domestic currency is sold to purchase foreign assets leads to a gain in international reserves, an increase in the money supply, and a depreciation of the domestic currency.[59] The second type of unsterilized intervention is when domestic currency is purchased by selling foreign assets. These transactions bring a reduction of international reserves, the monetary base and the money supply. The decrease in the money supply raises the interest rate. This means that people want to purchase more dollar deposits and the exchange rate rises.

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[58] MISHKIN, F. S. *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.

[59] MISHKIN, F. S. *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.

According to Jílek foreign exchange intervention is not regarded as a part of monetary policy since its primary goal is to influence exchange rate and not inflation, but this change of exchange rate has also an indirect effect on inflation. Jílek also states that FX interventions are more frequent in smaller countries, meaning in the USA and Eurozone are unusual.

FX interventions can really affect the exchange rate and the experience shows that foreign exchange interventions can help smoothing short-term fluctuations providing that they conform to the long-term trend, but interventions cannot determine the exchange rate systematically. Nowadays, the most of economists think that interventions are quite inefficient and thus needless. The effectiveness is also hard to estimate since one never knows how the exchange rate would behave if the central bank did not intervene.[60]

3.4.3.3 Discount loans

It is quite a slow process to affect inflation by interest rates changes. When the interest rates fall, banks are more willing to provide loans and start paying lower interests on deposits. Consumers spend more money, companies invest more, prices of both inputs and outputs increase. If the economy is open, lower interest rates result in the outflow of capital abroad and the exchange rate starts depreciating. All these events occur with a particular delay of one year or more.[61]

The discount rate is used when discount loans are made to banks. There three types of discount rates: primary credit, secondary credit, and seasonal credit. Primary credit is the discount lending when solvent banks can borrow from the primary credit facility. The interest rate on these loans is the discount rate and it is always higher than the federal funds rate. This facility is intended to be a backup source of liquidity. Secondary credit is given to banks that

[60] JÍLEK, J.: *Money and Monetary Policy : Current Practice*. In IEEP [online]. Praha: VŠE, 2006 <http://www.ieep.cz/editor/assets/publikace/pdf/jilek_money.pdf> [Accessed 20.12.2015]
[61] JÍLEK, J.: *Money and Monetary Policy : Current Practice*. In IEEP [online]. Praha: VŠE, 2006 <http://www.ieep.cz/editor/assets/publikace/pdf/jilek_money.pdf> [Accessed 20.12.2015]

are in financial trouble and are experiencing severe liquidity problems. The interest rate on secondary credit is set (approximately by 0.5 percentage points) above the discount rate.[62]

Seasonal credit is extended to relatively small depository institutions that have recurring intra-year fluctuations in funding needs, such as banks in agricultural or seasonal resort communities. The discount rate for seasonal credit is an average of selected market rates.[63]
Secondary credit is provided to banks, which are having liquidity problems and are in financial trouble. The interest rate on secondary credit is set 0.5% above the discount rate. This tool is used to affect the monetary base, reserves and the money supply, moreover, it is used to avoid and prevent financial panic. This function of central bank is called lender of last resort, meaning the central banks can provide reserves to bank with financial problem when no one else could. It is efficient way to supply money to banking system when financial crisis occurs. Even though discount policy works quite well, a loss of confidence in the banking system could still lead to runs on banks. The existence of the Fed's discount window can help prevent financial panics that are not triggered by bank failures, as was the case during the Black Monday stock market crash of 1987 and the terrorist destruction of the World Trade Center in September 2001.[64] Although, this has some disadvantages, for example costs. Banks can rely on the central bank that in case of trouble, the central bank will provide financial aid to help them. This is called "too big to fail" policy, meaning big banks can be sure that they can risk and the central bank will always help them, because their failure would likely cause a bank panic. Since discount loans are made by banks and are not completely controlled by the central bank, it is not the most frequently used monetary policy tool. Mishkin also explains that this is why the Fed moved in January 2003 to the current system, in which the discount facility is not used to set the federal funds rate, but is a backup facility to prevent the federal funds rate from rising too far above its target.

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[62] MISHKIN, F. S. *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.
[63] Board of Governors of the Federal Reserve System, *Discount Rate* [online] <http://www.federalreserve.gov/monetarypolicy/discountrate.htm> [Accessed 6.1.2016]
[64] MISHKIN, F. S. *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.

3.4.3.4 Reserve requirements

Reserve requirements are the amount of funds that a depository institution must hold in reserve against specified deposit liabilities.[65] Reserve requirements provide some protection, both liquidity and solvency risk. The cause of bankruptcies is usually to be found in inability of banks to meet withdrawals of deposits, meaning withdraws or transfer the deposits from one bank to another. The insufficient bank reserves on individual interbank accounts are one of the main reason for the implementation of reserve requirements. Reserve requirements have two functions, which are taxation of commercial banks and commercial bank's reserves cushion at the central bank. Taxation of commercial banks represents the profit of the central bank, i.e. in principle the profit of the government. Reserve requirements perform this function only if central bank does not pay interest on it or if the interests paid are lower than interests on the interbank market.[66] Commercial bank's reserve cushion at the central bank is important when a bank faces sudden withdraw of deposit by clients. An increase in reserve requirements leads to reduction of money supply. A rise in reserve requirements also increases the demand for reserves and raises the federal funds rate. Conversely, a decline in reserve requirements leads to an expansion of the money supply and a fall in the federal funds rate.[67]

Nowadays, the minimum reserve requirements as a monetary policy tool is used rarely. Reserve requirements as a monetary policy tool has some advantages, for instance neutrality, meaning all banks are affected equally regarding interest rates and money supply. Also the speed of impact is quite high, because changes in monetary aggregates, credit conditions and interest rates occur rapidly. Changes in reserve requirements affect thousands of banks and make them adjust their balance sheets. On the other hand, reserve requirements have more disadvantages including expensiveness. Extremely small changes in reserve requirements could be followed by small changes in the money supply. But this is not practical, since it is

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[65] Board of Governors of the Federal Reserve System, *Reserve Requirements* [online] <http://www.federalreserve.gov/monetarypolicy/reservereq.htm> [Accessed 6.1.2016]
[66] JÍLEK, J.: *Money and Monetary Policy : Current Practice*. In IEEP [online]. Praha: VŠE, 2006 <http://www.ieep.cz/editor/assets/publikace/pdf/jilek_money.pdf> [Accessed 6.1.2016]
[67] MISHKIN, F. S. *The economics of money, banking and financial markets*. 7th ed. Boston: Addison-Wesley, 2004. ISBN 0-321-12235-6.

very expensive to administer changes in reserve requirements. Another disadvantage of using reserve requirements to have power over interest rates and supply of money is that increasing the requirements can cause immediate liquidity problems for banks with low excess reserves and there is a lack of flexibility. Thomas states that central banks objectives could be achieved more easily and smoothly with other policy instruments. The rise of reserve requirement was expected to slow down the loan activity and hence the overall business activity. Nowadays, we know already that this causality doesn't hold, monetary policy consists solely in the open market operations that central bank employs to manage short-term interest rates. [68]

3.4.3.5 Other factors

Central banks influence monetary base by open market operations or discount loans, but also allow commercial banks acting on their own initiative. These operations are called automatic facilities and they also have influence on bank reserves. Automatic facilities are most often with an overnight maturity. Jílek defines these facilities as domestic currency operations happening on the proposal of commercial banks in order to increase or decrease their bank reserves. There are two types of automatic facilities defined: deposit facility and lending facility. Banks provide reserves to each other, there is always a bank with surplus of bank reserves and a bank with reserve shortage. The interest rate on the central bank's lending facility is always higher than interbank market interest rate and the interest rate on the central bank's deposit facility is always lower than interbank market interest rate.[69] Automatic facilities play a significant role in short-term interbank interest rate setting.

As Jílek states, the central bank is able to boost or weaken economic growth, but it cannot do it always. The continuous effort to expand the economy above its long-term potential can cause only the higher and higher inflation. Regarding inflation, there are many other factors that determine inflation and these factors are not under the control of the central bank. One of

[68] JÍLEK, J.: *Money and Monetary Policy : Current Practice*. In IEEP [online]. Praha: VŠE, 2006 <http://www.ieep.cz/editor/assets/publikace/pdf/jilek_money.pdf> [Accessed 10.1.2016]
[69] JÍLEK, J.: *Money and Monetary Policy : Current Practice*. In IEEP [online]. Praha: VŠE, 2006 <http://www.ieep.cz/editor/assets/publikace/pdf/jilek_money.pdf> [Accessed 10.1.2016]

these factors might be taxes or government expenditures. Level of taxation and government expenditures influence inflation more directly and unmistakably than interest rate changes.

To conclude, there are many players who can influence crucial variables such as interest rates or money growth rates, thus the central banks must retain flexibility in using its policy tools to achieve maximum influence over those variables.[70] A different case is small economies, since economic development and inflation in a small open economy depend much more on the development in foreign countries than on domestic interest rates.

[70] THOMAS, L. B.: *Money, Banking and Financial Markets*. Thomson South-Western 2006, 618 p. ISBN 978-0-324-17673-5

4. Practical Part

4.1 Introduction and description of the financial crisis of 2007-2008

The financial crisis of 2007-2008, also known as Global Financial Crisis, was the worst financial crisis since the Great Depression in 1930s. It started in the United States, but it quickly expanded around the World. Around the world stock markets have fallen, large financial institutions have collapsed or been bought out, and governments in even the wealthiest nations have had to come up with rescue packages to bail out their financial systems. Some of the world's largest financial institutions have collapsed, some have been saved by the government's rescue packages. From a world credit loss of $2.8 trillion in October 2009, US taxpayers alone spent $9.7 trillion in bailout packages and plans, $14.5 trillion, or 33%, of the value of the world's companies has been wiped out by this crisis. The UK and other European countries have also spent some $2 trillion on rescues and bailout packages.[71]

The starting point for big financial crisis was August 2007 with the onset of the global credit crunch and the fall of British bank, Northern Rock. The roots of the financial crisis can be found in the year 2001 when the U.S. economy experienced short and mild recession. Even though, the economy withstood dot-com boom or terrorist attack, the fear of recession was raising. That was a reason why the Federal Reserve System reduced 11 times the federal funds rates between May 2000 and December 2001. The rate decreased from 6.5% to 1.75% and it created very cheap money and a flood of liquidity in the economy. Low rates caused an increased amount of loans, mortgages, real estate buyers and also higher prices. In June 2003, the Fed lowered interest rates to 1%, the lowest rate in 45 years.[72] The cheap loans brought in market many insolvent borrowers with low income, no assets and no jobs. The banks decided to repackage mortgages and loans into collateralized debt obligations (CDOs) and pass on the

[71] Global Issues [online] <http://www.globalissues.org/article/768/global-financial-crisis#Thescaleofthecrisistrillionsintaxpayerbailouts> [Accessed 19.9.2015]

[72] The 2007-08 Financial Crisis In Review [online] <http://www.investopedia.com/articles/economics/09/financial-crisis-review.asp#ixzz3mAfhbIXC> [Accessed 20.9.2015]

debt to other institutions. Soon a big secondary market for originating and distributing subprime loans was developed. This process is called securitization, which means the transformation of non-liquid financial assets into saleable securities. Similar loans, such as mortgages, were packaged together by banks and other financial institutions, they were placed into a fund. Subsequently securities tied to the fund's assets were issued. Then investors buy the securities to earn the return on the fund's assets. On average, the pool of funds has a predictable cash flow as people pay their mortgages. The investor receives these payments as an investment.[73] Banks used the securitization to gain cash and move the default risk to investors. The fact that banks received cash gave them the opportunity to continue the process and grant new loans. According to Szulczyk, investment banks profited from the U.S. housing market. They used re-securitization, where the investment banks took securitized CDOs and placed them into a fund and issued new securities. Moreover, in October 2004 the net capital requirements for five big investment banks have been relaxed. These were Goldman Sachs, Merrill Lynch, Lehman Brothers, Bear Stearns and Morgan Stanley.

The primary problem of the U.S housing bubble was that banks relaxed all the loan and mortgage requirements. In the past all borrowers had to have a good credit history and a stable work with documentation that proved their income. During 2000s U.S. banks relaxed their standards, thus borrowers could state their income without verifying them. Loans provided to people with bad credit history are called subprime loans. After the beginning of the 2007 Financial Crisis, these loans became toxic, since subprime borrowers began defaulting on their loans.

Between the years 2004 and 2007 the interest rates became rise again from 1% to 5.25% and home ownership reached a saturation point. From 2005 home prices started to fall and it fell by 40% in one year. Many subprime borrowers could not withstand high interest rates and they started defaulting on their loans. During February and March 2007, more than 25 subprime lenders filed for bankruptcy, which was enough to start the trouble. According to 2007 news reports, financial firms and hedge funds owned more than $1 trillion in securities

[73] SZULCZYK, K.: "Securitization and the 2008 Financial Crisis" *Money, Banking, and International* [online] <https://www.boundless.com/users/233416/textbooks/money-banking-and-international-finance/the-banking-business-10/the-banking-business-31/securitization-and-the-2008-financial-crisis-102-15200/> [Accessed 20.9.2015]

backed by these now-failing subprime mortgages.[74] In August 2007 the problem spread beyond the U.S. borders and it was obvious that the subprime crisis cannot be saved by financial market only.

The crisis snowballed rapidly across the world. Apparently it spread to Europe very quickly, since the first sign of financial crisis appeared in summer 2007, when French bank BNP Paribas froze redemptions for three investment funds, citing its inability to value structured products. At that point, it was not obvious that this crisis could be a threat to Europe, but this began to change in the spring of 2008 with the failures of Bear Stearns in the United States and the European banks Northern Rock and Landesbank Sachsen.[75] About half a year later, the list of failed banks was extended by European banks such as the Central Bank of Iceland, Bradford & Bingley, Dexia, ABN-AMRO and Hypo Real Estate.

Governments and central banks around the world had to start dealing with the crisis and try to prevent future financial disaster. The main goal was to put the interbank market back on its feet, thus central banks had to provide liquidity support to financial institutions.

4.2 Evaluation of monetary policies of the FED and the ECB

REQUIRED RESERVES

The ECB requires credit institutions established in the euro area to hold deposits on accounts with their national central bank. These are called "minimum" or "required" reserves (MMR). The legal framework for the minimum reserve system is set out in the Regulation (EC) No. 2818/98 of the European Central Bank of 1 December 1998 on the application of minimum

[74] The 2007-08 Financial Crisis In Review [online] <http://www.investopedia.com/articles/economics/09/financial-crisis-review.asp#ixzz3mAfhbIXC> [Accessed 20.9.2015]

[75] EUROPEAN COMMISSION, Directorate-General for Economic and Financial Affairs. *Economic crisis in Europe: causes, consequences and responses*. Luxembourg: Office for Official Publications of the European Communities, 2009. ISBN 9789279113680.

reserves (ECB/1998/15), which is included in the publication entitled "Compendium: collection of legal instruments (June 1998 - December 2001)". [76]

Figure 7: Reserve coefficients – the European Union

Effective date	Overnight deposits, deposits with agreed maturity up to 2 years, debt securities issued with maturity up to 2 years, money market paper	Deposits with maturity over 2 years, repos, debt securities issued with maturity over 2 years
1 January 1999	2 %	0 %
18 January 2012	1 %	0 %

Source: European Central Bank <https://goo.gl/fvO7yA>

The minimum reserves used to be 2% in the Euro zone, since January 2012 it is 1%. The ECB and euro area national central banks are excluded from the reserve base.[77] The Federal Reserve System does not use reserve requirements as a monetary policy tool nowadays.

[76] The European Central Bank, (2015). *How to calculate the minimum reserve requirements.* [online] <https://www.ecb.europa.eu/mopo/implement/mr/html/calc.en.html> [Accessed 24.9.2015]
[77] The European Central Bank, (2015). *How to calculate the minimum reserve requirements.* [online] <https://www.ecb.europa.eu/mopo/implement/mr/html/calc.en.html> [Accessed 24.9.2015]

Figure 8: FED Reserve Requirements

Liability Type	Requirements	
	% of liabilities	Effective date
Net transaction accounts		
$0 - $15.2 million	0	21 January 2016
$15.2 million - $110.2 million	3	21 January 2016
More than $ 110.2 million	10	21 January 2016
Nonpersonal time deposits	0	27 December 1990
Eurocurrency liabilities	0	27 December 1990

Source: Board of Governors of the Federal Reserve System, *Reserve Requirements*

In the year 2016, the change happened only in the amount of dollars in particular category, not in the required reserves percentage.

INTEREST RATES

Interest rates are rates at which banks can borrow money from the central bank. A typical central bank has several interest rates that are used as monetary policy tools. These rates directly affect the rates in the money market, the market for short term loans

Main refinancing rate is a fixed interest rate that provides the bulk of liquidity to the banking system.[78] It is publicly announced by a central bank and currently this rate is 0.05%[79] in the Eurozone. Main refinancing rate may be also called minimum bid rate, in the United States it is known as federal funds rate and the value in the U.S. is currently 0.50 %[80]. This rate serves

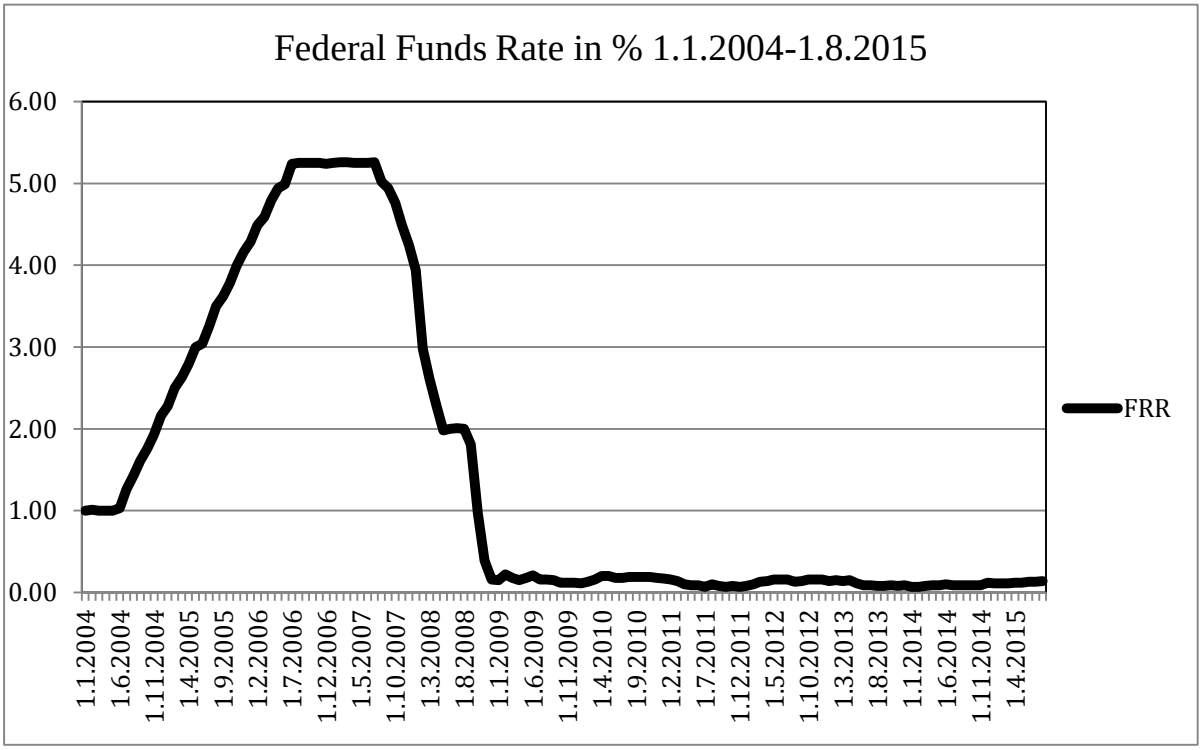
[78] The European central bank (2015): Key ECB intereste rates [online] <https://www.ecb.europa.eu/stats/monetary/rates/html/index.en.html> [Accessed 10.1.2016]
[79] Euribor-rates.eu [online] <http://www.euribor-rates.eu/ecb-refinancing-rate.asp> [Accessed 10.1.2016]
[80] Global-rates.com [online] <http://www.global-rates.com/interest-rates/central-banks/central-banks.aspx> [Accessed 10.1.2016]

as a bidding floor for refinancing loans. Federal funds rate is used to control the supply of available funds and also other interest rates and inflation.

Marginal lending rate is an interest rate for institutions to borrow money from central banks. This rate offers overnight credit to private banks. In the Eurozone the current value is 0.30%[81]. In the United States, where this rate is called federal discount rate, the value is 1.00%[82].

Rate on the marginal lending facility is an interest rate that offers overnight credit to banks.[83]

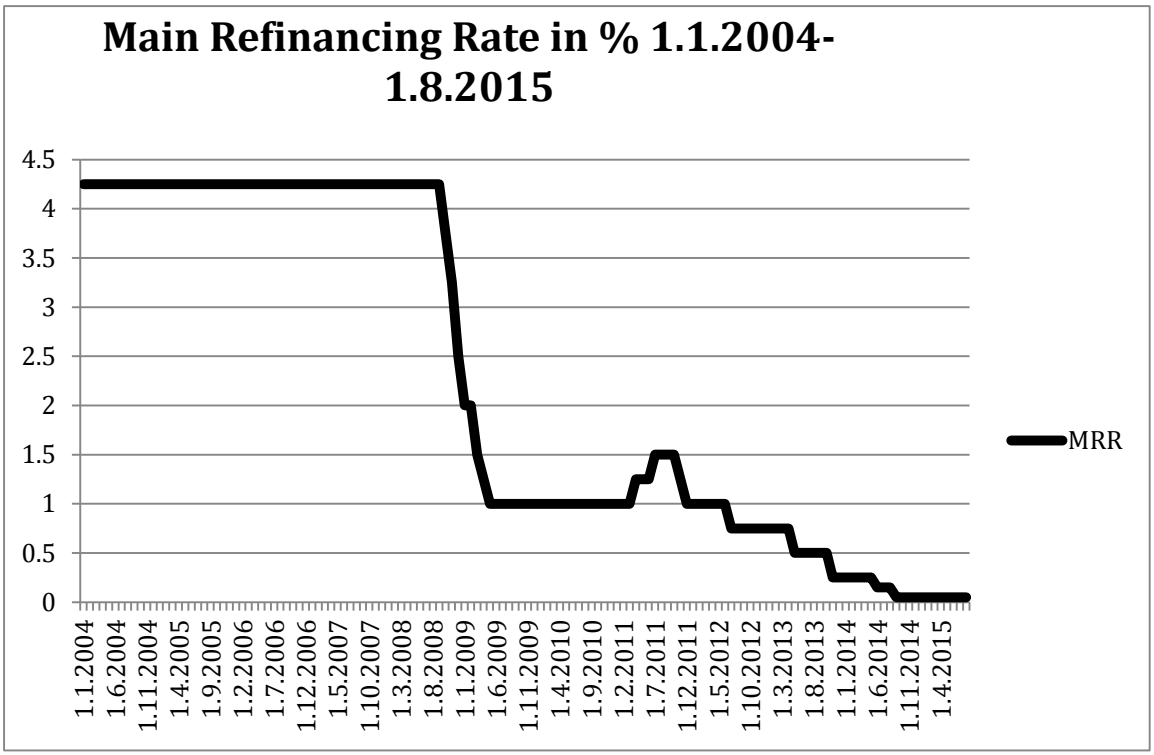
Graph 1: Federal Funds Rate development, 1.1.2004-1.8.2015, %



Source: own computation

[81] The European central bank (2015): Key ECB intereste rates [online] <https://www.ecb.europa.eu/stats/monetary/rates/html/index.en.html> [Accessed 10.1.2016]
[82] Bank rates: Federal discount rate [online] <http://www.bankrate.com/rates/interest-rates/federal-discount-rate.aspx> [Accessed 10.1.2016]
[83] The European central bank (2015): Key ECB intereste rates [online] <https://www.ecb.europa.eu/stats/monetary/rates/html/index.en.html> [Accessed 10.1.2016]

Graph 2: Main Refinancing Rate, 1.1.2004-1.8.2015, %



Source: own computation

Standard deviation and coefficient of variation are employed to evaluate activities of the central banks that relate to interest rates. The federal funds rate and main refinancing rate were compared. The activity of central bank was expressed by the calculation of the coefficient of variation of the interest rate for three periods. First period is a beginning of the financial crisis until the fall of Lehman Brothers. Second period is until the end of the year 2009 and third period is after the crisis from the year 2010 until the end of 2014. The value approaching to number 1 indicates a high activity of central bank in terms of changes in interest rates, while a value close to 0 indicates almost no activity.

$$\mathrm{Var}(X) = \frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2$$

$$v_x = \frac{s_x}{\overline{x}} \cdot 100\,[\%]$$

Figure 9: Coefficients of variation of FFR and MRR

	FED	ECB
2007 – 9/2008	0.53	0.31
9/2008 – 12/2009	0.90	0.54
2010-2014	0.43	0.52

Source: own computation

During the observed period the researcher assumed that the Fed was more active, since the coefficient of variation during the global crisis has reached 0.90. Calculations show the ECB's late respond to the crisis. The ECB started with lowering the main refinancing rate later as it is visible from 0.31 coefficient of variation in the first period. These figures follow that the Fed was significantly more active in its monetary activities regarding interest rates. This might be caused by the fact that the Fed takes into consideration besides the stable price level also stable economic growth. Another reason of highest activity might be the fact that the Fed has simpler and flexible decision making system. The ECB in its action does not react to short term deviations, and thinking more in the long run.

OPEN MARKET OPERATIONS

The Federal Reserve's approach to the implementation of monetary policy has changed since the financial crisis, and thus since 2008 the Federal Open Market Committee established a near-zero target range for the federal funds rate. From the end of 2008 until October 2014, the Fed expanded its holding of long-term securities through open market purchases with the goal of putting pressure on long-term interest rates and also supporting economic activity and job creation by making financial conditions more accommodating.[84] During the policy

[84] Board of Governors of the Federal Reserve System, *Open market operations* [online] <http://www.federalreserve.gov/monetarypolicy/openmarket.htm#2008> [Accessed 13.11.2015]

normalization process starting in December 2015, the Fed will use overnight reverse repurchase agreements as a policy tool, to help control the federal funds rate and keep it in the target range set by the FOMC.

4.3 Analysis of impact of anti-crisis measures: the FED vs the ECB

Central banks are aware of economic and social costs of inflation, the most important goal of monetary policy is stable price level. Inflation makes it harder to plan the future and also creates uncertainty that might hamper economic growth. The stable price level is the main goal of the European Central Bank, because according to Article 105 of the Maastricht Treaty "the primary objective of the European Central Bank shall be to maintain price stability" and that "without prejudice to the objective of price stability, the European Central Bank shall support the general economic policies in the Community." On the other hand, the Federal Reserve System does not have only one main objective. Even though, it has three main objectives, one of them is identical with the main goal of the European Central Bank, and it is the stable price level. According to Federal Reserve Act, the statutory objectives for monetary policy- in the United States are maximum employment, stable prices, and moderate long-term interest rates.[85]

4.3.1 The price level stability

Price stability in an economy means that the general price level in an economy does not change much over time. In other words, prices neither go up or down; there is no significant degree of inflation or deflation.[86] Inflation is an increase of the price level, deflation is a decrease in the price level. Inflation can be measured by some indices such as the most

[85] Board of Governors of the Federal Reserve System, *What are the Federal Reserve's objectives in conducting monetary policy?* [online] <http://www.federalreserve.gov/faqs/money_12848.htm> [Accessed 6.3.2016]

[86] Study.com, *Business Courses* [online] <http://study.com/academy/lesson/price-stability-in-monetary-policy-definition-lesson-quiz.html> [Accessed 6.3.2016]

popular one, consumer price index or producer price index, the house price index, index of private housing rental prices and construction price indices.[87]

Inflation is the percentage change in the value of the Consumer Price Index (CPI) on a year-on year basis. It effectively measures the change in the prices of a basket of goods and services in a year.[88]

Formula for calculating Inflation=

$$\frac{\text{(CPI in month of current year-CPI in same month of previous year)}}{\text{CPI in same month of previous year}} \times 100$$

The Consumer Price Index is an indicator of changes in consumer prices experienced by Canadians. It is obtained by comparing, over time, the cost of a fixed basket of goods and services purchased by consumers. Since the basket contains goods and services of unchanging or equivalent quantity and quality, the index reflects only pure price change.[89]

The ECB's Governing Council has defined price stability as "a year-on-year increase in the Harmonised Index of Consumer Prices for the euro area of below 2%. Price stability is to be maintained over the medium term". The Governing Council has also clarified that, in the pursuit of price stability, it aims to maintain inflation rates below, but close to, 2%.[90] This means the optimal inflation rate should be 2%.

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[87] Office for National Statistics [online] <https://www.ons.gov.uk/economy/inflationandpriceindices> [Accessed 6.3.2016]

[88] The Economic Times (2015) [online] <http://economictimes.indiatimes.com/definition/inflation> [Accessed 6.3.2016]

[89] Statistics Canada (2016) [online] <http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=2301> [Accessed 6.3.2016]

[90] The European Central Bank, (2016). *Benefits of price stability.* [online] <https://www.ecb.europa.eu/stats/prices/hicp/html/inflation.en.html> [Accessed 6.3.2016]

4.4 Data collection

Regression methods, namely an ordinary least squared method, provides a tool for comparison of monetary policy tools and their impact on the inflation rate changes. The development of the price level was set as the dependent variable and the monetary policy tools were set as independent variables. The researcher analyzes how and in what extend the independent variables influenced dependent variable. For ordinary least squared method, monthly data from the beginning of the year 2007 until the end of the year 2014 were included. For ARIMA model, monthly data from the beginning of the year 2007 until the end of the year 2015 were included.

As the dependent variable, data which express monetary policy goal of stable price level, were chosen. For the Federal Reserve System it means that a stable price level is displayed in the inflation rate in the United States, for the European Central Bank, the same was used. Naturally, the researcher only included 19 states of the European Union, where euro banknotes and coins are legal tender, thus stable price level is displayed in the inflation rate in the Eurozone. Historical inflation rates for both the U.S. and the EU were very easily reached. For the United States, US Inflation Calculator provides the table of historical inflation rates in the United States displays monthly and annual rates from 1914 to 2016.[91] For the European Union, the ECB provides all the data regarding inflation in the euro area.[92] The inflation rate is stated in percentage.

The monetary policy tools, analyzed in the third chapter, were set as independent variables. For data from the United States were most often used data provided by some federal reserve bank. For the Federal Reserve System, monetary policy tool were expressed by federal funds rate, federal discount rate, reserve requirements in billions USD, reverse repurchase agreements in billions USD and USD/EUR exchange rate.

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[91] US Inflation Calculator (2016) [online] <http://www.usinflationcalculator.com/inflation/historical-inflation-rates/> [Accessed 15.1.2016]

[92] The European Central Bank, (2016). *Inflation Dashboard.* [online] <https://www.ecb.europa.eu/stats/prices/hicp/html/inflation.en.html> [Accessed 15.1.2016]

Federal funds rate[93] not seasonally adjusted monthly data were gained from the database of the Federal Reserve Bank of St. Louis. From the same database the researcher gained also data regarding reserve requirements[94] in billions of USD and open market operations[95] expressed as the amount of reverse repurchased agreements in billions of USD. Reverse repurchase agreements are transactions in which securities are sold to a set of counterparts under an agreement to buy them back from the same party on a specified date at the same price plus interest. Reverse repurchase agreements absorb reserve balances from the banking system for the length of the agreement, thus this operation reflects the transaction from the counterparts' perspective, the Federal Reserve receives cash in a reverse repurchase agreement and provides collateral to the counterparts.[96] The list of discount rates[97] expressed in percentage was gained from the Federal Reserve Bank of San Francisco's website. US Dollar to Euro exchange rate was set as an indicator of foreign exchange interventions and was expressed as a monthly average ratio.[98]

For the European Central Bank monetary policy tool were expressed by main refinancing rate, marginal lending rate, percentage of required reserves, main refinancing operations in billions EUR and EUR/USD exchange rate.

Most of the data for the Euro zone were gained from the European Bank Statistical Data Warehouse. Both, main refinancing rate[99] and marginal lending rate[100] are monthly data

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93 Federal Reserve Bank of St. Louis. *Economic Research*. [online] <https://research.stlouisfed.org/fred2/series/FEDFUNDS#> [Accessed 24.9.2015]

94 Federal Reserve Bank of St. Louis. *Economic Research*. [online] <https://research.stlouisfed.org/fred2/series/REQRESNS#> [Accessed 25.9.2015]

95 Federal Reserve Bank of St. Louis. *Economic Research*. [online] <https://research.stlouisfed.org/fred2/series/WLRRA> [Accessed 25.9.2015]

96 Federal Reserve Bank of St. Louis. *Economic Research*. [online] <https://research.stlouisfed.org/fred2/series/WLRRA/downloaddata> [Accessed 5.3.2016]

97 Federal Reserve Bank of San Francisco. *Discount window*. [online] <http://www.frbsf.org/banking/discount-window/discount-rate/#2008> [Accessed 24.9.2015]

98 X-rates [online] <http://www.x-rates.com/average/?from=USD&to=EUR&amount=1&year=2010> [Accessed 25.9.2015]

99 The European Central Bank, (2015). *Statistical Data Warehouse.* [online] <https://sdw.ecb.europa.eu/browseTable.do?node=2018801&SERIES_KEY=143.FM.B.U2.EUR.4F.KR.MRR_FR.LEV> [Accessed 24.9.2015]

100 The European Central Bank, (2015). [online] <https://www.ecb.europa.eu/stats/monetary/rates/html/index.en.html> [Accessed 24.9.2015]

expressed in percentage. As the ECB does not really use a change in reserve requirements as a monetary policy tool and data expressed in money are not published, reserve requirements[101] were expressed as a percentage of customer deposits that must be held as a reserve by commercial banks. Open market operations[102] expressed as the amount of main refinancing operations in billions of EUR. Euro to US Dollar exchange rate was set as an indicator of foreign exchange interventions and was expressed as a monthly average ratio.[103]

4.5 Time series data

4.5.1 Test of stationarity

When performing empirical analysis of the time series, the goal is to find the best model to forecast a future development of the time series. The goal might also be an identification of the time series characteristics for the purpose of studying their relationships. Stochastic process is referred to as stationary if its characteristics are not changed in time. But in an economy, there are many time series constituted by non-stationary stochastic processes. These time series are characterized by a presence of a trend. Characteristic attribute of macroeconomic time series is non-stationarity. During modeling of the time series, there is a risk of spurious relationships. It means that test shows significant relationships, but these might be spurious.[104] This could also be one of the limitations of the models in this diploma thesis.

A common assumption for time series techniques is that the data are stationary. A stationary process has the property that the mean, variance and autocorrelation structure do not change

[101] The European Central Bank, (2015). [online] <https://www.ecb.europa.eu/mopo/implement/mr/html/calc.en.html> [Accessed 24.9.2015]
[102] The European Central Bank, (2015). *Economic Bulletin.* [online] <https://www.ecb.europa.eu/mopo/implement/omo/html/top_history.en.html> [Accessed 24.9.2015]
[103] Oanda Corporation [online] *Historical Exchange Rates* <http://www.oanda.com/currency/historical-rates/> [Accessed 25.9.2015]
[104] ARLT, Josef a Markéta ARLTOVÁ. *Ekonomické časové řady*. V Professional Publishing vyd. 1. Praha: Professional Publishing, 2009, 290 p. ISBN 978-80-86946-85-6.

over time. Stationarity means flat looking series, without trend, constant variance over time, a constant autocorrelation structure over time and no seasonality.[105] Using non-stationary time series data in financial models produces unreliable and spurious results and leads to poor understanding and forecasting. The solution to the problem is to transform the time series data so that it becomes stationary. If the non-stationary process is a random walk with or without a drift, it is transformed to stationary process by differencing.[106] The non-stationary data cannot be used for a data modeling and non-stationarity must be removed by time series differencing. The assumption is that 1st differentiation will make the data stationary in the most cases. The data utilized in this diploma thesis are all economic time series where high probability of non-stationarity occurs. All of the used data will be tested for stationarity using Augmented Dickey-Fuller Unit Root Test in Gretl software.

4.5.1.1 Augmented Dickey-Fuller Unit Root Test

ADT is a test for a unit root in a time series. In this diploma thesis this test was done in econometrics software Gretl. The null hypothesis was tested and this null hypothesis is that the time series is non-stationary, meaning the existence of the unit root. To declare the data stationary, null hypothesis must be rejected. Otherwise, non-stationarity must be removed by time series differencing.

H_0: Unit Root (non-stationarity)

H_1: No Unit Root (stationarity)

H_0 is rejected when p-value is smaller than the selected level of significance which is 0.05.

The lag order for ADT test was set as 12. The figures show results for ADT for inflation.

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[105] Engineering Statistics Handbook [online] <http://www.itl.nist.gov/div898/handbook/pmc/section4/pmc442.htm> [Accessed 16.2.2016]

[106] Introduction to Stationary and Non-Stationary Process [online] <http://www.investopedia.com/articles/trading/07/stationary.asp#ixzz3yZg4JaPP> [Accessed 9.2.2016]

The Federal Reserve System

Figure 10: Testing for stationarity (Inflation, FED)

```
Augmented Dickey-Fuller test for Inflation
including 12 lags of (1-L)Inflation
(max was 12, criterion AIC)
sample size 83
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0902055
  test statistic: tau_c(1) = -1.68689
  asymptotic p-value 0.438
  1st-order autocorrelation coeff. for e: 0.064
  lagged differences: F(12, 69) = 5.193 [0.0000]

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0928867
  test statistic: tau_ct(1) = -1.66033
  asymptotic p-value 0.7688
  1st-order autocorrelation coeff. for e: 0.065
  lagged differences: F(12, 68) = 5.116 [0.0000]
```

Source: own computation

$0.438 > 0.05$

H_0 cannot be rejected

This means that data for inflation in the United States are non-stationary and the researcher must repeat the Augmented Dickey-Fuller Test with 1st differences of these data.

Figure 11: Testing for stationarity (Inflation, FED, 1st differences)

```
Augmented Dickey-Fuller test for d_Inflation
including 11 lags of (1-L)d_Inflation
(max was 12, criterion AIC)
sample size 83
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -1.30208
  test statistic: tau_c(1) = -5.41835
  asymptotic p-value 2.633e-06
  1st-order autocorrelation coeff. for e: 0.057
  lagged differences: F(11, 70) = 2.861 [0.0037]

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -1.30553
  test statistic: tau_ct(1) = -5.38982
  asymptotic p-value 2.893e-05
  1st-order autocorrelation coeff. for e: 0.057
  lagged differences: F(11, 69) = 2.826 [0.0042]
```

Source: own computation

2.633e-06 < 0.05

H_0 is rejected

This means 1st differences of data for inflation in the United States are stationary. Naturally, for the next analysis in this diploma thesis, 1st differences of data for inflation in the United States will be used.

The European Central Bank

Figure 12: Testing for stationarity (Inflation, ECB)

```
Augmented Dickey-Fuller test for Inflation
including 12 lags of (1-L)Inflation
(max was 12, criterion AIC)
sample size 83
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0654667
  test statistic: tau_c(1) = -1.61464
  asymptotic p-value 0.475
  1st-order autocorrelation coeff. for e: -0.019
  lagged differences: F(12, 69) = 3.453 [0.0005]

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.0758559
  test statistic: tau_ct(1) = -1.76529
  asymptotic p-value 0.7217
  1st-order autocorrelation coeff. for e: -0.017
  lagged differences: F(12, 68) = 3.455 [0.0005]
```

Source: own computation

$0.475 > 0.05$

H_0 cannot be rejected

This means that data for inflation in the European Union are non-stationary and the researcher must repeat the ADT with 1st differences of these data.

Figure 13: Testing for stationarity (Inflation, ECB, 1st differences)

```
Augmented Dickey-Fuller test for d_Inflation
including 11 lags of (1-L)d_Inflation
(max was 12, criterion AIC)
sample size 83
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.793459
  test statistic: tau_c(1) = -3.78209
  asymptotic p-value 0.003111
  1st-order autocorrelation coeff. for e: -0.037
  lagged differences: F(11, 70) = 3.238 [0.0013]

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.799703
  test statistic: tau_ct(1) = -3.73946
  asymptotic p-value 0.0198
  1st-order autocorrelation coeff. for e: -0.037
  lagged differences: F(11, 69) = 3.197 [0.0015]
```

Source: own computation

0.003111 < 0.05

H_0 is rejected

This means 1st differences of data for inflation in the European Union are stationary. For the next analysis in this diploma thesis, 1st differences of data for inflation in the European Union will be used.

The Augmented Dickey-Fuller Tests were done in Gretl econometric software for all the time series collected for the purpose of this thesis. These time series are federal funds rate, federal discount rate, main refinancing rate, marginal lending rate, reserve requirements, reverse

repurchase agreements, main refinancing operations and exchange rates. Depending on the proposed extent of this diploma thesis, the rest of all the Augmented Dickey-Fuller tests are in supplements. The result for all the time series was as expected, all the data are non-stationary and this must be removed by time series first differencing.

4.5.2 Autoregressive Integrated Moving Average Model

The stable price level is the most important objective for both central banks, the FED and the ECB, the forecast of inflation rate in the United States and the Euro zone were done in this diploma thesis. Forecasting of inflation is crucial for all the financial planning, budgeting, investments, spendings, savings etc. Inflation rate is critical for all actors in the economy, households, companies, state. Without an exact measure of the inflation rate, it is not possible to accurately plan all the expenses. This prognosis is helpful for decision making regarding central bank's steps and for the purpose of this diploma thesis, the researcher will estimate the development of price levels in the U.S. and the EU in the year 2016.

The inflation rate forecast was done with ARIMA model, which means autoregressive integrated moving average model. ARIMA is a forecasting technique that projects the future values of a series based entirely on its own inertia. Its main application is in the area of short term forecasting requiring at least 40 historical data points. It works best when the data exhibit a stable or consistent pattern over time with a minimum amount of outliers.[107] The first step in applying ARIMA model is to check for stationarity, which has been done in the previous chapter.

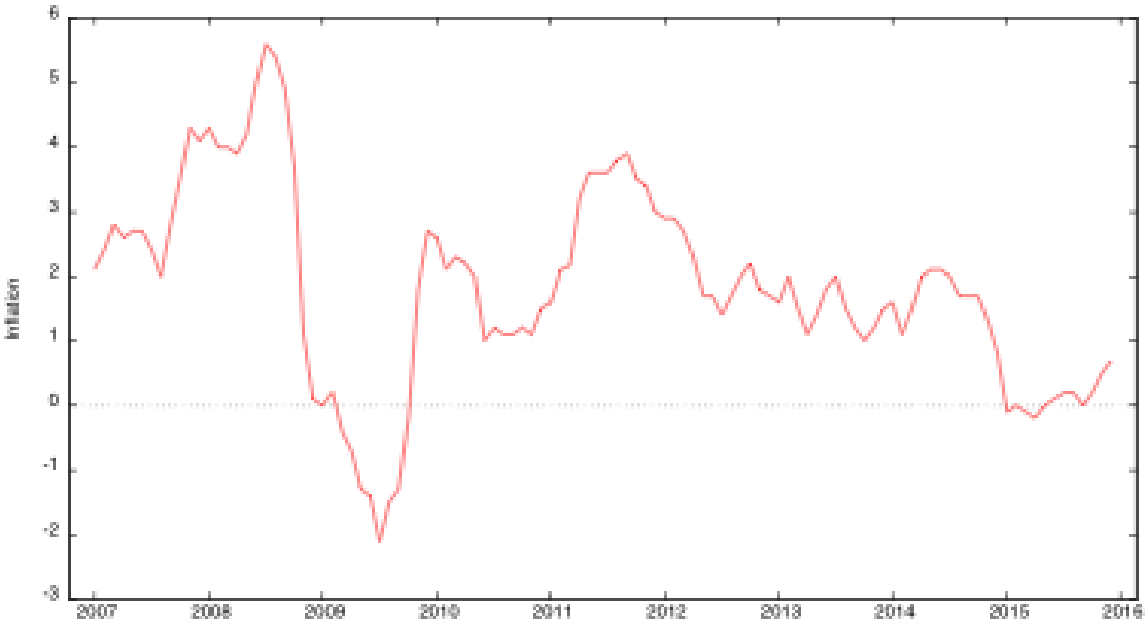
As low and stable inflation is the main goal of the ECB and the FED, monthly values will be forecasted for the year 2016. The data used for this forecast are monthly data from January 2007 to December 2015. With ADT the non-stationarity of data has been detected, thus for ARIMA model the data has been "first differenced".

[107] Forecasting solutions {online] <http://www.forecastingsolutions.com/arima.html> [Accessed 17.2.2016]

4.5.2.1 Prognosis of the inflation rate in the U.S. in 2016

For time series data prognosis, stationary data are needed. As it was already mentioned, the inflation rate data were non-stationary and it is depicted on the graph number 7. On the graph number 8, there are 1st differences that are stationary. For both graphs, on the axis x there are years from 2007 to 2015 and on the axis y there is inflation rate expressed in percentage.

Graph 3: Inflation – the FED



Source: own computation

Graph 4: Inflation – the FED, 1st differences

Source: own computation

ARIMA (p,d,q) model:

P… number of autoregressive lags, it is on dependent variable

d…number of differences that were done for the dependent variable

q…number of lags on the moving average

As a next step, autocorrelation function was computed. Autocorrelation function usage is a part of the Box-Jenkins approach, which is related to the time series modelling. By plotting the autocorrelation function, it is possible to establish the appropriate lags in p in and AR (p) model.

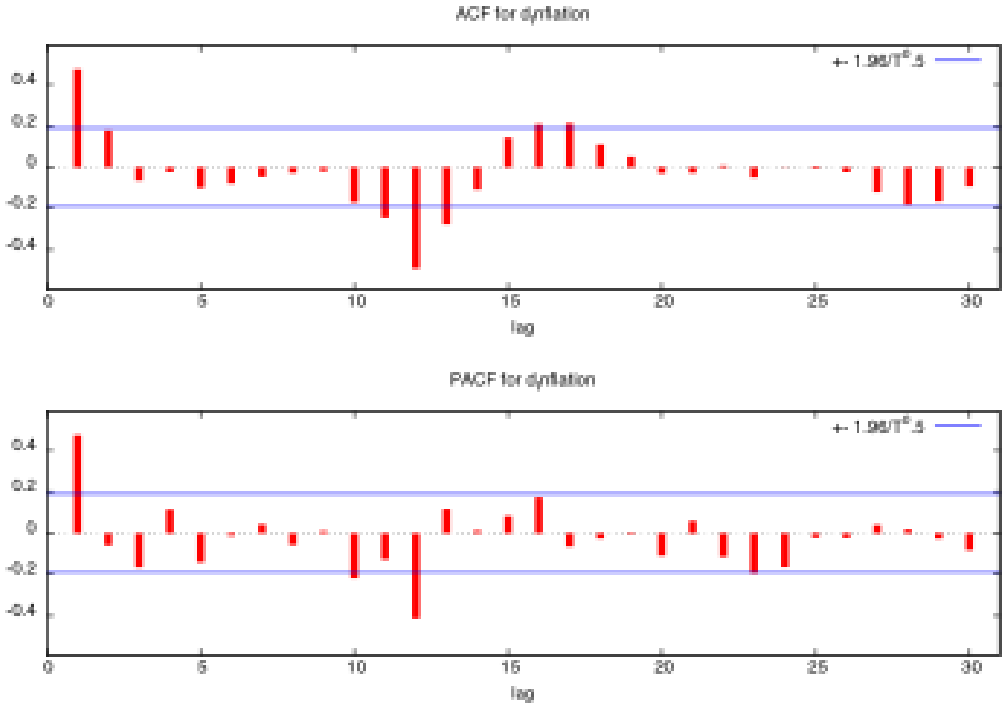
Figure 14: Autocorrelation function for Inflation (the FED, 1st differences)

```
Autocorrelation function for d_Inflation
***, **, * indicate significance at the 1%, 5%, 10% levels
using standard error 1/T^0.5

  LAG      ACF          PACF         Q-stat. [p-value]

    1   0.4736  ***   0.4736 ***     24.6840  [0.000]
    2   0.1770  *    -0.0611         28.1633  [0.000]
    3  -0.0666       -0.1639 *       28.6612  [0.000]
    4  -0.0204        0.1147         28.7084  [0.000]
    5  -0.1007       -0.1406         29.8683  [0.000]
    6  -0.0804       -0.0116         30.6148  [0.000]
    7  -0.0481        0.0418         30.8845  [0.000]
    8  -0.0258       -0.0587         30.9629  [0.000]
    9  -0.0170        0.0109         30.9974  [0.000]
   10  -0.1678  *    -0.2186 **      34.3826  [0.000]
   11  -0.2445  **   -0.1273         41.6475  [0.000]
   12  -0.4919  ***  -0.4123 ***     71.3497  [0.000]
   13  -0.2758  ***   0.1182         80.7864  [0.000]
   14  -0.1084        0.0133         82.2609  [0.000]
   15   0.1440        0.0814         84.8911  [0.000]
   16   0.2074  **    0.1736 *       90.4065  [0.000]
   17   0.2111  **   -0.0669         96.1800  [0.000]
   18   0.1087       -0.0240         97.7293  [0.000]
   19   0.0501       -0.0057         98.0619  [0.000]
   20  -0.0277       -0.1096         98.1646  [0.000]
   21  -0.0259        0.0579         98.2553  [0.000]
   22   0.0088       -0.1141         98.2660  [0.000]
   23  -0.0514       -0.1959 **      98.6322  [0.000]
   24  -0.0011       -0.1626 *       98.6324  [0.000]
   25  -0.0070       -0.0187         98.6395  [0.000]
   26  -0.0212       -0.0203         98.7039  [0.000]
   27  -0.1206        0.0394        100.8234  [0.000]
   28  -0.1810  *     0.0183        105.6582  [0.000]
   29  -0.1639  *    -0.0246        109.6758  [0.000]
   30  -0.0928       -0.0836        110.9795  [0.000]
```

Source: own computation

The image for correlation statistic is correlogram. It is also known as autocorrelation plot.

Graph 5: Correlogram for inflation (the FED, 1st differences)



Source: own computation

Based on the previous analysis, the ARIMA model for inflation rate in the United States was estimated as

ARIMA (1,12),1,24

Figure 15: ARIMA model for the FED

Model 1: ARIMA, using observations 2007:02-2015:12 (T = 107)
Dependent variable: (1-L) Inflation
Standard errors based on Hessian

	Coefficient	*Std. Error*	*z*	*p-value*	
const	−0.0171446	0.0150741	−1.1374	0.2554	
phi_1	0.202924	0.0744725	2.7248	0.0064	***
phi_12	−0.745568	0.103979	−7.1703	<0.0001	***
theta_24	−0.619729	0.177082	−3.4997	0.0005	***

Mean dependent var	−0.013084	S.D. dependent var	0.523211
Mean of innovations	0.005153	S.D. of innovations	0.359741
Log-likelihood	−49.05005	Akaike criterion	108.1001

Schwarz criterion		121.4643	Hannan-Quinn		113.5178
		Real	*Imaginary*	*Modulus*	*Frequency*
AR					
	Root 1	0.2815	0.9821	1.0216	0.2056
	Root 2	0.2815	-0.9821	1.0216	-0.2056
	Root 3	-1.0043	0.2732	1.0408	0.4577
	Root 4	-1.0043	-0.2732	1.0408	-0.4577
	Root 5	0.9734	-0.2552	1.0063	-0.0408
	Root 6	0.9734	0.2552	1.0063	0.0408
	Root 7	-0.7255	-0.7414	1.0373	-0.3733
	Root 8	-0.7255	0.7414	1.0373	0.3733
	Root 9	0.7258	-0.7059	1.0124	-0.1228
	Root 10	0.7258	0.7059	1.0124	0.1228
	Root 11	-0.2509	-0.9996	1.0306	-0.2891
	Root 12	-0.2509	0.9996	1.0306	0.2891
MA					
	Root 1	0.5101	0.8835	1.0201	0.1667
	Root 2	0.5101	-0.8835	1.0201	-0.1667
	Root 3	-1.0201	0.0000	1.0201	0.5000
	Root 4	0.7213	-0.7213	1.0201	-0.1250
	Root 5	0.7213	0.7213	1.0201	0.1250
	Root 6	-0.7213	-0.7213	1.0201	-0.3750
	Root 7	-0.7213	0.7213	1.0201	0.3750
	Root 8	1.0201	0.0000	1.0201	0.0000
	Root 9	-0.9854	-0.2640	1.0201	-0.4583
	Root 10	-0.9854	0.2640	1.0201	0.4583
	Root 11	0.8835	-0.5101	1.0201	-0.0833
	Root 12	0.8835	0.5101	1.0201	0.0833
	Root 13	-0.8835	-0.5101	1.0201	-0.4167
	Root 14	-0.8835	0.5101	1.0201	0.4167
	Root 15	0.0000	1.0201	1.0201	0.2500
	Root 16	0.0000	-1.0201	1.0201	-0.2500
	Root 17	-0.2640	-0.9854	1.0201	-0.2917
	Root 18	-0.2640	0.9854	1.0201	0.2917
	Root 19	0.2640	-0.9854	1.0201	-0.2083
	Root 20	0.2640	0.9854	1.0201	0.2083
	Root 21	0.9854	-0.2640	1.0201	-0.0417
	Root 22	0.9854	0.2640	1.0201	0.0417
	Root 23	-0.5101	-0.8835	1.0201	-0.3333
	Root 24	-0.5101	0.8835	1.0201	0.3333

Source: own computation

Figure 16 shows prediction of the inflation rate in percentage in the United States, estimated

for a year 2016. The table includes also standard error and 95% confidence interval that is of course wider every additional month.

Figure 16: Forecast of inflation in the U.S. for 2016

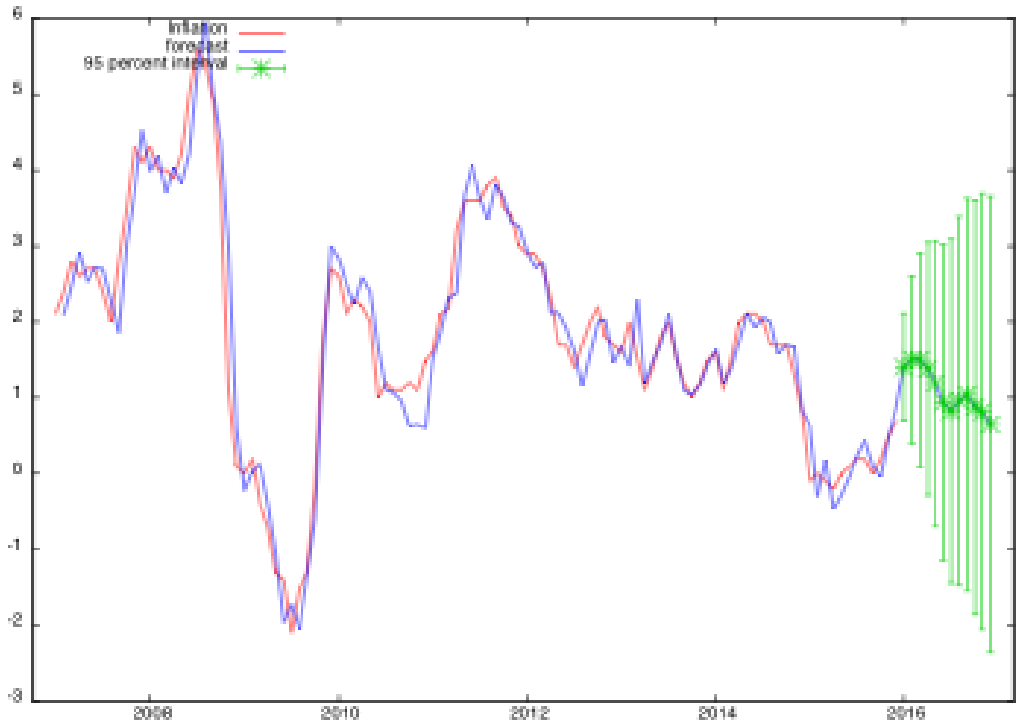
For 95% confidence intervals, z(0.025) = 1.96

Obs	prediction	std. error	95% interval
2016:01	**1.40611**	0.359741	(0.701031, 2.11119)
2016:02	**1.50276**	0.562742	(0.399804, 2.60571)
2016:03	**1.49898**	0.719015	(0.0897309, 2.90822)
2016:04	**1.38320**	0.848521	(-0.279867, 3.04627)
2016:05	**1.18781**	0.961011	(-0.695738, 3.07136)
2016:06	**0.941843**	1.06170	(-1.13905, 3.02274)
2016:07	**0.825785**	1.15365	(-1.43532, 3.08689)
2016:08	**0.960174**	1.23879	(-1.46780, 3.38815)
2016:09	**1.03721**	1.31844	(-1.54689, 3.62131)
2016:10	**0.878100**	1.39355	(-1.85321, 3.60941)
2016:11	**0.820845**	1.46481	(-2.05013, 3.69183)
2016:12	**0.650929**	1.53277	(-2.35324, 3.65510)

Source: own computation

The forecasted data are depicted on graph 6.

Graph 6: Forecast of inflation in the U.S. for 2016



Source: own computation

It is visible on the graph, that according to the researcher prognosis the inflation rate in the United States will be decreasing. The value will oscillate around 1 %, but with declining trend.

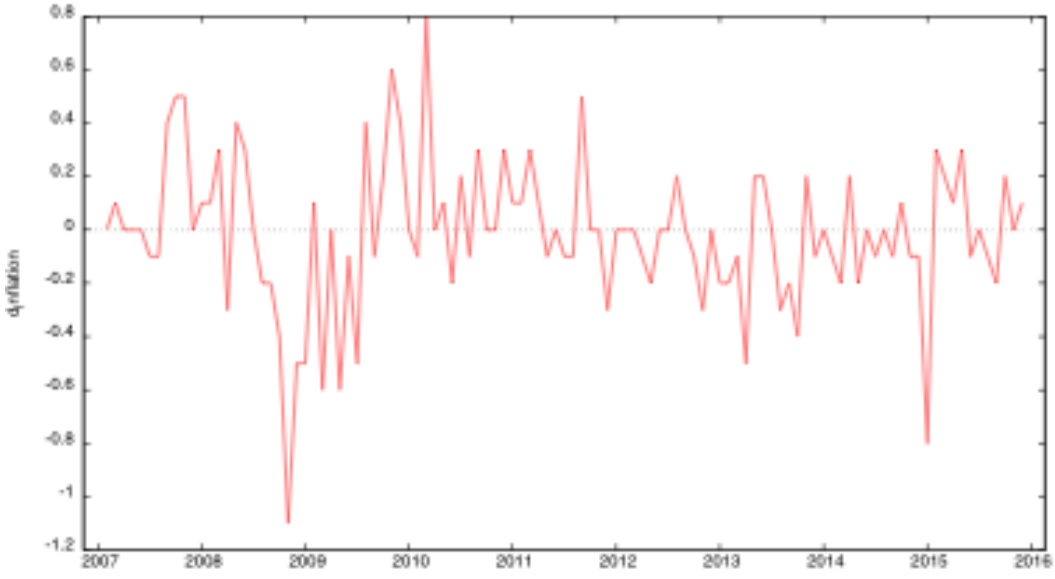
4.5.2.2 Prognosis of the inflation rate in the Euro zone in 2016

The inflation rate data for the European Union were non-stationary and it is depicted on graph 7. On graph 8, there are 1st differences that are stationary. For both graphs, on the axis x there are years from 2007 to 2015 and on the axis y there is inflation rate expressed in percentage.

Graph 7: Inflation – the ECB

Source: own computation

Graph 8: Inflation – the ECB, 1st differences



Source: own computation

As a next step, autocorrelation function was computed, which is shown in figure 17.

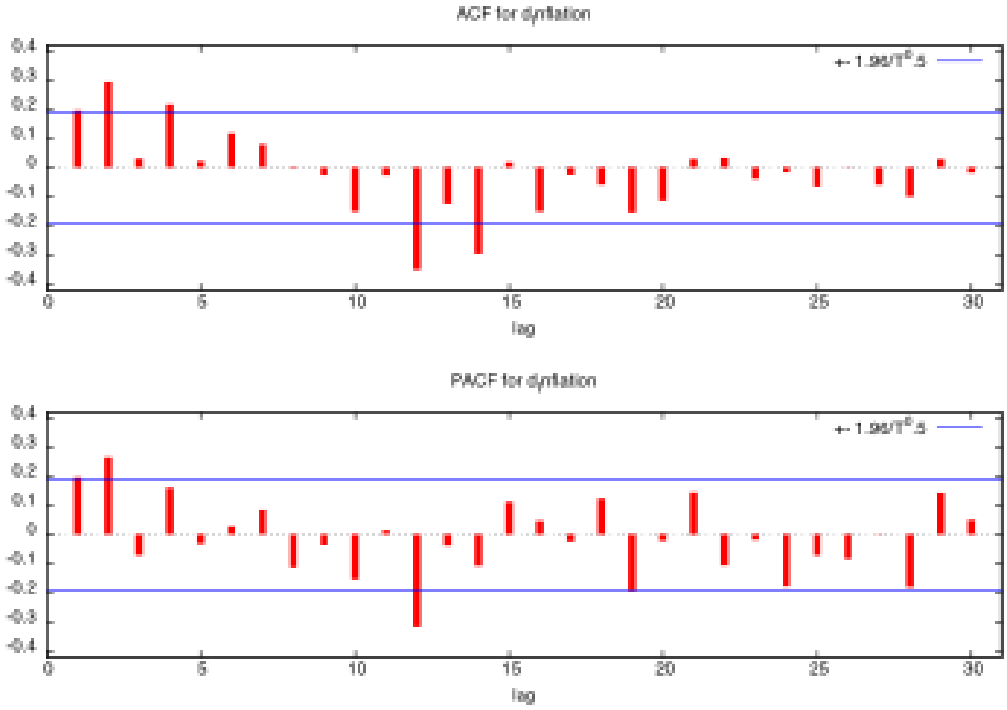
Figure 17: Autocorrelation function for Inflation (the ECB, 1st differences)

Autocorrelation function for d_Inflation
***, **, * indicate significance at the 1%, 5%, 10% levels
using standard error 1/T^0.5

LAG	ACF		PACF		Q-stat.	[p-value]
1	0.1965	**	0.1965	**	4.2497	[0.039]
2	0.2949	***	0.2666	***	13.9114	[0.001]
3	0.0324		-0.0700		14.0291	[0.003]
4	0.2167	**	0.1616	*	19.3469	[0.001]
5	0.0209		-0.0321		19.3967	[0.002]
6	0.1172		0.0275		20.9831	[0.002]
7	0.0803		0.0851		21.7345	[0.003]
8	-0.0040		-0.1140		21.7364	[0.005]
9	-0.0255		-0.0353		21.8140	[0.009]
10	-0.1507		-0.1532		24.5440	[0.006]
11	-0.0262		0.0132		24.6273	[0.010]
12	-0.3508	***	-0.3148	***	39.7380	[0.000]
13	-0.1248		-0.0377		41.6702	[0.000]
14	-0.2947	***	-0.1082		52.5638	[0.000]
15	0.0170		0.1111		52.6006	[0.000]
16	-0.1507		0.0483		55.5099	[0.000]
17	-0.0250		-0.0242		55.5906	[0.000]
18	-0.0573		0.1225		56.0206	[0.000]
19	-0.1544		-0.1930	**	59.1782	[0.000]
20	-0.1140		-0.0215		60.9196	[0.000]
21	0.0307		0.1465		61.0471	[0.000]
22	0.0354		-0.1066		61.2188	[0.000]
23	-0.0381		-0.0181		61.4206	[0.000]
24	-0.0156		-0.1766	*	61.4549	[0.000]
25	-0.0649		-0.0703		62.0548	[0.000]
26	-0.0005		-0.0817		62.0548	[0.000]
27	-0.0575		-0.0010		62.5376	[0.000]
28	-0.1006		-0.1798	*	64.0325	[0.000]
29	0.0299		0.1447		64.1665	[0.000]
30	-0.0173		0.0514		64.2118	[0.000]

Source: own computation

Graph 9: Correlogram for inflation (the ECB, 1st differences)



Source: own computation

Based on the previous analysis, the ARIMA model for the inflation rate in the Euro zone was estimated as

ARIMA (2,12),1,12

Figure 18: ARIMA model for the ECB

Model 1: ARIMA, using observations 2007:02-2015:12 (T = 107)
Dependent variable: (1-L) Inflation
Standard errors based on Hessian

	Coefficient	*Std. Error*	*z*	*p-value*	
const	−0.0191914	0.020036	−0.9578	0.3381	
phi_2	0.211845	0.0998473	2.1217	0.0339	**
phi_12	−0.208049	0.211437	−0.9840	0.3251	
theta_12	−0.209138	0.264106	−0.7919	0.4284	

Mean dependent var	−0.014953	S.D. dependent var	0.280096
Mean of innovations	0.004468	S.D. of innovations	0.247179
Log-likelihood	−3.385163	Akaike criterion	16.77033

Schwarz criterion	30.13447	Hannan-Quinn		22.18797

		Real	*Imaginary*	*Modulus*	*Frequency*
AR					
	Root 1	-0.8258	0.7891	1.1422	0.3786
	Root 2	-0.8258	-0.7891	1.1422	-0.3786
	Root 3	1.0820	-0.2743	1.1162	-0.0395
	Root 4	1.0820	0.2743	1.1162	0.0395
	Root 5	-1.0820	-0.2743	1.1162	-0.4605
	Root 6	-1.0820	0.2743	1.1162	0.4605
	Root 7	-0.3116	-1.1188	1.1614	-0.2932
	Root 8	-0.3116	1.1188	1.1614	0.2932
	Root 9	0.8258	-0.7891	1.1422	-0.1214
	Root 10	0.8258	0.7891	1.1422	0.1214
	Root 11	0.3116	-1.1188	1.1614	-0.2068
	Root 12	0.3116	1.1188	1.1614	0.2068
MA					
	Root 1	-0.5696	-0.9866	1.1393	-0.3333
	Root 2	-0.5696	0.9866	1.1393	0.3333
	Root 3	1.1393	0.0000	1.1393	0.0000
	Root 4	-1.1393	0.0000	1.1393	0.5000
	Root 5	0.5696	-0.9866	1.1393	-0.1667
	Root 6	0.5696	0.9866	1.1393	0.1667
	Root 7	-0.9866	-0.5696	1.1393	-0.4167
	Root 8	-0.9866	0.5696	1.1393	0.4167
	Root 9	0.9866	-0.5696	1.1393	-0.0833
	Root 10	0.9866	0.5696	1.1393	0.0833
	Root 11	0.0000	-1.1393	1.1393	-0.2500
	Root 12	0.0000	1.1393	1.1393	0.2500

Source: own computation

Figure 18 shows prediction of the inflation rate in percentage in the European Union (Euro zone), estimated for a year 2016. The table includes also standard error and 95% confidence interval that is of course wider every additional month.

Figure 19: Forecast of inflation in the Euro zone for 2016

For 95% confidence intervals, z(0.025) = 1.96

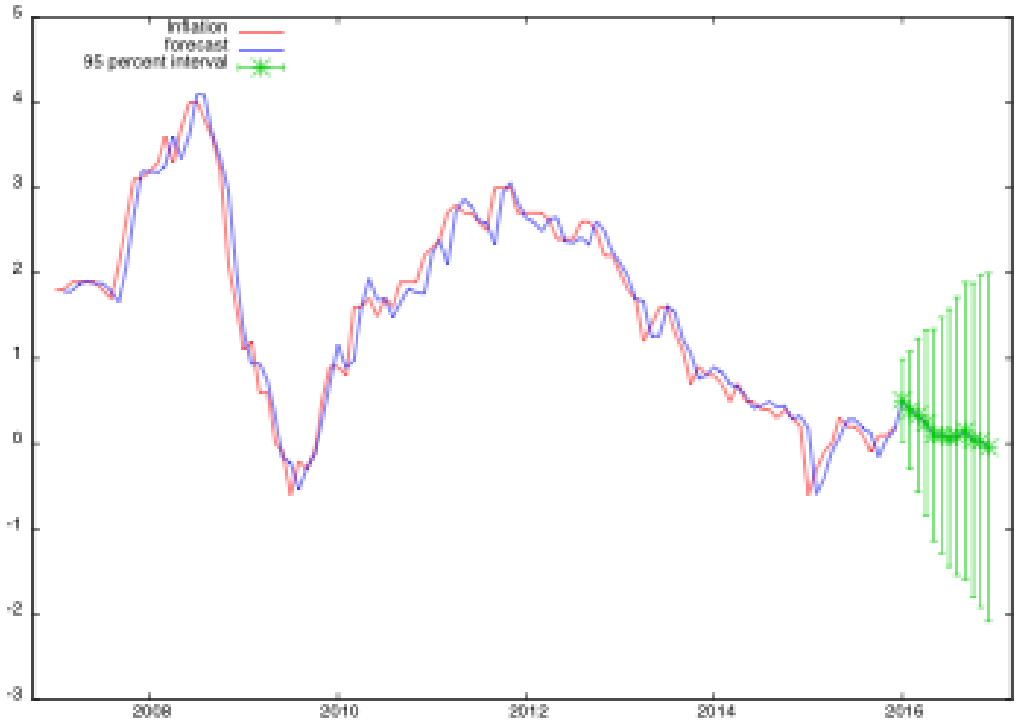
Obs	prediction	std. error	95% interval
2016:01	**0.510010**	0.247179	(0.0255481, 0.994473)

2016:02	**0.388723**	0.349564	(-0.296410, 1.07386)
2016:03	**0.329881**	0.460349	(-0.572386, 1.23215)
2016:04	**0.242256**	0.549224	(-0.834203, 1.31872)
2016:05	**0.101957**	0.630984	(-1.13475, 1.33866)
2016:06	**0.102606**	0.703304	(-1.27584, 1.48106)
2016:07	**0.0692352**	0.769803	(-1.43955, 1.57802)
2016:08	**0.0876657**	0.830997	(-1.54106, 1.71639)
2016:09	**0.150856**	0.888160	(-1.58991, 1.89162)
2016:10	**0.0411594**	0.941860	(-1.80485, 1.88717)
2016:11	**0.0264504**	0.992692	(-1.91919, 1.97209)
2016:12	**-0.0429801**	1.04105	(-2.08339, 1.99743)

Source: own computation

The forecasted data are depicted on graph 10.

Graph 10: Forecast of inflation in the Euro zone for 2016



Source: own computation

It is visible on the graph, that according to the researcher prognosis the inflation rate in the European Union will be decreasing. The value will be approaching 0 %, in December 2016 the inflation could even reach a negative value which means deflation.

4.5.3 Cointegration

The analysis of time series is possible if these time series are cointegrated. When the time series are not cointegrated it means they have different direction of development. Such time series cannot be analyzed with regression, since phenomenon called spurious regression might occur. One of the method how to distinguish regression and spurious regression is, for instance Engle-Granger test of cointegration. A group of cointegrated time series can be described by the error correction model, which can differ long-term and short-term relationships between time series.[108] For economical and financial time series, it is often possible to create a linear combination of non-stationary time series with the result of stationary time series. This case is called cointegration, which may be explained as a relationship of long-run equilibrium between economic quantities. Individual time series are non-stationary, but their cointegration movement is oriented to a certain state of equilibrium in a long-term.[109]

Depending on the proposed extent of this diploma thesis author presupposes cointegration of all the time series used in this thesis. Thus, this thesis works on the assumption that all the time series are cointegrated and these time series can be analyzed with regression.

4.6 Econometric model

To work with OLS regression in a time series context, we add several assumptions to those made in the context of a cross section model. First, we assume that the set of variables [x, y] is stationary and weakly dependent. Stationary is not critical in this context, but weak dependence is very important.[110]

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[108] ARLT, Josef a Markéta ARLTOVÁ. *Ekonomické časové řady*. V Professional Publishing vyd. 1. Praha: Professional Publishing, 2009, 290 s. ISBN 978-80-86946-85-6.

[109] CIPRA, Tomáš. *Finanční ekonometrie*. 2., upr. vyd. Praha: Ekopress, 2013, 538 s. ISBN 978-80-86929-93-4.

[110] Financial Econometrics, Spring 2013: *OLS with time series data* [online] <http://fmwww.bc.edu/ec-c/s2013/327/EC327.S2013.nn3.pdf> [Accessed 12.2.2016]

4.6.1 Regression model I. - the FED

Formulation of economic model

The inflation rate is influenced by many factors such as monetary policies, fiscal policies, speculation about future inflation, declining productivity, higher taxes, increase of raw material prices, rising wages, import prices, people's expectations, information, political situation in the country, global conflicts and crises etc. This model covers only central bank's monetary policy tools that influence the inflation rate. These are federal funds rate (FFR), discount rate, exchange rate, required reserves (RR) and open market operations (OMO). All these tools do not influence inflation directly, but with different lags.

Assumption in the model

If the interest rate decreases, the inflation rate increases.

If the exchange rate decreases (depreciation), the inflation rate increases.

If the minimum reserve requirements decrease, the inflation rate increases.

If the amount of open market operations (repurchase agreement held by the FED) increases, the inflation rate increases.

Formulation of econometrics model:

$$y_{1t} = \gamma_1 x_{1t} + \gamma_2 x_{2t} + \gamma_3 x_{3t} + \gamma_4 x_{4t} + \gamma_5 x_{5t} + \gamma_6 x_{6t} + u_{1t}$$

Declaration of variables:

y1 ……inflation rate (%)

x1 ……...unit vector

x2……Federal Funds Rate (%)

x3……Discount Rate (%)

x4……exchange rate USD/EUR

x5……required reserves (billions USD)

x6……open market operations (repurchase agreement held by the FED; billions USD)

For all variables 96 observations were included.

A multiple regression model does not express the structure of relationships between independent variables. Multiple regression detects the power of influence of each independent variable on the dependent variable and shows how much of the variance of the dependent variable is explained by the independent variables. The model determines the relative strength of the independent variables on the dependent variable and also which variables have the greatest impact on the variance of the dependent variable.

The method used for this model was to eliminate statistically nonsignificant variables in the model. From the first model, which included all the variables with lags from 1 to 12, all the nonsignificant variables were removed one by one, thus the model includes only statistically significant variables. This regression model simulates only the variables, which affect the price level and which are influenced by central banks, meaning this model simulates the inflation rate from a statistical perspective. From an economic view, this regression is not that precise, because there are many inflation influencing factors apart from the monetary policy, such as speculations, import prices, people's expectations, information, political situation in the country, global conflicts and crises etc.

The regression model of the price level in the United States between the years 2007 and 2014 simulates the influence of the Federal Reserve System's monetary policy on the price level.

Since monetary policy tools usually do not affect the inflation immediately, lagged variables from 1 to 12 were included.

The Federal Reserve System

Figure 20: OLS model with dependent variable Inflation – the FED

Model 39: OLS, using observations 2008:02-2014:12 (T = 83)
Dependent variable: d_Inflation

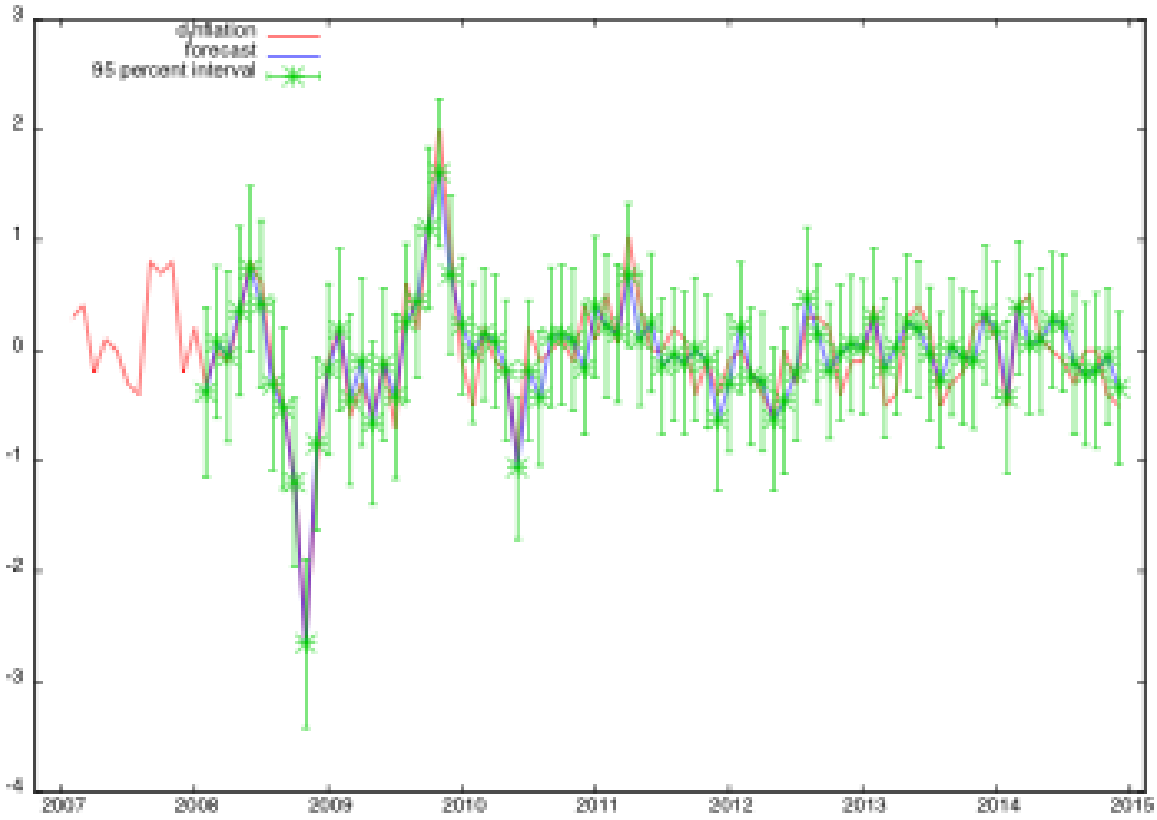
	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	0.309497	0.0626943	4.9366	<0.0001	***
d_FFR	0.929861	0.268135	3.4679	0.0010	***
d_FFR_2	2.07658	0.489828	4.2394	<0.0001	***
d_FFR_3	2.82063	0.625443	4.5098	<0.0001	***

d_FFR_5	4.50258	0.617652	7.2898	<0.0001	***
d_FFR_6	1.88152	0.46005	4.0898	0.0001	***
d_FFR_7	1.16941	0.39398	2.9682	0.0044	***
d_FFR_9	1.86155	0.355556	5.2356	<0.0001	***
d_FFR_10	−1.89062	0.373773	−5.0582	<0.0001	***
d_discountrate_3	−1.78589	0.370997	−4.8137	<0.0001	***
d_discountrate_4	−3.99731	0.527321	−7.5804	<0.0001	***
d_discountrate_5	−1.45749	0.324157	−4.4963	<0.0001	***
d_discountrate_6	−1.46713	0.320482	−4.5779	<0.0001	***
d_discountrate_7	−1.22265	0.260042	−4.7017	<0.0001	***
d_discountrate_12	−1.24817	0.241764	−5.1628	<0.0001	***
d_USDEUR	−6.53727	1.95055	−3.3515	0.0015	***
d_USDEUR_4	−5.56747	2.01964	−2.7567	0.0079	***
d_USDEUR_6	−9.91163	1.94456	−5.0971	<0.0001	***
d_USDEUR_8	−5.56657	2.01435	−2.7635	0.0078	***
d_RR	0.0434833	0.0133543	3.2561	0.0019	***
d_RR_1	−0.0358879	0.014532	−2.4696	0.0167	**
d_RR_3	−0.073665	0.0150697	−4.8883	<0.0001	***
d_RR_8	−0.057785	0.0138888	−4.1606	0.0001	***
d_RR_9	−0.0547488	0.0151754	−3.6077	0.0007	***
d_RR_11	−0.0254285	0.0147337	−1.7259	0.0900	*
d_OMO_1	−0.000918392	0.00036437	−2.5205	0.0146	**
d_OMO_4	0.000933002	0.000393679	2.3700	0.0213	**
d_OMO_9	0.00113848	0.000409887	2.7776	0.0075	***

Mean dependent var	−0.042169	S.D. dependent var	0.556319
Sum squared resid	4.464734	S.E. of regression	0.284916
R-squared	0.824072	Adjusted R-squared	0.737708
F(27, 55)	9.541783	P-value(F)	1.44e-12
Log-likelihood	3.517284	Akaike criterion	48.96543
Schwarz criterion	116.6930	Hannan-Quinn	76.17456
rho	−0.014275	Durbin-Watson	2.021402

Source: own computation

Graph 11: OLS model with dependent variable Inflation – the FED



Source: own computation

OLS model, the output of Gretl

The parameter's estimation is shown in the second column of the Gretl output.

y_{1t} = 0.309 x_{1t} + 0.929x_{2t} + 2.076x_{2t-2} + 2.820x_{2t-3} + 4.502x_{2t-5} + 1.881x_{2t-6} + 1.169x_{2t-7} + 1.861x_{2t-9} - 1.890x_{2t-10} - 1.785x_{3t-3} - 3.997x_{3t-4} - 1.457$_{3t-5}$ - 1.467x_{3t-6} - 1.222x_{3t-7} - 1.248x_{3t-12} - 6.537x_{4t} - 5.567x_{4t-4} - 9.911x_{4t-6} - 5.566x_{4t-8} + 0.043x_{5t} - 0.035x_{5t-1} - 0.073x_{5t-3} - 0.057x_{5t-8} - 0.054x_{5t-9} - 0.025x_{5t-11} + 0.001x_{6t-9} +u_{1t}

Model verification

- *No multicollinearity*

One of the model assumptions is no multicollinearity, which was confirmed by the correlation matrix. Numbers in the matrix show the correlation among the explanatory variables in the equation. The number that is greater than 0.8 in absolute value denotes multicollinearity. In this matrix, non of the explanatory variables exceeds the level of strong correlation.

Figure 21: Correlation matrix

Correlation coefficients, using the observations 2007:02 - 2014:12
5% critical value (two-tailed) = 0.2017 for n = 95

d_FFR	d_discountrate	d_USDEUR	d_RR	d_OMO	
1.0000	0.5419	-0.1390	-0.0493	-0.0525	d_FFR
	1.0000	0.0844	-0.0542	-0.1188	d_discountrate
		1.0000	0.0836	0.1296	d_USDEUR
			1.0000	0.2584	d_RR
				1.0000	d_OMO

source: own computation

- *No heteroskedasticity*

White's test is used for testing of heteroskedasticity. Hypothesis of White's test:

H_0: homoskedasticity

H_1: heteroskedasticity

Since p-value is greater than level of significance, null hypothesis cannot be rejected, which means there is homoscedasticity in this model.

Figure 22: White's test for heteroskedasticity

White's test for heteroskedasticity -
Null hypothesis: heteroskedasticity not present
Test statistic: LM = 42.8001
with p-value = P(Chi-square(54) > 42.8001) = 0.863765

Source: own computation

- *No autocorrelation*

H_0: no autocorrelation

H_1: autocorrelation is present

Since p-value is greater than level of significance, null hypothesis cannot be rejected, which means there is no autocorrelation in this model.

Figure 23: Test for autocorrelation

```
LM test for autocorrelation up to order 12 -
 Null hypothesis: no autocorrelation
 Test statistic: LMF = 1.95903
 with p-value = P(F(12, 43) > 1.95903) = 0.0633581
```

Source: own computation

- *Variables have normal distribution*

Test for null hypothesis of normal distribution

H_0: error is normally distributed

H_1: error is not normally distributed

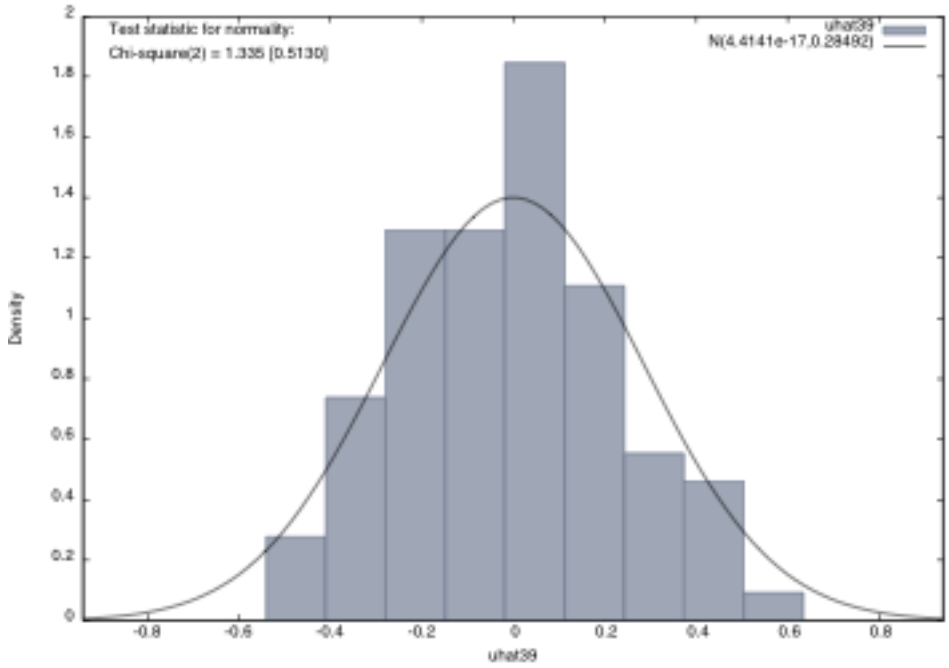
Test for normality of residual validates null hypothesis, because p-value is greater than the significance level α (α=0.05).

Figure 24: Test for null hypothesis of normal distribution

```
Test for normality of residual -
 Null hypothesis: error is normally distributed
 Test statistic: Chi-square(2) = 1.33514
 with p-value = 0.512952
```

Source: own computation

Graph 12: Test for null hypothesis of normal distribution



Source: own computation

- *Coefficient of determination – R-squared*

The determination coefficient R^2 is the percentage way of the behavior of the model.
The result of 0.824072 means that 82.41 % of variability of the dependent variable (inflation rate) is explained by the behavior of the explanatory variables.

- *Statistical significance of parameters*

The statistical significance of parameters is being determined by basic comparison of the Gretl test p-values with the chosen level of significance α value. In this model, the statistical significance of 95%, meaning that α = 0.05, is being compared. In basic explanation, smaller the p-value of the Gretl testing is, the bigger is the significance of the statistical outcome. Moreover, statistical significance is depicted by stars next to the Gretl outcome's p-values, showing also the actual level of significance. This regression model is designed to work only with statistically significant parameters, thus all the parameters in the model are statistically significant.

Model application

An intensity of explanatory variables influence on endogenous variables can be expressed by the relative expression on base of elasticity coefficients. Elasticity is the measurement of how responsive an economic variable is to a change in another. This expresses the influence on dependent variable if explanatory variable changes by 1%.

$$E = \delta y / \delta x * x / y \ [\%]$$

The model estimation results allowed us to calculate an average elasticities for the case of the price level in the United States. This elasticity was calculated by taking the estimated parametr from OLS model multiply by the average of lagged data for the relevant independent variable divided by the average of matrixes, which were calculated by multiplying the data value for the relevant month of the year and all the estimated parameters.

The resulting average elasticity for federal funds rate is −0.020197. That is, a 1% increase in the federal founds rate is expected to lower the inflation rate in about 0.020197%.

The resulting average elasticity for the discount rate is -0.045302. That is, a 1% increase in the discount rate is expected to decrease the inflation rate in about 0.045302%.

The resulting average elasticity for USD/EUR exchange rate is -0.100537. That is, a 1% increase in the USD/EUR exchange rate (appreciation) is expected to decrease the inflation rate in about 0.100537%.

The resulting average elasticity for reserve requirement is −0.078725. That is, a 1% increase in the reserve requirements is expected to increase the inflation rate in about 0.078725%. This is an opposite effect that expected according to economic theory.

The resulting average elasticity for open market operations is 0.021513. That is, a 1% increase in the open market operations is expected to increase the inflation rate in about 0.021513%.

Figure 25: Average elasticities of the relevant independent variables

-0.020197	-0.045302	-0.100537	0.078725	0.021513
FFR	discount rate	USD/EUR	RR	OMO

source: own computation

4.6.2 Regression model II. - the ECB

Formulation of economic model

There are the same rules for the European Central Bank as for the Federal reserve System. The inflation rate is influenced by many factors such as monetary policies, fiscal policies, speculation about future inflation, people's expectations and other factors mentioned above. This model covers only central bank's monetary policy tools that influence the inflation rate. These are main refinancing rate (MRR), marginal lending rate (MLR), exchange rate, required reserves (RR) and open market operations (OMO). All these tools do not influence inflation directly, but with different lags.

Assumption in the model

If the interest rate decreases, the inflation rate increases.

If the exchange rate increases (appreciation), the inflation rate decreases.

If the minimum reserve requirements decrease, the inflation rate increases.

If the amount of open market operations (main refinancing operations) increases, the inflation rate increases.

Formulation of econometrics model:

$$y_{1t} = \gamma_1 x_{1t} + \gamma_2 x_{2t} + \gamma_3 x_{3t} + \gamma_4 x_{4t} + \gamma_5 x_{5t} + \gamma_6 x_{6t} + u_{1t}$$

Declaration of variables:

y1 ……inflation rate (%)

x1 ……...unit vector

x2……Main Refinancing Rate (%)

x3……Marginal Lending Rate (%)

x4……exchange rate EUR/USD

x5……required reserves (%)

x6……open market operations (main refinancing operations; billions EUR)

For all variables 96 observations were included.

The regression model of the price level in the Euro zone between the years 2007 and 2014 simulates the influence of the European Central Bank's monetary policy on the price level. Since monetary policy tools usually do not affect the inflation immediately, lagged variables from 1 to 12 were included.

The European Central Bank

Figure 26: OLS model with dependent variable Inflation – the ECB

Model 43: OLS, using observations 2008:02-2014:12 (T = 83)
Dependent variable: d_Inflation

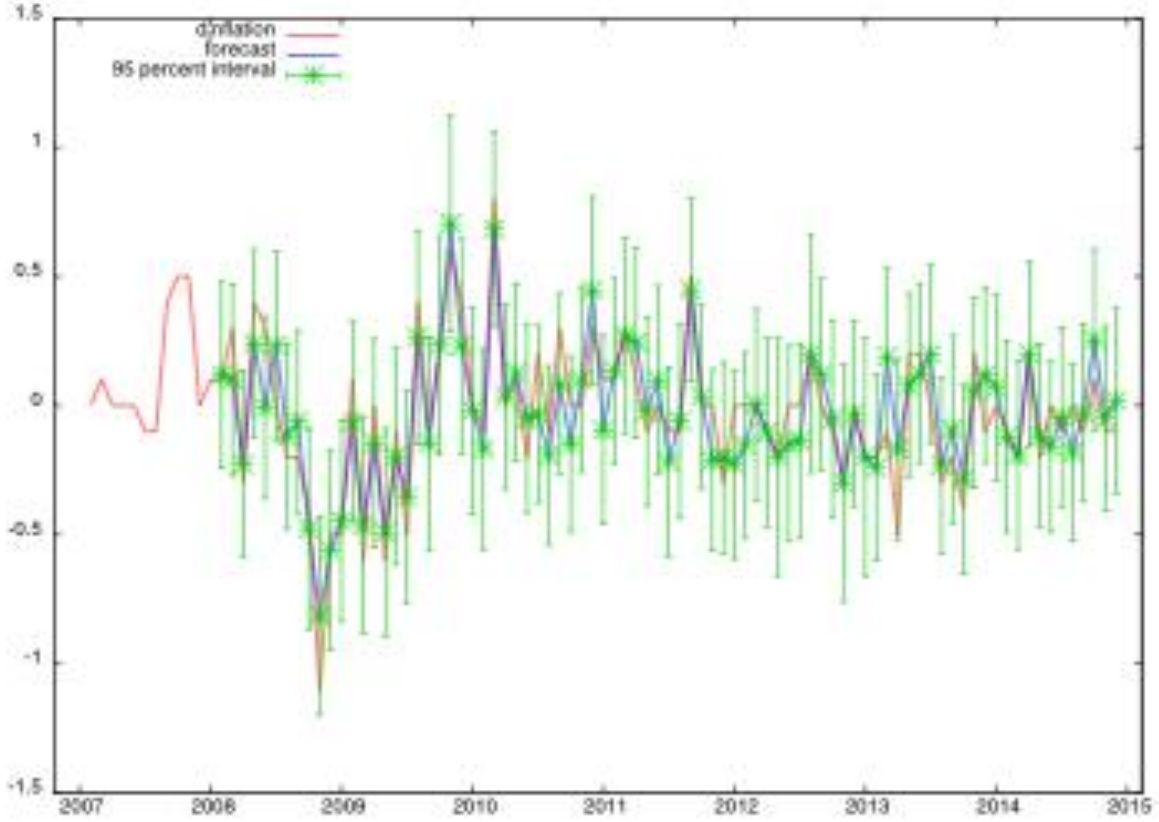
	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	0.032015	0.0227942	1.4045	0.1657	
d_MRR	0.885929	0.138138	6.4134	<0.0001	***
d_MRR_6	1.30828	0.296105	4.4183	<0.0001	***
d_MRR_9	−0.60851	0.320635	−1.8978	0.0629	*
d_MRR_10	0.593794	0.219448	2.7059	0.0090	***
d_MRR_11	−0.435475	0.172817	−2.5199	0.0146	**
d_MRR_12	−0.430413	0.157759	−2.7283	0.0085	***
d_MLR_4	−0.39329	0.142624	−2.7575	0.0078	***
d_MLR_5	0.510257	0.151764	3.3622	0.0014	***
d_MLR_6	−0.801581	0.256057	−3.1305	0.0028	***
d_MLR_8	−0.366259	0.151975	−2.4100	0.0193	**

d_MLR_9	0.892948	0.250549	3.5640	0.0008	***
d_EURUSD_3	−1.47964	0.468803	−3.1562	0.0026	***
d_EURUSD_5	1.0119	0.505001	2.0038	0.0499	**
d_EURUSD_8	−2.61334	0.609587	−4.2871	<0.0001	***
d_EURUSD_9	−1.74954	0.52656	−3.3226	0.0016	***
d_EURUSD_10	−0.931321	0.491974	−1.8930	0.0635	*
d_EURUSD_12	−1.75545	0.522075	−3.3625	0.0014	***
d_RR_4	0.413763	0.188825	2.1912	0.0326	**
d_RR_7	0.454247	0.20219	2.2466	0.0286	**
d_RR_10	0.798965	0.180081	4.4367	<0.0001	***
d_RR_12	0.320176	0.181996	1.7592	0.0840	*
d_OMO	0.000290583	0.000123814	2.3469	0.0225	**
d_OMO_3	−0.000318013	0.000118421	−2.6854	0.0095	***
d_OMO_7	−0.0003363	0.000116615	−2.8838	0.0056	***
d_OMO_8	−0.000713976	0.000109622	−6.5131	<0.0001	***
d_OMO_11	0.000239889	0.000112993	2.1230	0.0382	**

Mean dependent var	−0.036145	S.D. dependent var	0.282661
Sum squared resid	1.471985	S.E. of regression	0.162128
R-squared	0.775323	Adjusted R-squared	0.671009
F(26, 56)	7.432570	P-value(F)	2.09e-10
Log-likelihood	49.56558	Akaike criterion	−45.13117
Schwarz criterion	20.17753	Hannan-Quinn	−18.89379
rho	−0.109046	Durbin-Watson	2.206209

Source: own computation

Graph 13: OLS model with dependent variable Inflation – the ECB



Source: own computation

OLS model, the output of Gretl

The parameter's estimation is shown in the second column of the Gretl output.

$y_{1t} = 0.032\ x_{1t} + 0.885x_{2t} + 1.308x_{2t-6} - 0.608x_{2t-9} + 0.593x_{2t-10} - 0.435x_{2t-11} - 0.430x_{2t-12} - 0.393x_{3t-4} - 0.510x_{3t-5} - 0.801x_{3t-6} - 0.366_{3t-8} + 0.892x_{3t-9} - 1.479x_{4t-3} + 1.0119x_{4t-5} - 2.613x_{4t-8} - 1.749x_{4t-9} - 0.931x_{4t-10} - 1.755x_{4t-12} + 0.413x_{5t-4} + 0.454x_{5t-7} - 0.798x_{5t-10} - 0.320x_{5t-12} + u_{1t}$

Model verification

One of the model assumptions is no multicollinearity, which was confirmed by the correlation matrix. Numbers in the matrix show the correlation among the explanatory variables in the

equation. The number that is greater than 0.8 in absolute value denotes multicollinearity. In this matrix, non of the explanatory variables exceeds the level of strong correlation.

Figure 27: Correlation matrix

Correlation coefficients, using the observations 2007:02 - 2014:12
5% critical value (two-tailed) = 0.2017 for n = 95

d_MRR	d_MLR	d_EURUSD	d_RR	d_OMO	
1.0000	0.7184	0.1412	-0.0318	-0.0042	d_MRR
	1.0000	0.2802	-0.0274	-0.0726	d_MLR
		1.0000	-0.0268	-0.0555	d_EURUSD
			1.0000	0.1726	d_RR
				1.0000	d_OMO

source: own computation

- *No heteroskedasticity*

White's test is used for testing of heteroskedasticity. Hypothesis of White's test:

H_0: homoskedasticity

H_1: heteroskedasticity

Since p-value is greater than level of significance, null hypothesis cannot be rejected, which means there is homoscedasticity in this model.

Figure 28: White's test for heteroskedasticity

White's test for heteroskedasticity -
Null hypothesis: heteroskedasticity not present
Test statistic: LM = 45.3828
with p-value = P(Chi-square(48) > 45.3828) = 0.580711

Source: own computation

- *No autocorrelation*

H_0: no autocorrelation

H_1: autocorrelation is present

Since p-value is greater than level of significance, null hypothesis cannot be rejected, which means there is no autocorrelation in this model.

Figure 29: Test for autocorrelation

```
LM test for autocorrelation up to order 12 -
 Null hypothesis: no autocorrelation
 Test statistic: LMF = 0.471511
 with p-value = P(F(12, 44) > 0.471511) = 0.920692
```

Source: own computation

- *Variables have normal distribution*

Test for null hypothesis of normal distribution

H_0: error is normally distributed

H_1: error is not normally distributed

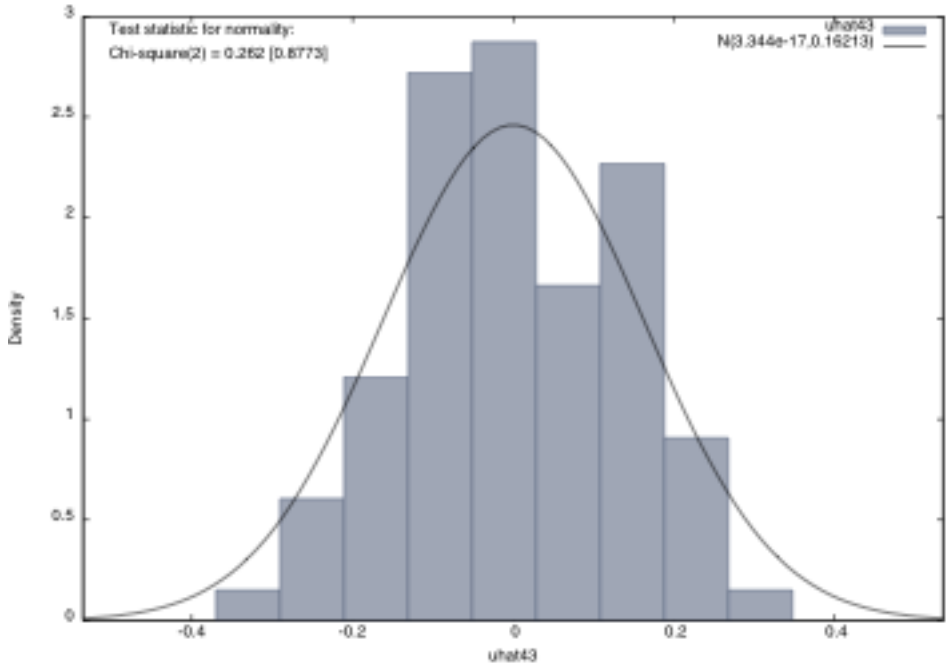
Test for normality of residual validates null hypothesis, because p-value is greater than the significance level α (α=0.05).

Figure 30: Test for null hypothesis of normal distribution

```
Test for normality of residual -
 Null hypothesis: error is normally distributed
 Test statistic: Chi-square(2) = 0.261792
 with p-value = 0.877309
```

Source: own computation

Graph 14: Test for normality



Source: own computation

- *Coefficient of determination – R-squared*

The determination coefficient R^2 is the percentage way of the behavior of the model.
The result of 0.775323 means that 77.53 % of variability of the dependent variable (inflation rate) is explained by the behavior of the explanatory variables.

- *Statistical significance of parameters*

The statistical significance of parameters is being determined by basic comparison of the Gretl test p-values with the chosen level of significance α value. In this model, the statistical significance of 95%, meaning that α = 0.05, is being compared. In basic explanation, smaller the p-value of the Gretl testing is, the bigger is the significance of the statistical outcome. Moreover, statistical significance is shown by stars next to the Gretl outcome p-values, showing also the actual level of significance. This regression model is designed to work only with statistically significant parameters, thus all the parameters in the model are statistically significant.

Model application, economic verification

The resulting average elasticity for main refinancing rate is −0.011769. That is, a 1% increase in the main refinancing rate is expected to lower the inflation rate in about 0.011769 %.

The resulting average elasticity for marginal lending rate is -0. 060265. That is, a 1% increase in the marginal lending rate is expected to decrease the inflation rate in about 0.060265 %.

The resulting average elasticity for USD/EUR exchange rate is -0.094641. That is, a 1% increase in the USD/EUR exchange rate (appreciation) is expected to decrease the inflation rate in about 0.094641 %.

Figure 31: Average elasticities of the relevant independent variables

-0.011769	-0.060265	-0.094641	0.036171	0.011632
MRR	MLR	EUR/USD	RR	OMO

Source: own computation

The resulting average elasticity for reserve requirement is 0.036171. That is, a 1% increase in the reserve requirements is expected to increase the inflation rate in about 0.036171 %. This is an opposite effect than expected, according to economic theory.

The resulting average elasticity for open market operations is 0.011632. That is, a 1% increase in the open market operations is expected to increase the inflation rate in about 0.011632 %.

5. Results and discussion

The primary goal of the diploma thesis was to identify and compare the anti-crisis measures of the Federal Reserve System and the European Central Bank, and to evaluate their impact on the development of the price level in the European Union and the United States. The results and discussion of the thesis are supposed to answer the research questions:

"Which central bank was more successful in influencing the development of basic economic indicators during the financial crisis of 2007-2008? The Federal Reserve System or the European Central Bank?"

"Which central bank had a larger impact on the development of the price level during the financial crisis?"

These research questions are answered mainly on the basis of the research done in the practical part of this diploma thesis. The research was divided into three parts. First part was the comparisons of the steps made by the FED and the ECB during and after the financial crisis, regarding the calculation of coefficient of variation. The second part of the diploma thesis was dedicated to the autoregressive integrated moving average model and the prognosis of the monthly inflation rate for the United States and the European Union for the year 2016 was calculated. The third part of the research was focused on the monetary policy tool influencing the price level. This was expressed by regression models and elasticities computation. The comparison of the success of the particular monetary policy tool was expressed by the comparison of the individual elasticity coefficients. Also the determination coefficient R^2 was considered as one of the criterion of the regression models and the comparison of both models was performed.

The calculation of the coefficient of variation was employed to evaluate activities of central banks that relate to interest rates, namely the federal funds rate and main refinancing rate were compared. The activity of central bank was expressed by the calculation of the coefficient of variation of the interest rate for three periods. First period is a beginning of the financial crisis

until the fall of Lehman Brothers. Second period is until the end of the year 2009 and third period is after the crisis from the year 2010 until the end of 2014. The value approaching to number 1 indicates a high activity of central bank in terms of changes in interest rates, while a value close to 0 indicates almost no activity. The figures from Figure 9 follow that the Federal Reserve System was significantly more active in its monetary activities regarding interest rates, the variation coefficient reached 0.9 during the crisis. In the very beginning of the crisis, even during the crisis, the Federal Reserve System was much more active than the European Central Bank, since the variation coefficients were significantly greater for the Fed. On the other hand, after the height of the crisis, the ECB was slightly more active than the Fed, which evidences the late response of the European Central Bank to the financial crisis.

This might be caused by the fact that for the ECB the main monetary policy goal is only the stable price level, on the other hand, for the Fed the monetary policy goals are besides the stable price level also stable economic growth. Another reason of highest activity might be the fact that the Fed has simpler and flexible decision making system, so the decisions and the following steps can be implemented faster. The ECB in its action does not react to short-term deviations, and thinks more in the long run.

In the practical part of the diploma thesis the autoregressive integrated moving average model was performed. It is a forecasting technique that projects the future values of a series based entirely on its own inertia. The inflation rate for the year 2016 in the United States and the European Union was forecasted. Forecasting of inflation is very important for the financial planning, budgeting, investments, spendings, savings etc. Inflation rate is crucial for all actors in the economy, households, companies, state. Without an exact measure of the inflation rate, it is not possible to accurately plan all the expenses. According to the prognosis done in this diploma thesis, the inflation rate will be decreasing in both countries. This would be an unpleasant issue, since the optimal inflation rate is around 2 %. Based on the prognosis, in the United States the rate of inflation could increase a little in the beginning of the year and then oscillate around 1 % and in the end of the year 2016 the price level could possibly drop to 0.6 %. The inflation rate in the Euro zone, according to the forecast done in this diploma thesis,

will be decreasing and at the end of the year 2016 could even drop below 0 %, which means negative inflation rate.

Even though, it is not possible to compare real values of the monthly inflation rate in the U.S. and the EU, since the year 2016 is still running, the values for January are quite close to the estimated values of the prognosis. The inflation rate in the United States in January 2016 was 1.4 %[111], which is exactly the same number as it was calculated in the prognosis in this diploma thesis. The inflation rate in the European Union in January 2016 was 0.3 %[112], which is slightly lower number than it was calculated in the prognosis in this diploma thesis.

To conclude the autoregressive integrated moving average model which was performed in this diploma thesis, the estimate is that in the future, meaning in the year 2016, more favourable price level will be in the United States. This is partly influenced by a central bank, thus it could be assumed that the Federal Reserve System will be more successful in affecting the price level.

As a third part of the research, the regression models were performed. The inflation rate is influenced by many factors such as monetary policies, fiscal policies, speculation about future inflation, declining productivity, higher taxes, increase of raw material prices, rising wages, import prices, people's expectations, information, political situation in the country, global conflicts and crises etc. These models cover only central bank's monetary policy tools that influence the inflation rate. Both models had a very high coefficient of determination, which is used to measure the accuracy of the model. It is the measure how well the least squares equation performs as a predictor of the dependent variable.[113] The result of the FED's model was 0.824072, which means that 82.41 % of variability of the dependent variable (inflation rate) was explained by the behavior of the explanatory variables. The result of the EU's model was 0.775323, which means that 77.53 % of variability of the dependent variable (inflation rate) was explained by the behavior of the explanatory variables. Based on this criterion, the

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111 US Inflation Calculator [online] <http://www.usinflationcalculator.com/inflation/historical-inflation-rates/> [Accessed 29.2.2016]

112 The European Central Bank, (2016). *Inflation Dashboard.* [online] <https://www.ecb.europa.eu/stats/prices/hicp/html/inflation.en.html> [Accessed 19.2.2016]

113 Coefficient of determination, Iowa State University [online] <http://www.public.iastate.edu/~alicia/stat328/Regression%20inference-part3.pdf> [Accessed 13.3.2016]

Federal Reserve System's model has a better result.

As an important tool for comparing the impact of the central banks to the price level, the elasticity coefficients were calculated. An intensity of explanatory variables influence on endogenous variables can be expressed by the relative expression on base of elasticity coefficients. Elasticity is the measurement of how responsive an economic variable is to a change in another. For better comparison, the results are stated again, this time in one table, where values of the elasticities are depicted.

Figure 32: Average elasticities of the relevant independent variables the FED vs. the ECB

	FFR X MRR	Discount rate X MLR	USD/EUR X EUR/USD	RR	OMO
The FED model	-0.020197	-0.045302	-0.100537	~~0.078725~~	0.021513
The ECB model	-0.011769	-0.060265	-0.094641	~~0.036171~~	0.011632

source: own computation

The higher value of the elasticity coefficient, the higher influence of the monetary policy tool on the price level in a given area. As the most successful tool, the exchange rate can be pronounced. This indicator is influenced by a central bank only partly. Among other factors that affect exchange rate are for instance, political stability or economic performance of the country. As from the number the table provides, it is possible to say, that the Federal Reserve System was able to affect the price level more than the European Central Bank. The influence was stronger for three monetary policy tools. Last but not least, the reserve requirements must be mentioned, since it had an opposite effect than expected according to the economic theory. That is why the reserve requirements could not be included in the overall evaluation. The reason might be that it is very complicated to find accurate data from relevant sources for this indicator the ECB was more successful only in the marginal lending rate indicator.

Based on the research done in this diploma thesis, the Federal Reserve System was probably more successful in influencing the price level and had stronger impact on this indicator. The financial crisis began in the United States and it had a very fast and strong progress. The

Federal Reserve System has more simple and flexible decision making system, so the decisions and the following steps could be implemented faster. The Federal Reserve System intervened in American economy more often and also injected more money into anti-crisis measures. In general, the United States are much more compact entity than the European Union, regarding history, politics, finance. These might be some of the reasons why the Federal Reserve System was more successful than the European Central Bank in influencing the price level.

The financial crisis of 2007-2008, also known as Global Financial Crisis, was the worst financial crisis since the Great Depression in 1930s. The crisis caused reduction of total economic output, job loss and additional government spendings. Even six years after the financial crisis, some parts of the economy have not fully recovered. Nowadays, there are some opinions that the world's economy is under the threat of financial crisis again. The risk of a global financial crash has increased because a slowdown in China and decline in world trade are undermining the stability of highly indebted emerging economies. In the fourth quarter of 2015 the International Monetary Fund downgraded its forecast for global growth in 2015 to 3.1%, which would mark the weakest performance since the trough of the downturn in 2009.[114]

The recommendation to central banks could be the implementation of preventive anti-crisis measures and early and strong responses to warning indicators.

[114] The Guadian [online] <http://www.theguardian.com/business/2015/oct/07/risk-global-financial-crash-increased-imf-emerging-economies-eurozone-stability-report> [Accessed 14.3.2016]

6. Conclusion

This diploma thesis is a case study focused on anti-crisis measures used by central banks during the financial crisis of 2007-2008 in the United States and the European Union. The primary goal of the diploma thesis was to identify and compare the anti-crisis measures of the Fed and the ECB, and to evaluate their impact on the development of the price level in the European Union and the United States. This thesis is focused on the monetary policy of two huge central banks and their anti-crisis measures. The attention was directed to the central banks, namely the Federal Reserve System and the European Central Bank and their steps taken during the global financial crisis.

The financial crisis of 2007-2008, also known as Global Financial Crisis, was the worst financial crisis since the Great Depression in 1930s. It started in the United States, but it quickly expanded around the World. All the stock markets have fallen, large financial institutions have collapsed or been bought out, and governments in even the wealthiest nations have had to come up with rescue packages to bail out their financial systems. The primary problem of the U.S. housing bubble was that banks relaxed all the loan and mortgage requirements. In the past all borrowers had to have a good credit history and a stable work with documentation that proved their income. During 2000s U.S. banks relaxed their standards, thus borrowers could state their income without verifying them. After the beginning of the 2007 Financial Crisis, these loans became toxic, since subprime borrowers began defaulting on their loans.

This thesis is focused on monetary policies performed by the central banks in the United States and the European Union. One of the main responsibilities of these central banks is to control the quantity of money that is made available in the economy, called the money supply. For both central banks, the main goal is to ensure a stable price level in the country. Moreover, the Federal Reserve System aims to ensure full employment and moderate long-term interest rates. Monetary policy is a process when the policy maker – central bank - uses its tools and instruments to achieve given goals. Monetary policy tools represent the implementation of

monetary policy and monetary policy goals are its expected results. Although the literature shows different definitions of monetary policy, they all basically agree that it is a macroeconomic policy conducted by the monetary authority, which is usually the central bank, in order to ensure price stability. The most frequently used monetary policy tools are discussed in the theoretical part of this diploma thesis. These tools are open market operations, foreign exchange operations, discount loans and reserve requirements.

The practical part was divided into three sections. First part was the comparisons of the steps made by the FED and the ECB during and after the financial crisis, regarding the calculation of coefficient of variation. The second part of the diploma thesis was dedicated to the autoregressive integrated moving average model and the prognosis of the monthly inflation rate for the United States and the European Union for the year 2016 were calculated. The third part of the research was focused on the monetary policy tools influencing the price level. This was expressed by regression models and elasticities computation. The comparison of the success of the particular monetary policy tool was expressed by the comparison of the individual elasticity coefficients. Also the determination coefficient R^2 was considered as one of the criterion of the regression models and the comparison of both models was performed.

Based on the research done in this diploma thesis, the Federal Reserve System was probably more successful in influencing the price level and had stronger impact on this indicator. The financial crisis began in the United States and it had a very fast and strong progress. The Federal Reserve System has more simple and flexible decision making system, so the decisions and the following steps could be implemented faster. The Federal Reserve System intervened in American economy more often and also injected more money into anti-crisis measures. These might be some of the reasons why the Federal Reserve System was more successful than the European Central Bank in influencing the price level.

Regarding inflation, there are many other factors that determine the price level and these factors are not under the control of the central bank. The practical part covers only central bank's monetary policy tools that influence the price level.

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8. List of Figures and Graphs

9. Appendixes

The Federal Reserve System

Appendix 1: Testing for stationarity (d_FFR, the Fed)

```
Augmented Dickey-Fuller test for d_FFR
including 12 lags of (1-L)d_FFR
(max was 12, criterion AIC)
sample size 83
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.194333
  test statistic: tau_c(1) = -9.22027
  asymptotic p-value 9.846e-17
  1st-order autocorrelation coeff. for e: 0.229
  lagged differences: F(12, 69) = 7.279 [0.0000]

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.20143
  test statistic: tau_ct(1) = -9.1108
  asymptotic p-value 2.381e-16
  1st-order autocorrelation coeff. for e: 0.217
  lagged differences: F(12, 68) = 7.383 [0.0000]
```

source: own computation

Appendix 2: Testing for stationarity (d_discount rate, the Fed)

```
Augmented Dickey-Fuller test for d_discountrate
```

```
including 9 lags of (1-L)d_discountrate
(max was 12, criterion AIC)
sample size 86
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.124155
  test statistic: tau_c(1) = -4.97996
  asymptotic p-value 2.243e-05
  1st-order autocorrelation coeff. for e: -0.128
  lagged differences: F(9, 75) = 3.079 [0.0034]

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.123259
  test statistic: tau_ct(1) = -4.79843
  asymptotic p-value 0.0004348
  1st-order autocorrelation coeff. for e: -0.128
  lagged differences: F(9, 74) = 2.987 [0.0043]
```

source: own computation

Appendix 3: Testing for stationarity (d_USD/ECB, the Fed)

```
Augmented Dickey-Fuller test for d_USDEUR
including 6 lags of (1-L)d_USDEUR
(max was 12, criterion AIC)
sample size 88
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.924545
```

```
  test statistic: tau_c(1) = -4.12985
  asymptotic p-value 0.0008634
  1st-order autocorrelation coeff. for e: 0.010
  lagged differences: F(6, 80) = 2.351 [0.0384]

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.942172
  test statistic: tau_ct(1) = -4.17565
  asymptotic p-value 0.0048
  1st-order autocorrelation coeff. for e: 0.010
  lagged differences: F(6, 79) = 2.359 [0.0379]
```

source: own computation

Appendix 4: Testing for stationarity (d_RR, the Fed)

```
Augmented Dickey-Fuller test for d_RR
including 10 lags of (1-L)d_RR
(max was 12, criterion AIC)
sample size 83
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -8.5905
  test statistic: tau_c(1) = -6.2895
  asymptotic p-value 2.336e-08
  1st-order autocorrelation coeff. for e: 0.043
  lagged differences: F(10, 71) = 10.366 [0.0000]

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
```

```
  estimated value of (a - 1): -8.68487
  test statistic: tau_ct(1) = -6.28235
  asymptotic p-value 2.278e-07
  1st-order autocorrelation coeff. for e: 0.041
  lagged differences: F(10, 70) = 10.299 [0.0000]
```

source: own computation

Appendix 5: Testing for stationarity (d_OMO, the Fed)

```
Augmented Dickey-Fuller test for d_OMO
including 2 lags of (1-L)d_OMO
(max was 12, criterion AIC)
sample size 92
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -1.22403
  test statistic: tau_c(1) = -4.56902
  asymptotic p-value 0.0001428
  1st-order autocorrelation coeff. for e: -0.033
  lagged differences: F(2, 88) = 16.335 [0.0000]

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -1.4436
  test statistic: tau_ct(1) = -5.20971
  asymptotic p-value 6.895e-05
  1st-order autocorrelation coeff. for e: -0.017
  lagged differences: F(2, 87) = 17.485 [0.0000]
```

source: own computation

The European Central Bank

Appendix 6: Testing for stationarity (d_MRR, the ECB)

```
Augmented Dickey-Fuller test for d_MRR
including one lag of (1-L)d_MRR
(max was 12, criterion AIC)
sample size 93
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.379687
  test statistic: tau_c(1) = -3.82063
  asymptotic p-value 0.002715
  1st-order autocorrelation coeff. for e: -0.011

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + e
  estimated value of (a - 1): -0.465574
  test statistic: tau_ct(1) = -5.26554
  p-value 0.0001796
  1st-order autocorrelation coeff. for e: -0.091
```

source: own computation

Appendix 7: Testing for stationarity (d_MLR, the ECB)

```
Augmented Dickey-Fuller test for d_MLR
including 0 lags of (1-L)d_MLR
(max was 12, criterion AIC)
sample size 94
unit-root null hypothesis: a = 1
```

```
  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + e
  estimated value of (a - 1): -0.620171
  test statistic: tau_c(1) = -6.43038
  p-value 3.284e-07
  1st-order autocorrelation coeff. for e: -0.034

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + e
  estimated value of (a - 1): -0.620365
  test statistic: tau_ct(1) = -6.398
  p-value 2.212e-06
  1st-order autocorrelation coeff. for e: -0.035
```

source: own computation

Appendix 8: Testing for stationarity (d_ EUR/USD, the ECB)

```
Augmented Dickey-Fuller test for d_EURUSD
including 2 lags of (1-L)d_EURUSD
(max was 12, criterion AIC)
sample size 92
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.77426
  test statistic: tau_c(1) = -4.23673
  asymptotic p-value 0.0005662
  1st-order autocorrelation coeff. for e: 0.019
  lagged differences: F(2, 88) = 2.542 [0.0845]

  with constant and trend
```

```
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.790314
  test statistic: tau_ct(1) = -4.27311
  asymptotic p-value 0.0034
  1st-order autocorrelation coeff. for e: 0.020
  lagged differences: F(2, 87) = 2.403 [0.0964]
```

source: own computation

Appendix 9: Testing for stationarity (d_ RR, the ECB)

```
Augmented Dickey-Fuller test for d_RR
including 0 lags of (1-L)d_RR
(max was 12, criterion AIC)
sample size 94
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + e
  estimated value of (a - 1): -1.01075
  test statistic: tau_c(1) = -9.69536
  p-value 6.175e-08
  1st-order autocorrelation coeff. for e: -0.000

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + e
  estimated value of (a - 1): -1.01288
  test statistic: tau_ct(1) = -9.66138
  p-value 6.301e-12
  1st-order autocorrelation coeff. for e: -0.000
```

source: own computation

Appendix 10: Testing for stationarity (d_ OMO, the ECB)

```
Augmented Dickey-Fuller test for d_OMO
including 12 lags of (1-L)d_OMO
(max was 12, criterion AIC)
sample size 82
unit-root null hypothesis: a = 1

  test with constant
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -2.49154
  test statistic: tau_c(1) = -4.12236
  asymptotic p-value 0.0008888
  1st-order autocorrelation coeff. for e: 0.037
  lagged differences: F(12, 68) = 2.327 [0.0146]

  with constant and trend
  model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -2.85666
  test statistic: tau_ct(1) = -4.33896
  asymptotic p-value 0.002675
  1st-order autocorrelation coeff. for e: 0.037
  lagged differences: F(12, 67) = 2.498 [0.0090]
```

source: own computation