# THE MACROECONOMIC EFFECTS OF QUANTITATIVE EASING

A Thesis

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# Abstract

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Quantitative easing have become a topic of discussion in most major world economies since the start of global financial crisis in 2008. It was a relatively new policy used to increase inflation, GDP growth and accelerate economic recovery. Quantitative easing was implemented at different time in United States, United Kingdom, Japan, Eurozone and some other countries. Results of this unconventional monetary policy measure are still controversial. Main objective of this paper is to analyze what impact quantitative easing made to mentioned economies and to measure the effectiveness as well as possible dangers of this policy. Analysis of scientific literature shows that quantitative easing helped to diminish the scale of economic downturn of the crisis, but its long term consequences are still unclear. In empirical analysis part several regression models were implemented to measure the significance of this monetary policy measure on inflation. Results of the main models suggest that quantitative easing has a positive impact on inflation rate.

*Keywords:* quantitative easing, unconventional monetary policy, inflation.

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# Introduction

After the global financial crisis hit in 2008 many developed countries faced huge problems with stabilizing their economies. During these years GDP of some countries contracted by more than 10% and Eurozone's GDP returned to pre-crisis level only in 2016 (Thomson, 2016). Most important reasons of such a slow recovery include more rigid requirements from banks to get new loans and therefore declining investment (Solomon, 2014). Central banks obviously seen that happening and used monetary policy tools to spark the economy and make recovery as fast as possible. But conventional measures were not enough: despite interest rates were driven close to 0% and even to the negative territory in some countries, inflation was not increasing and employment or investment was not getting back to pre-crisis levels very quickly. Therefore central banks started using quantitative easing (QE) – unconventional monetary policy tool used by purchasing assets in the financial market with central banks money. The main issue analyzed in this paper is that this type of monetary policy measure is relatively new (first implemented by Japan in early 2000s) and its effects or long term consequences to the economy are not quite clear. That is why the goal of this work is going to be to evaluate macroeconomic impacts of QE. Not only the positive effects of QE will be measured – how much it helped to increase inflation, demand or lending rates, but also the main risks including complexity to unwind (do this process backwards) or malfunction of a credit market. This paper analyzes 4 biggest economies in which quantitative easing has been implemented or is still in a process: Eurozone, United States, United Kingdom and Japan. To achieve the goal mentioned above these objectives and methods were chosen:

1. Analysis of the present situation in Eurozone, US, UK and Japan. How, when and why quantitative easing was implemented in these economies? Overview of the main characteristics of the QE will be given and explained.
2. Research on the scientific literature of the quantitative easing effects and empirical research methodology. Main arguments and ideas of other papers on this topic will be presented. Methods of a regression analysis will be provided.
3. Regression analysis with the appropriate models to measure QE effects on the inflation rate.

Quantitative easing is still a questionable topic nowadays. This paper might provide some insight on its advantages and disadvantages and might help central banks to decide whether to implement it or not in the future.

# 1 Situation analysis

## 1.1 Understanding monetary policy and its tools

Before going deeper into this topic an explanation of what is a quantitative easing and what are some other conventional and unconventional monetary policy tools will be provided.

### 1.1.1 Monetary policy and conventional monetary policy tools

With the small differences across countries main objective of monetary policy is to maintain price stability or in other words low and stable inflation rate. Central banks are trying to achieve this goal by controlling money supply. There are many tools to do that, but most common is open market operations: by selling or buying securities and raising or lowering interest rates (Amadeo, What Is Monetary Policy? Objectives,Types and Tools, 2016). Another conventional monetary policy tool is called reserve requirements. These are by law specified amount of funds which depository institutions have to hold for some specified deposit liabilities. Third main tool is the discount rate. It is the interest rate charged to the depository institutions like commercial banks on loans they receive from the central bank. These are the main conventional monetary policy tools, but after the crisis they were not able to generate desirable effects and new measures of monetary policy were implemented.

### 1.1.2 Unconventional monetary policy tools

First of all it has to be mentioned that often there is a thin line between conventional and unconventional tools or in between of unconventional tools.

**Quantitative easing.** Quantitative easing is one of the unconventional monetary policy tools where a Central Bank with its money buys financial assets with the goal to increase

spending in the economy and reach targeted inflation (Bank of England, 2017). It differs from the open market operations, because QE purchases have normally a larger scale and include not only government securities, but corporate bonds as well. Because banks sell those assets for cash, their liquidity increases. In theory because amount of money available in the economy increases, interest rates decrease then people and businesses are able to borrow more, because of that spending and investment increase, inflation increases and economy grows (BBC news, What is quantitative easing?, 2016).

**Credit easing.** This tool is very similar to quantitative easing but asset purchases or lending to financial institutions are made with the goal to increase investment and lending, especially for small and medium-sized businesses (Vukovic, 2011).

**Forward guidance.** It is when central bank's communication about future has a goal to influence present behavior. For example announcing that interest rates will be low for a while and in that way encourage investment (R.A., 2014).

**Signaling.** In terms of monetary policy it is the idea that with policy rates central bank signals about economic development to other parties (e.g. investors) who doesn't have a full information.

### 1.2 Risks of quantitative easing and other unconventional monetary policy tools.

Even if conventional monetary policy tools doesn't help to maintain price stability and low unemployment there should be a serious consideration before using unconventional measures like quantitative easing. For many economists these policies are considered very risky and still information about their long term effects is extremely limited.

The most relevant risks include:

1. Economic distortions – extremely low interest rates could lead to too little saving among households and too many debt funded businesses “zombie households and firms”.

2. Ineffectiveness – negative interest rates make incentives for banks to lend more, but this doesn’t make debtors and businesses more reliable therefore many banks decide to hold their liquidity and money velocity collapses.

3. QE foreign exchange transmission (which might be expected to be a positive effect) become a zero-sum game – currency weakening by monetary easing would not work if several major central banks would do the same policy.

4. Asset bubbles – low interest rates might lead to bubbles in housing, commodity, bond or credit markets.

5. Moral hazard – QE might discourage governments to make needed reforms, achieve balanced budget, because deficits can be monetized.

6. Hard to do it backwards – exiting too slowly might lead to inflation and bubbles and selling assets bought on QE would lead to financial losses.

7. Income redistribution – period of negative interest rates might lead to income and wealth moving from savers and creditors to borrowers and debtors. It also does serious harm to retirement savings forcing people to lose money or to choose risky investments.

8. Other unintended consequences – inflation might rise too much and lending may decrease rather than increase, because of unexpected changes in decisions of banks or consumers (Roubini, 2013).

### 1.3 History of implementation of QE

Information on how quantitative easing was implemented in major world economies will be provided.

**United States**

In response to global financial crisis Federal Reserve used several rounds of quantitative easing to help the economy to recover.

First round (later called QE1) was implemented in November 2008. Fed announced a program to buy $100 billion of agency debt and $500 billion of mortgage-backed securities (MBS). This round was extended in March 2009 when Fed again bought mortgage-backed securities and debt for $850 billion. Another $300 billion was used to buy longer-dated treasuries.

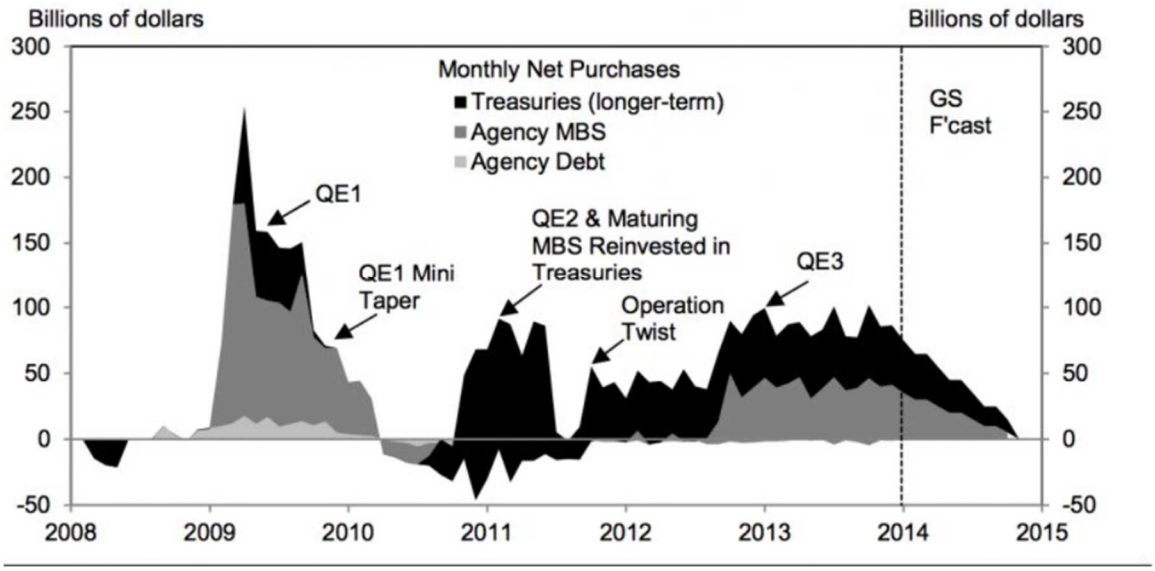
Second quantitative easing program (QE2) started in November 2010. Fed proposed to buy longer-dated treasuries for $600 billion by the middle of 2011. In September 2011 Fed announced new program called Operation Twist. Main purpose was to increase bank's treasury portfolio's maturity. That was done by buying treasuries with the maturities between 72 and 360 months for $400 billion and selling same amount of treasuries with the maturities from 3 to 36 months.

QE3 was announced in September 2012. Fed initiated buying mortgage-backed securities for almost $40 billion every month. Along with Operation Twist cost of purchases reached $85 billion per month. In December 2013 Fed commited to reduce amount spent by $10 billion. In October 2014 QE3 ended (Trefis Team, 2015).

*Figure 1* below shows monthly net purchases during all this period. From 2014 there is a Goldman Sachs forecast therefore most representative is the part until this date. Probably the

biggest part of purchases consists of long term treasuries. These are treasury bills, bonds and notes guaranteed by US government. Another big share of QE especially at the start was mortgage-backed securities – investments which value is secured by the bundle of mortgages.

*Figure 1*. Federal Reserve's quantitative easing program




Source: Federal Reserve Board. Federal Reserve Bank of New York.

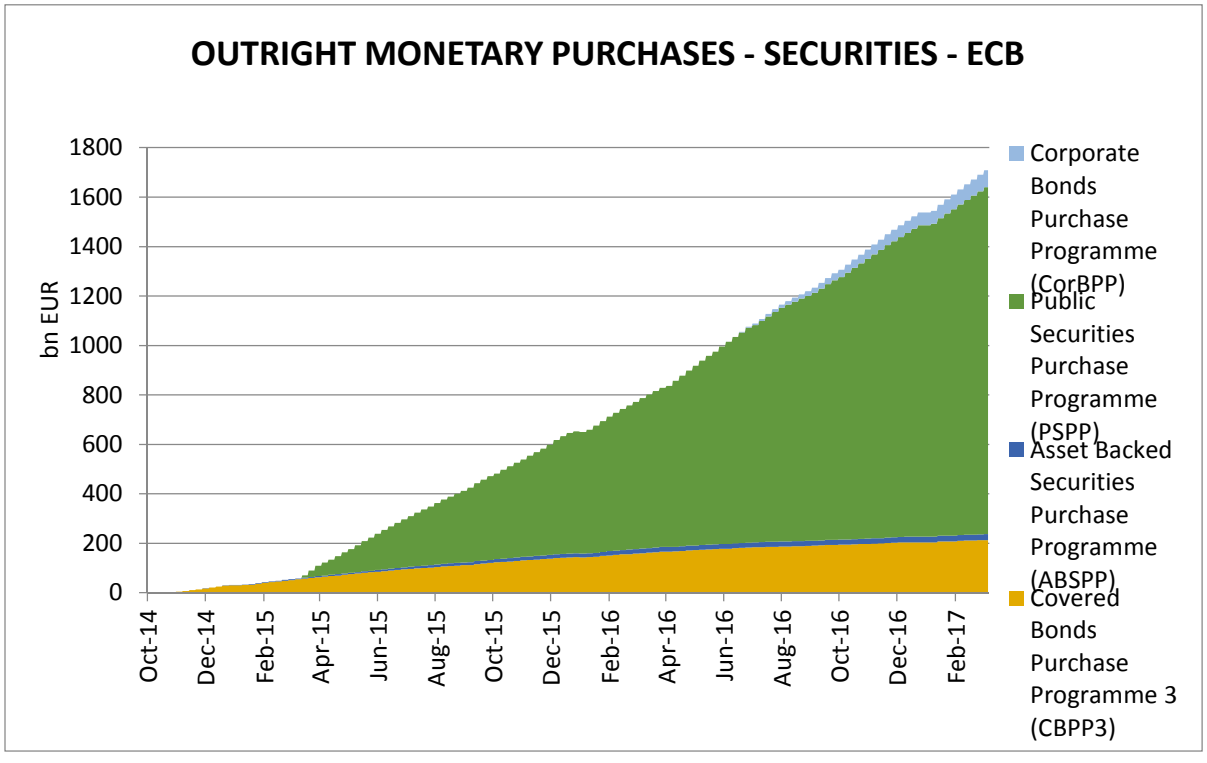
**Eurozone**

ECB started quantitative easing program in March, 2015. Monthly asset purchases amounted to 60 billion euros and were planned to continue until the September of 2016. Main goals were to maintain price stability and inflation close to, but below 2% (ECB, 2015). On December 3, 2015 there was an announcement that program was extended at least until the March of 2017. With this announcement a variety of assets eligible to purchase was extended as well (Leandro, 2016). What is more in March, 2016 ECB announced that monthly purchases will be increased from 60 billion euros to 80 billion euros. Program intended to run until the end of March of 2017 (ECB, Introductory statement to the press conference (with Q&A), 2016).

However after a month decision was made to return to the previous amount of 60 billion euros per month.

*Figure 2* shows monthly amounts of each of the four asset purchase programs of ECB. Covered Bond Purchase Programme 3 (CBPP3) and Asset-Backed Securities Purchase Programme (ABSPP) were introduced in the second half of 2014, but amounts were relatively low. Quantitative easing accelerated with the start of Public Sector Purchase Program (PSPP). PSPP includes purchases of debt securities from national agencies and European institutions and the governments of euro area sovereign bonds (Demertzis & Wolf, The effectiveness of the European Central Bank's asset purchase programme, 2016). In 2016 QE started including corporate bonds with the Corporate Bonds Purchase Programme (CorBPP).

*Figure 2*. Monthly purchases under the four asset purchase programs of ECB (billion euros)




Source: European Central Bank

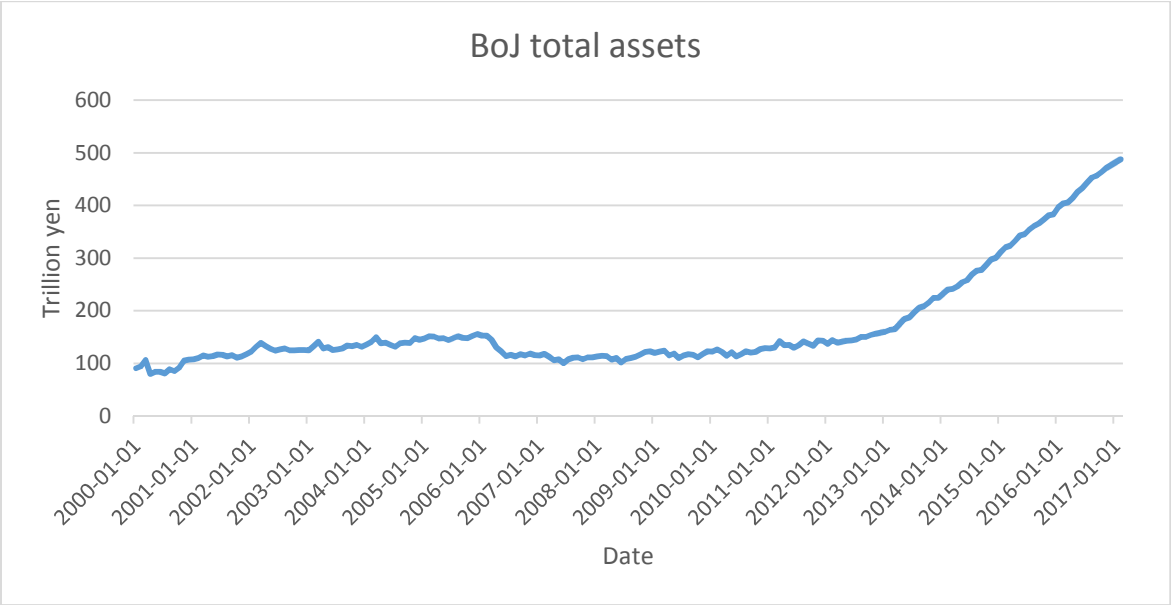
**Japan**

First policy decision now known as quantitative easing was made by the Bank of Japan in 2001. After the years of stagnation and overnight interest rates being close to 0% Bank of Japan started focusing on the current account balance of commercial banks. Increasing their liquidity was one of the ways to stimulate long term investments and increase inflation. Due to the lack of economic stability and uncertainty in the banking sector results were much slower than expected and total amount of operations reached 35 trillion yens at the end of 2004. Overall program helped stimulating economy and was considered successful even though it didn't help to fight domestic deflation (Cavallo, 2015).

During the global economic crisis Japan renewed its quantitative easing policy. In April 2013 Bank of Japan started spending new money and buying bonds. In October 2014 program was expanded to 80 trillion yens a year up from 60-70 trillion. After that amount of purchases was not changed, but some minor adjustments were made. Maturity of bonds was increased and purchases of exchange-traded funds (ETFs) were started (*The Economist*, 2015).

*Figure 3* shows how quantitative easing policies influenced balance sheet of the Bank of Japan. Comparing with recent purchases first quantitative easing program made quite a low increase in total assets, but effect was not that insignificant because during that period (2001-2006) balance sheet almost doubled and that was the first asset purchase program known as QE. However second program was much larger: from 2013 Bank of Japan total assets already increased by more than 300 trillion yen.

*Figure 3*. Total assets of the Bank of Japan

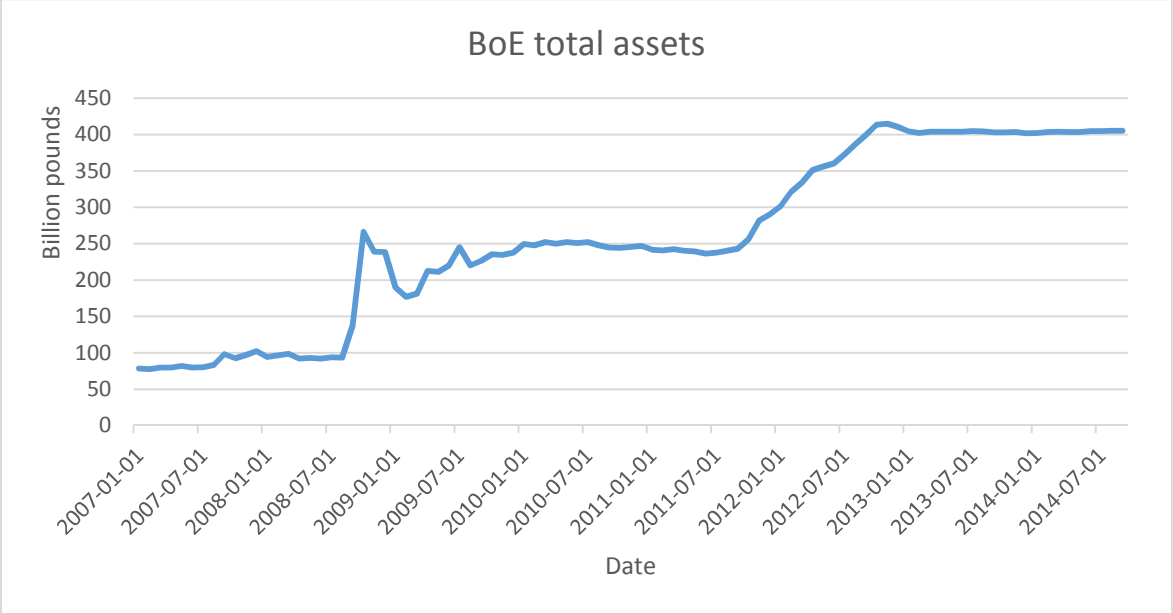



Source: Federal Reserve Bank of St. Louis

**United Kingdom**

Announcement about the start of QE was made on March 2009 together with the decrease of the interest rates to the record low of 0.5%. In May amount of purchases was extended to 125 billion pounds. In the following couple years despite inflation increased to more than 5% QE program still continued. On July 2012 total amount of purchases was raised to 375 billion pounds (Allen, 2016). On August 2016 Bank of England announced that quantitative easing program is going to be expanded by additional 60 billion pounds extending total amount of purchases to 435 billion pounds (*Figure 4*).

*Figure 4.* Total assets of the Bank of England




Source: Federal Reserve Bank of St. Louis

### 1.4 Results of Quantitative easing

In this segment there is an overview of how effects of quantitative easing are being seen in 4 analyzed economies by famous economists, researchers or economic literature.

**United States.** In US critics still argue that QE could lead to a new financial crisis and too high inflation rate, but for now it looks like asset purchase program stimulated job creation, increased investment and helped US economy to avoid much more severe downturn.

Subprime mortgages were removed from the banks' balance sheets restoring some trust in them during the crisis period. Housing market recovered - QE was one of the reasons why interest rates were kept low enough which helped to revive housing market. Federal Reserve's chairman, Ben Bernanke, said in 2012: "There is substantial evidence that the Federal Reserve's asset purchases have lowered longer-term yields and eased broader financial conditions." He also

argued that QE increased economic activity by almost 3 percent and comparing to what would have happened without QE, increased a number of jobs in private sector by 2 million (Bernanke, 2012).

On the contrary critics argue that credit have not become more available, because banks haven't lent the money they got or believe that QE might have fuelling risk and increase inflationary pressure. Some asset bubbles were created (e.g. gold price per ounce increased from less than $900 in 2008 to almost $1900 in 2012) and yields of 10-year treasury notes reached 200 year low (Amadeo, What Is Quantitative Easing? Definition and Explanation, 2016). Low interest rates make very easy to borrow money therefore investment to extremely risky financial assets may increase. What is more professor Martin Feldstein argues that commercial banks in the future can decide to use their expanded reserves to increase lending which would boost inflation dramatically. On the other hand he also admits that FED has tools prevent very high inflation (Walker, 2014).

**United Kingdom.** QE in UK decreased yields on some assets and had a positive impact on some macroeconomic indicators, but it haven't stopped the fall of the broad money growth.

Most of scientific papers authors tend believe that QE in UK had a positive impact on consumer and business confidence, inflation and real GDP. During the period of QE inflation fluctuated around targeted 2%, unemployment was gradually decreasing and GDP growth was quite low, but stable. On the other hand broad money growth fell dramatically since the crisis started and asset purchases were not able to return it to previous levels – in early 2010 broad money growth was below 1 percent, which is much lower than nominal GDP growth. What is

more GDP growth forecasts were being cut for 2017, official interest rates were cut to 0.25% and even with the stimulus Bank of England forecasts 250 000 job losses (Elliott, 2016).

**Japan.** QE was another possible solution to a couple decades lasting Japan's inflation problem which still has unclear results.

During the period from 1993 to 2013 average inflation in Japan fluctuated around 0%. By some economists inflation this low is viewed as harmful for country's economic performance. There were several attempts to increase price level in the country. Most recent ones include 2% inflation target together with the expansion of QE program. Major part of BOJ asset purchases consist of Japanese government bonds. This kind of monetary policy can be called "monetization of the debt" and is widely considered to be inflationary (Andolfatto & Li, 2013). That was not the case in Japan. As it is shown in this paper (*1.5.2*) inflation in Japan even after a significant expansion of balance sheet have not been increasing consistently. According to economic theory even large changes in monetary base might not have any inflationary results if people believe that in the future program is going to be reversed. Amount of available government bonds to buy is decreasing and long term Japanese bonds are not being traded because of low yields. What is more country is remaining with the highest debt to GDP ratio in the world. On the other hand unemployment rate is in very low level of around 3%.

**Euro area.** ECB's asset purchase programs possibly have a positive impact on inflation and aggregate demand, but might increase nexus between monetary and fiscal policies and make harm to banks' profitability.

Positive impact:

- Bond yields dropped. It helped to stimulate financial markets, reduce financial cost and expand credit.
- Inflation increased. Release of liquidity and euro depreciation have led to higher asset prices and inflation.
- Manufacturing level increased – Purchasing Managers Index (PMI) on December 2015 reached the highest value in 20 months – 53.1.
- Expansion of trade surplus – depreciation of euro helped Eurozone countries to increase their exports.
- Increase of private consumption – household credit has rebounded as well as car sales (Min, 2016).

Side effects might include interdependence between monetary and fiscal policy, making them less effective in the future (Deutsche Bundesbank, 2016). Another important channel through which QE has a significant impact is banks' profitability:

- QE increases bond prices which leads to an expansion of banks' holding these bonds balance sheets.
- QE reduces term spreads (because of reducing long term yields) decreasing banks' interest income on new loans.
- QE improves economic outlook which should help banks to find new lending opportunities and reduce proportion of non-performing loans.

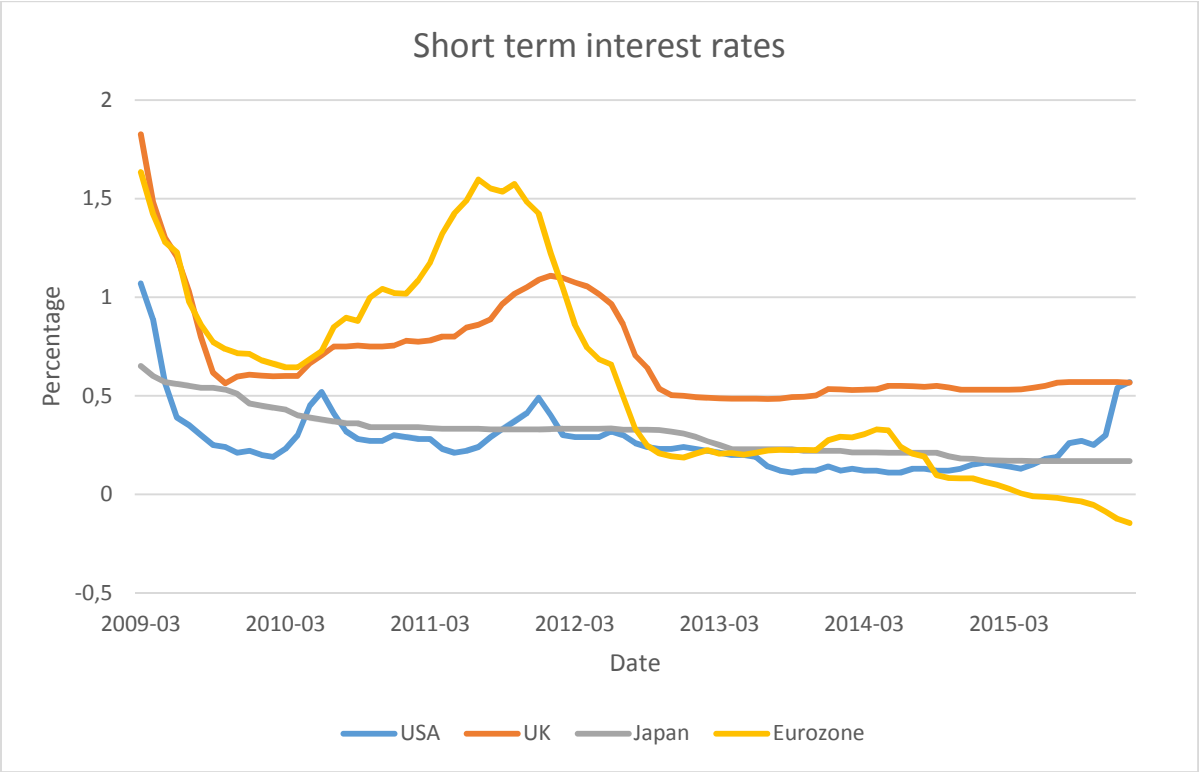
Therefore QE effects on bank lending are not one directional, but in most of the cases immediate effects should be positive (Demertzis & Wolf, What impact does the ECB's quantitative easing policy have on bank profitability?, 2016).

## 1.5 Important economic indicators on which unconventional monetary policy has or might have an effect.

### 1.5.1 Interest rates

*Figure 5* below shows US, UK, Japan and Eurozone short term interest rates from the middle of the crisis in 2009 until the end of 2016. Short term interest rates provide information about the price of borrowings between financial institutions and the rate on which short term government papers are issued. In this case interest rates are based on three-month money market rates. As it is seen from the graph these rates plummeted in these economies after the crisis. Central banks tried to stimulate the economy, increase lending therefore borrowing prices were lowered.

*Figure 5.* Short term interest rates




Source: OECD data

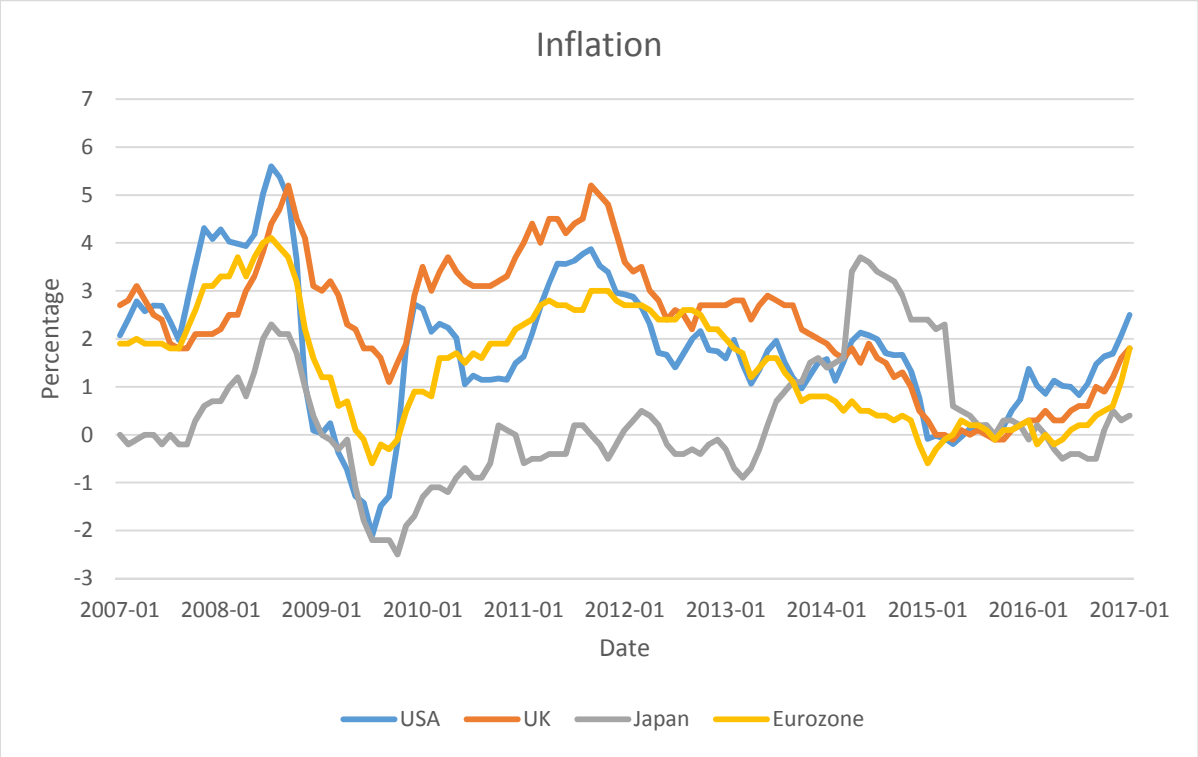
But even close to 0% interest rates were not enough: inflation was not increasing, unemployment still high, GDP not increasing fast enough. That is why these countries tried unconventional monetary policy tools. Recently looks like FED doesn't see that much need to increase lending and finally increased federal funds rate from 0.5% to 0.75%. Whereas in other measured economies rates are not changing and in Eurozone deposit facility rate was even lowered to -0.4% on March 2016 and is still holding at that level (ECB, 2016).

### 1.5.2 Inflation

Inflation is one of the most important economic indicators which is also directly affected by countries monetary and fiscal policies. Thereby European Central Bank is paying a lot of

attention to keep inflation stable and low (close to, but not more than 2%). Federal Reserve, Bank of England and Bank of Japan similarly target 2% inflation as well. As *Figure 6* below shows all of these economies, except of United Kingdom during the global financial crisis fell into deflation. Something had to be done about it and central banks as mentioned above decreased short term interest rates. It helped to some degree for several years, but was not quite enough. Therefore unconventional monetary policy tools were used. It can be seen that in US and UK for most of the period inflation was close to 2% whereas in Eurozone this indicator from 2013 to 2015 was close to 0% and Japan experienced deflation for about 5 years. Recent increase in inflation in all of these economies should not be associated too much with recovering economy or effects of countries policies because real and not core inflation is measured in the graph thereby increase should be associated mostly with the growing energy prices.

*Figure 6*. Inflation (CPI)

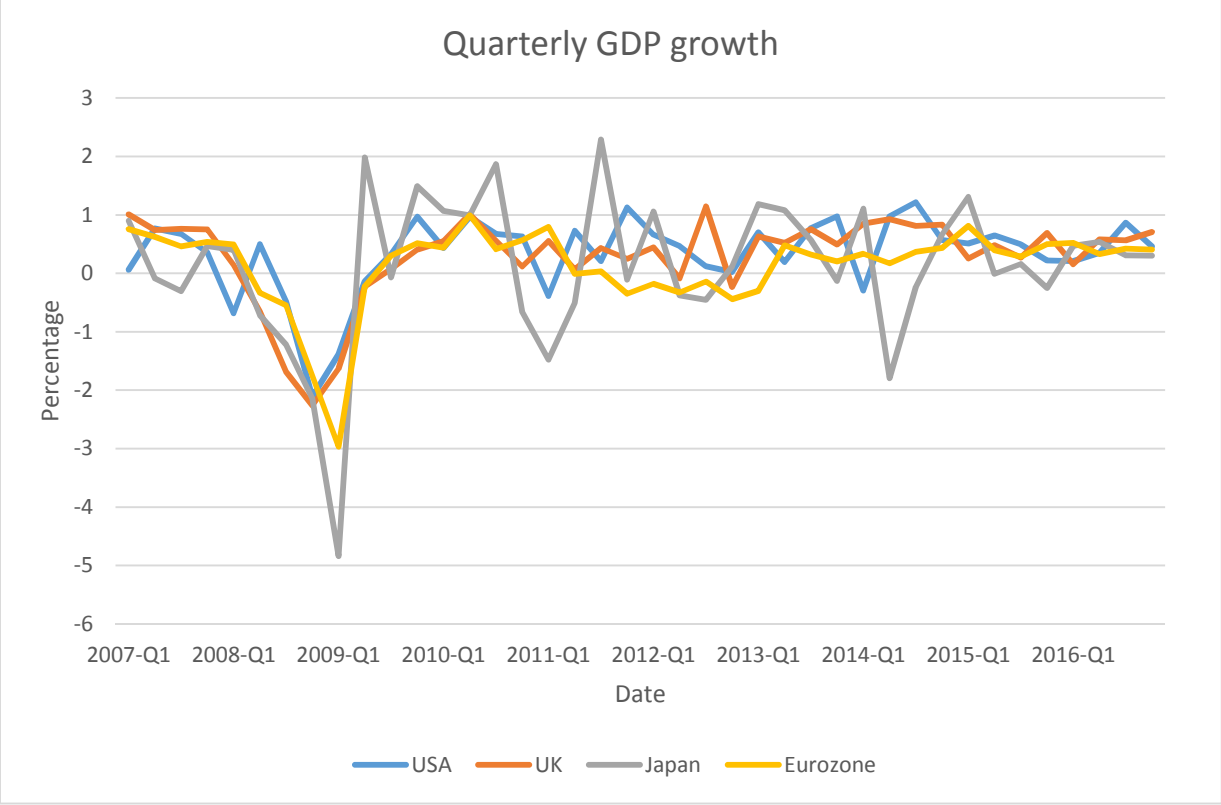


Source: OECD data

### 1.5.3 Gross domestic product

Gross domestic product is one of the most important indicators showing economic strength and development of the country. Graph below shows quarterly GDP growth at market prices, which means expenditures on final goods, total capital increase and net exports. It is seen that there is a very slow recovery of this indicator after a sharp decrease during economic crisis. GDP growth of Japan in recent years was fluctuating the most and highest growth in last couple quarters was performed by UK *(Figure 7).*

*Figure 7*. Quarterly GDP growth

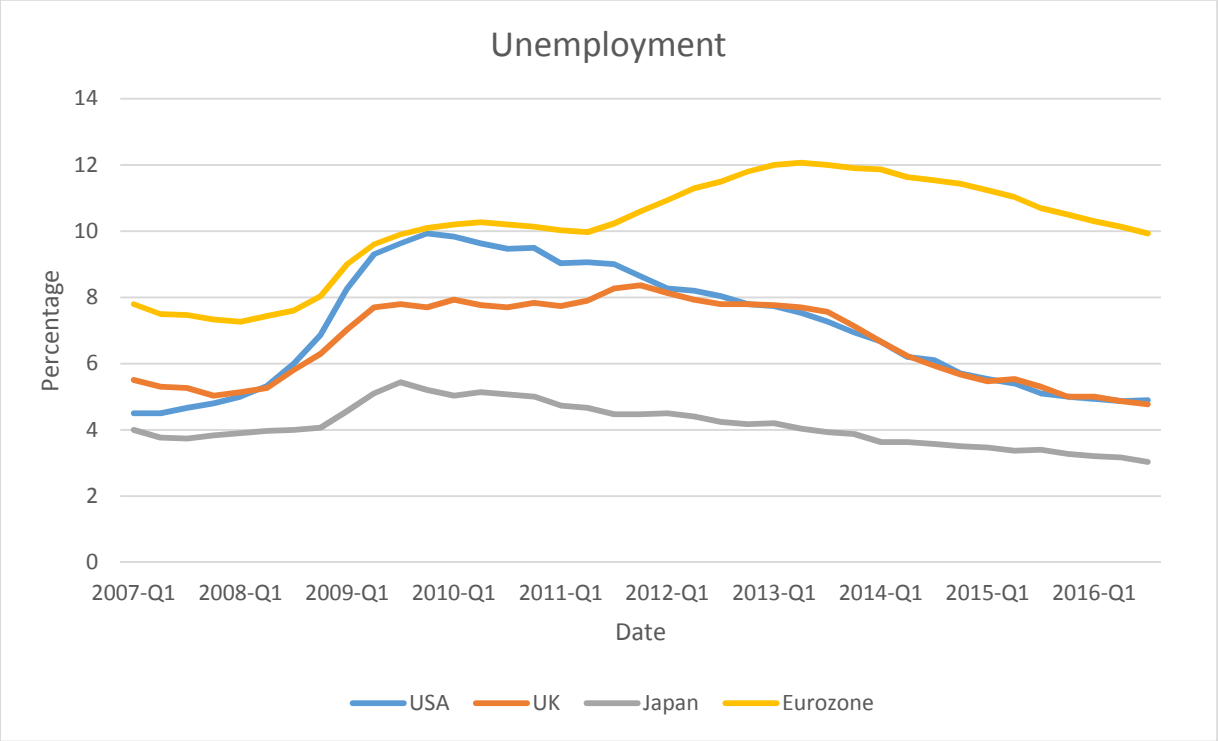



Source: OECD data

### 1.5.4 Unemployment

Unemployment rate is closely related to all monetary policy decisions made by central banks. Even main goal of Federal Reserves is to maintain not only price stability, but also low unemployment. Therefore one of the measures to evaluate how successful are unconventional monetary policy tools is to look if they helped to reduce unemployment rate. Graph below clearly shows that United States and United Kingdom from the crisis improved this indicator quite significantly and Japan even managed to keep unemployment rate below 6% during the crisis. Whereas in euro area countries unemployment increased quite substantially during this period. Although it is worth mentioning that this average is heavily influenced by Southern Europe countries like Greece and Spain where unemployment rate exceeds 15%.

*Figure 8*. Unemployment rate



Source: OECD data

### 1.6 Conclusion of situation analysis

After the biggest world economies implemented quantitative easing program results were ambiguous. Some countries achieved their main goals and stopped the program, some are facing new problems and considering more and more policy measures. It is clear that the effects of unconventional monetary policy tools might cover quite a wide range of economic aspects and might differ depending on a country, timing or types of tools implemented.

# 2 Literature Review and Methodology

In the second part of this paper literature covering the effects of quantitative easing is going to be analyzed and methodology of the empirical study will be provided.

## 2.1 Literature review

This chapter analyzes the factors affecting inflation rate, effects of QE in theoretical level and results of other authors' econometric studies on unconventional monetary policy tools. Before going into details of empirical analysis it is important to understand most important determinants of inflation and how they can be related to unconventional monetary policy tools such as quantitative easing. Also it is crucial to investigate what QE effects are directly observable and how economic situation changed in the biggest economies since the implementation of QE. There will be an analysis of the methods and findings of other scientific papers on the macroeconomic effects of QE.

### 2.1.1 Determinants of inflation

QE was a new method used to increase inflation after conventional monetary policy tools were not able to do that. It can affect inflation through various different channels and other QE effects might be closely related to inflation as well. Therefore it is important to understand in both theory and practice what factors have biggest impact on price levels and how QE might be connected to them.

**Quantity theory of money**. As Irving Fisher said "Other things remaining unchanged, as the quantity of money in circulation increases, the price level also increases in direct proportion

and the value of money decreases and vice versa." For example if quantity of money increases by 10%, prices would increase by the same 10% as well. This can be written with this equation:

$$MV=PT$$

M = total quantity of money

V = the velocity of circulation of M

P = price level

T = total amount of transactions performed for money (can be replaced by Y as total output or Q as total quantity of goods and services produced)

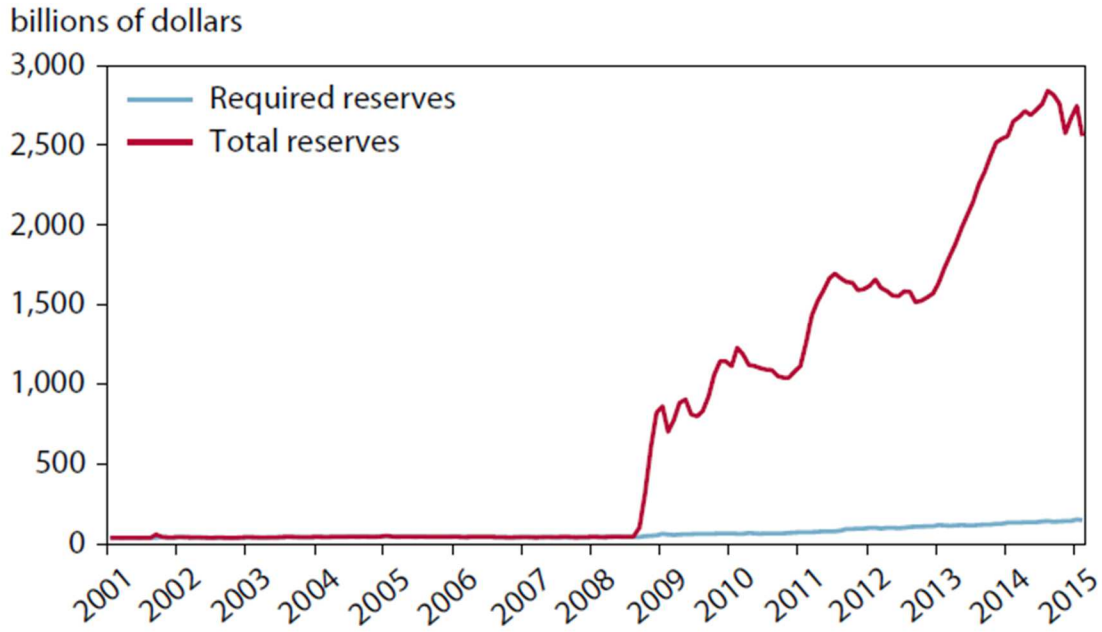
**Quantity theory of money as an explanation of inflation.**

According to the theory (MV=PQ) and assuming that velocity is constant, sum of percentage changes in prices (or just inflation rate) and in real output should be equal to percentage change in money supply. It is considered that percentage change in output actually can be called real growth rate and this term is moved to right-hand side. In that case inflation should be equal to percent increase in money supply over the rate of growth. This equation explains hyperinflation as a consequence of excessive printing of money in third-world economies or Weimar republic during the Great Depression. Theory holds to some extent for US from 1962 to 1984 as well. From 1985 there was no longer any positive correlation and even there was minor negative relation between excess money growth and inflation. Therefore quantity theory of money no longer explained changes in inflation (Cline, 2015).

Quantitative easing in US started in 2008 and it supposed to work by reducing the term premium (or just long term interest rates). This reduction should have decreased the cost of long-

term capital, increased investment and stimulated economy. However as a side effect QE substantially increased money supply and banks' reserves (*Figure 9*). From 2007 to 2014 balance sheet of Federal Reserve rose by $3.6 trillion and excess reserves of the banking system during the same period rose by $2.5 trillion. This meant that QE stimulated bank lending much less than it potentially would have (Cline, 2015).

*Figure 9*. Banks' reserves (US)




Source: Federal Reserve

This increase of reserves together with low interest rates have led to sharp decrease of money multiplier during the recent years. Money multiplier here relates broad money to the monetary base and is calculated 1/R where R is a reserve ratio. This multiplier during the period from 2007 to 2014 collapsed from 14 to only 4. That is the reason why a surge in Federal Reserve balance sheet have not led to that big of an increase in broad money. On the other hand

money velocity during the same period have not fallen that much. This indicator gradually declined from 1.26 to 1.13 (Cline, 2015).

It can be concluded that in US risk of severe inflation seems quite low. Monetary expansion doesn't hold anymore as an explanation of inflation and in recent years decreased money multiplier was the main explanation why with an increase of Federal Reserve's balance sheet inflation was not increasing. On the other hand there still might be a money expansion leading to high inflation if banks would significantly decrease a proportion of their excess reserves (Cline, 2015).

**Macroeconomic indicators as determinants of inflation.** Malin Andersson et al (2009) in their paper "Determinants of inflation and price level differentials across the euro area countries" find that inflation rates can be explained with macroeconomic factors. These are the most important indicators affecting inflation differentials and price levels:

- Differences in GDP per capita – it is assumed that there is a positive link between price levels and real GDP per capita if:
    1. More labor intensive services are non-tradable
    2. More developed countries (with higher GDP per capita) are more capital-abundant

  This hypothesis was supported by empirical analysis: results show that rise in GDP per capita causes an increase in price levels.

- Differences in productivity levels – Balassa-Samuelson effect states that an increase in sectorial productivity has a positive effect on price level.
- Wage growth – it is expected to be positively related to price levels and inflation.

- Changes in product market regulations – in the analysis it was found that an increase of these regulations in a country (other things being constant) leads to higher level of inflation comparing to euro area average.

Eftekhari Mahabadi, S. and Kiaee, H. (2015) used Random effect log-linear and ordinal logistic models for the inflation rate analysis. Both models show that inflation next year depends on several macroeconomic variables:

- Money growth – increase in money supply leads to higher inflation rate. QE asset purchases also directly increase narrow money supply (M1).
- GDP – it was found out that to achieve higher GDP growth countries have to accept higher inflation as well.
- Oil price – increase of oil prices leads to an increase in prices of most of the other products and services and to higher inflation rates.
- Income levels – in countries having higher income levels inflation is expected to be lower.

For ordinal inflation variable[1] significant determinants were found to be:

- Government expenditure
- Exchange rate regime
- Capital formation

[1] In the ordinal logistic mixed effect model, as a new approach, the inflation rate variable is categorized based on two threshols to increase model predictability and precision.

Higher government expenditure and exchange rate increases the odds of higher inflation category whereas higher capital formation growth leads to lower odds of higher inflation category.

**Monetary indicators as determinants of inflation.** Cheng Hoon Lim and Laura Papi (1997) analyzed determinants of inflation in Turkey. They found that monetary variables play a very important role affecting inflation. Active exchange rate depreciation made by policymakers over the 15 year period was found to have a significant impact on inflation. Authors found that public sector deficits have direct effect on inflation as well.

### 2.1.2 Review of other econometric analyses on the impact of the QE

In this section methods and results of several empirical studies on macroeconomic effects of QE are going to be analyzed.

**Some researchers see not only a stimulating QE effect on the economy, but also some dangers and risks connected with this policy.** Unconventional monetary policy measures do work because asset purchases lower long term interest rates and yields. These changes affect economy positively and because of that some central banks are continuing their QE programs. However even if QE have boosted the economy to some extent, recovery in many countries is still extremely slow. This might suggest to increase the scale of QE in order to achieve larger positive effects. Although evidence is very limited, QE returns might be diminishing. Another concern is the costs of unconventional monetary policy measures. Too high level of reserves and decreased interbank lending might lead to malfunction of that market. What is more government bond purchases might be contributing to unsustainable government debt levels. Therefore despite it is clear that QE has an effect to the economy, because of the short period of it working in practice there is a lot of uncertainty about the duration and size of these effects and possible

risks. In the future micro and macro prudential frameworks should be improved so that reliance on unconventional monetary policy tools would not be that significant (Joyce, Miles , Scott, & Vayanos, 2012).

**Another analysis made on Euro area, US, UK and Japan economies show that QE had a significant positive impact on output growth and inflation.** Quarterly data frequency was used with the maximum time span from 1954 to 2008. Variables used to achieve as accurate effect as possible include short term interest rates, 5 and 10 year corporate bond yields, real GDP growth and others. Impact of yield spread on inflation and GDP was analyzed using Bayesian time-varying parameter structural vector autoregression (VAR) model with a lag order set to p=2. (Baumeister & Benati, 2010). This type of model allows to predict value of a variable from its past observations.

Results suggest that QE had a significant positive impact on UK and US economy. In US in the absence of QE output would have fallen by 10% comparing to the real decrease of 3% and in UK model predicted 14% downturn in GDP and lower than -4% inflation (Baumeister & Benati, 2010). On the other hand when the crisis started QE was only one of the wide series of interventions. These other policies were not included in the model therefore the impact of QE might have included effects of other interventions. This argument is also supported by the fact that the model estimates imply an immediate impact of QE. For both US and UK highest impact was estimated in 2009 Q1 whereas in both countries serious asset purchases started only in the middle or the second half of this quarter.

**A couple scientific papers were analyzed on UK alone and they also confirm positive QE effects on inflation and GDP, but assumptions on long term yields were slightly**

**diferent.** Kapetanios *et al* (2012) analyzed economy wide effects of the first round of QE in the UK. Three models were used focusing on the links between government bond spreads and macroeconomic variables: Bayesian vector autoregression (BVAR), switching VAR with 4 regimes (SWAR) and VAR in which errors are allowed to change as random walks (TVP-SWAR).

BVAR uses a monthly data from 1993 to 2011. Variables measure economic activity including prices, yields, GDP, financial activity, interest rates, monetary aggregates and others. Estimation of SWAR models was used with not that many variables, but longer time span. In TVP-SWAR model quarterly data were used from 1968 to 2011.

Findings imply that in UK QE increased both inflation and output growth. Average model prediction shows that without the implementation of QE output would have been from 1.4% to 3.6% lower and CPI inflation would have been reduced by 1.2-2.6 percentage points (Kapetanios, Mumtaz, Stevens, & Theodoridis, 2012). In 2009 when measured impact was almost the highest UK GDP fell by 4.9% and inflation was 2.1%. Therefore results suggest that with no QE UK would have fallen into much deeper recession of around 7% GDP decline and inflation fluctuating on the verge of deflation. Also it is worth noting that all these models operated under an assumption that QE in UK decreased long term yields by 100bp, which is quite questionable. Possibly 50bp decrease which was used in Baumeister and Benati (2010) model would have been more accurate.

In other paper there is an overview of the implementation of QE in UK and explanation of some key impacts on both financial markets and widely on the economy. Authors state that as it is expected QE directly affected gilt yields decreasing them by 100 bps in total until the middle

of 2010 out of which by 75 bps in March of 2009 when the program started. Out of other assets clearest impact can be seen on corporate yields – during the period of QE announcements they decreased by 70-150 bps (Joyce, Tong, & Woods, The United Kingdom's quantitative easing policy: design, operation and impact, 2011).

**In euro area economies unconventional monetary policy measures are considered to act as a supplement of conventional policy.** SVAR model was used with a monthly data from 1991 to 2009 to evaluate the impact of policy interventions on money multiplier and the monetary base. Then further analysis is being implemented on the effect on real economy through this channel. In paper it is found that several instruments can be used to influence the economy. For example unconventional policies increasing central bank balance sheet or the monetary base have a hump-shaped impact on economic activity and a long lasting effect on consumer prices. Conventional monetary policy measures have a similar impacts, but these are more immediate. Therefore it is suggested that these different types of policies can be seen as a supplements to maintain a stable growth of the economy (Peersman, 2011).

**Analyses of the QE effects in United States show that it takes time for this kind of policies to take maximum effect and these impacts might be diminishing.** Martin Feldkircher and Florian Huber (2016) investigate the impact of United States unconventional monetary policy tools on real economy using the term spread and monetary policy shocks. Besides other results empirical analysis show that the term spread shock (which is considered as a direct consequence of quantitative easing) impacts output growth. Strongest effects were found during the global financial crisis and weaker in its aftermath. This implies that FED's unconventional monetary policy programs might have a diminishing effects. What is more authors show that

quantitative easing effects on investment growth have diminished over time as well (Feldkircher & Huber, 2016).

Eric M. Engen et al (2015) estimated the economic stimulus provided by quantitative easing and other unconventional monetary policies in US since 2009. Analysis implies that effects on the most important macroeconomic indicators were limited and should have peaked after this paper was written. Results show that the highest impact on unemployment rate should have occurred in the early 2015 - 1.25 percentage points less than what was expected with no unconventional monetary policy actions. Effect on inflation rate should have peaked even later reaching an increase of 0.5 percentage points in 2016 (Engen, Laubach, & Reifschneider, 2015).

Econometric estimates of the effects of QE programs show that this policy tool has a significant impact on the most important macroeconomic indicators like inflation or GDP growth. Despite some questionable assumptions and a quite wide variation of results scientific literature almost unanimously states that QE has diminished the scale of economic downturn caused by the financial crisis in 2008. However most of the scientists have to admit that by itself QE cannot spark an economic recovery and the positive effects might be diminishing. What is more some authors (M. Joyce, D. Miles) propose that unconventional monetary policy might increase risks of the market malfunction and unsustainable levels of government debt.

**2.2 Methodology**

In this section most important details about the data and methods of empirical analysis will be provided.

### 2.2.1 Data type

Panel data type has been chosen because observations vary in time and the effects on 4 different economies are being measured. In panel data behavior of entities (in this case countries) are observed across some time period. This type of data allows to control for unobservable and immeasurable factors or variables which vary across time, but not across entities. This means that it accounts for individual heterogeneity.

### 2.2.2 Possible methods for empirical analysis

In most of other scientific papers vector autoregression method was used to measure the impact of QE. Given that the data type is panel model for empirical analysis was also chosen from pooled ordinary least squares (POLS), fixed effects and random effects.

**Vector autoregression (VAR) model.** It generally measures several variables among multiple time series. There is an equation for each variable which is based on lags of all variables and error term. Structural VAR is one of the most popular models measuring effects of unconventional monetary policy. It uses structural shocks (in most of the cases a decrease of long term yields due to QE) and compares what impact this shock have done to other variables. Problem is that the scale of QE effect on these long term yields is quite questionable and differ in different papers. Therefore other variable – central bank reserves were chosen in this paper as a measurement of QE. This indicator in most of the cases changes gradually and over a long period of time and its impact was expected to be proportional to these changes thereby VAR was considered not to be the most suitable model in this analysis.

**Ordinary least squares model.** Ordinary least squares (OLS) is a linear regression method with the goal to minimize sum of squares between given data set values and predicted

values. This type of regression is very commonly used, but it has some assumptions. A.H.Studenmund (2010) distinguishes seven of them:

1. Linearity. Regression model has to be linear with an additive error term
2. Population mean of the error term should be 0
3. Independent variables can't be correlated with the error term
4. No serial correlation. Error term observations can't be correlated
5. Homoskedasticity. Error terms should have constant variance
6. No multicollinearity. Explanatory variables can't be a perfect functions of each other
7. Normality. Error terms should be normally distributed

In OLS model the relationship between output and explanatory variables can be stated as follows:

$$Y_i = \beta_0 + \beta_1 X_{1,i} + \beta_2 X_{2.i} + \cdots + \beta_k X_{k,i} + \varepsilon_i$$

Y is dependent variable, i shows the time period, $\beta_0$ is an intercept, X is independent variable, $\beta_k$ is the coefficient for independent variable, ε is the deviation from linear relationship between variables, k is a number of independent variables.

**Fixed effects model.** Fixed effects (FE) is the model which is most useful when analyzing the variables impact over time. FE explore the relation between dependent and independent variables within an entity. In FE there is an assumption that some characteristics of an entity might impact or bias the outcome variable and there is a need to control for that. FE remove time invariant characteristics effects so there are only net impacts of the predictors left on dependent variable.

Another assumption of this model is that those time invariant characteristics are unique and not correlated with other individual features. Constant and the error term of each entity should not be correlated with the others. Otherwise FE method is not suitable.

FE model looks like this:

$$Y_{it} = \beta_0 + \beta_1 X_{1,it} + \beta_2 X_{2.it} + \cdots + \beta_k X_{k,it} + \alpha_i + \varepsilon_{it}$$

It looks similar like simple OLS equation, but here i means entity and t - time and $\alpha$ is the unknown intercept for each entity.

**Random effects model.** Unlike in FE, random effects model (RE) assumes the variation between entities to be random and uncorrelated with the controlled variable included in the model. Therefore RE should be used if it is expected that these differences across entities have some influence on outcome variable. Advantage of RE comparing to FE is that in RE it is possible to include time invariant variables.

RE equation can be stated as follows:

$$Y_{it} = \beta_0 + \beta_1 X_{1,it} + \beta_2 X_{2.it} + \cdots + \beta_k X_{k,it} + \alpha + u_{it} + \varepsilon_{it}$$

Here the main difference is that $u_{it}$ measures between entity errors and $\varepsilon_{it}$ – within entity errors.

# 3 Empirical analysis

In this chapter regression analysis models are going to be presented and explained. Although QE might have various impacts on the economy, one of the main goals of implementing this type of unconventional monetary policy tool is to achieve price stability. During the years of financial crisis some developed economies experienced serious deflation risks and unconventional measures was the way to achieve desirable (for most of these countries) 2% inflation rate. Therefore the main objective of this empirical research is to evaluate if QE might have contributed to this goal.

## 3.1 Information about data

QE impact was measured for 4 economies: US, UK, Japan and Euro area. Quarterly data were used from 2001 Q1 to 2016 Q3. Therefore maximum number of observations was 252 (in some models slightly lower). Output variable was inflation and one of the input variables – a measurement of QE. Other control variables were the most import economic indicators which are expected to be determinants of inflation.

**3.1.1 Dependent variable.** CPI (Consumer Price Index) was chosen to measure an inflation rate. Year over year rate was subtracted from OECD database and quarter over quarter data retrieved from FRED (Federal Reserve Bank of Saint Louis). Quarter over quarter data seasonally adjusted by transforming it into price indices (where 1999 quarter 4 was equal to 100) and using EViews program, method X-13.

**3.1.2 A measurement of QE.** There were a several options of how to measure QE: yield spreads, central banks' balance sheet or the reserve balances of the central bank. According to Fawley and Neely "...QE describes any policy that unusually increases the magnitude of central

bank liabilities - currency and bank reserves - particularly at the zero bound" (Fawley & Neely, 2013). Looking at the balance sheets of the 4 analyzed economies it was clear that the amount of currency in circulation was not changing very sharply in any period since 2000s. Whereas bank reserves (which is another component of the total liabilities of the central bank) were increasing quite dramatically in these economies during the financial crisis and when most of unconventional monetary policy measures were used. Therefore these reserves were chosen as a measure of QE. It is also worth noting that bank's reserves increase not only during the purchases of financial assets, but also when central bank provides credit to financial institutions, which by some economists is called a credit easing. Data of the reserves outstanding were extracted from the central banks of each of the 4 economies (Federal Reserve, Bank of England, Bank of Japan and European Central Bank). This data represented total worth of reserves of each central bank, but were not suitable for comparison between these economies because of different currencies and sizes of the economies. To solve this problem nominal amount of reserves was divided by nominal GDP of each of the 4 economies. Nominal GDP data was extracted from OECD database.

**3.1.3 Other independent variables.** Other independent variables were chosen with an intuition to help explaining changes in inflation and also used in other scientific papers analyzing the effects of QE: short term interest rates, long term interest rates, real GDP growth (Baumeister & Benati, 2010), unemployment rate, oil price, (Kapetanios *et al*, 2012). To make the model even more accurate a several additional common determinants of inflation were added: average wages, food prices and industrial inputs prices.

**Long term interest rates.** This indicator is one of the determinants of consumer borrowing and business investment. It is important to inflation, because higher long term interest

rates might increase saving, decrease lending and therefore reduce inflation. Long term interest rates were measured as 10-year government bond yields. Quarterly data generally show the average of daily rates and prices at which bonds are traded on financial market measured as a percentage. Data retrieved from OECD database.

**Short term interest rates.** Similarly as long term interest rates, short term interest rates indicate the cost of borrowing: rate at which short term government papers are issued or price of borrowings between financial institutions. Short term interest rates are measured in a percentage and as average of the daily rates. Data retrieved from OECD database.

**Unemployment rate.** According to the Phillips curve inflation rate and unemployment rate should be inversely related. However this relation was proven to be broken many times during the recent years. Therefore this indicator was chosen to check if unemployment rate can still help to explain inflation during the times of economic crisis and unconventional monetary policies. Total, harmonized unemployment rate was used for all persons. Data subtracted from OECD database.

**Real GDP.** Growth of real GDP might have a positive impact on future growth expectations and consumption in the economy. This would lead to higher price levels and inflation rates. Seasonally adjusted expenditure approach data of real GDP growth from the previous year or from the previous quarter (depending on a model) were used. Quarter over quarter data were used to make indices where needed (1999 Q4 =100). Data retrieved from OECD database.

**Oil prices.** Given that not core inflation, but real inflation was chosen as dependent variable energy and food prices should play an important role into determining that indicator.

"Crude oil prices: West Texas Intermediate (WTI)" was the exact name of the variable used for all 4 economies and retrieved from FRED database. Prices were measured as US dollars per barrel at the end of each quarter.

**Average wages.** Increasing wages in the economy might have positive impact on spending and inflation rate. In different economies average wages are calculated differently therefore there was no possibility to compare real levels of this variable. Only indices and growth rates were calculated using following types of data: USD per hour for average worker (US), GBP per week or average worker (UK), total labor compensation Yens per quarter (Japan), total labor compensation euros per quarter (Euro area). This indicator might be biased because it doesn't account for population changes and exchange rate changes. Data gathered from Thomson Reuters Datastream.

**Industrial inputs prices.** Similarly as oil price industrial inputs price might influence all other prices and is expected to have positive impact on inflation. These prices are considered as global therefore one index was used for all 4 economies. In that index 2005 = 100 and agricultural raw materials and metals prices are included. Monthly data were turned into quarterly data by using last observation of the quarter. Source of data – IMF (International Monetary Fund).

**Food prices.** It is assumed that inflation rate also should depend on food prices. Depending on the harvest during the year food prices can be very volatile (especially for vegetable and fruits). These changes to some extent might have an impact on all prices in the economy. Data of food and beverage price index where 2005 = 100 were used for all 4 economies. Data subtracted from IMF.

### 3.2 Regression models

To achieve the most accurate model which would help explain inflation and determine the effect of QE different regressions were implemented. Inflation was chosen as a dependent variable and economic indicators listed above were chosen as explanatory variables. There will be several different attempts changing the independent variables or including lags out of which the most relevant ones will be presented (more detailed information on how variables were measured and used in models is given in Appendix A and Appendix B). The main goal is to evaluate effect of QE by looking at the significance and coefficient of QE variable in the most precise model.

#### 3.2.1 Fixed effects model with an inclusion of only reserves as independent variable.

Fixed effects model was used, because 4 measured economies are quite different and each of them are expected to have some unobservable effects. Different political systems, geopolitical environment, culture and other factors might have an important role. Fixed effects method can account for these differences, so it was the first choice in regression analysis. QE variable which was called “Reserves” was found insignificant and some fraction of inflation variation was explained only because of a constant (*Table 1*). This model is very inaccurate because none of the other determinants of inflation were included.

*Table 1*. Regression results for the model with an inclusion of only reserves as independent variable

| Model 1: Fixed-effects, using 252 observations | | | | | |
|---|---|---|---|---|---|
| Included 4 cross-sectional units | | | | | |
| Time-series length: | 63 | | | | |
| Dependent variable: | Inflation | | | | |
| | *Coefficient* | *Std. Error* | *t-ratio* | *p-value* | |
| Const. | 1.50516 | 0.092891 | 16.2035 | <0.0001 | *** |
| Reserves | −0.0301925 | 0.900103 | −0.0335 | 0.9733 | |
| LSDV R-squared | 0.354747 | | | | |
| Akaike criterion | 793.2718 | | | | |

### 3.2.2 Fixed effects model with year over year changes.

Another fixed effects model was implemented with most of the data used as changes from the previous year. Only long term interest rates ("Long_IR"), short term interest rates ("Short IR") and unemployment rate ("Unemployment") were measured as values of given date, because both interest rates already represent changes and unemployment rate was expected to have a direct impact on inflation. Results have shown that an increase in reserves and food prices ("Food_price") as expected lead to an increase in inflation (*Table 2*). On the other hand coefficients of long term interest rates and average wages ("Wages") were significant and counterintuitive. These unusual result can be explained in several ways:

1. There was no time lag included therefore impact of these variables were not taken effect yet during the observed time moment.
2. Year over year changes are not appropriate for this type of regression.

3. Wages variable might be not suitable because it ignores exchange rate effect and is calculated differently in different economies.
4. Increase in long term interest rates and decrease in wages actually have a positive impact on inflation rate

Whichever explanation would be correct there was a need to try a couple different models and compare their results before reaching any conclusions.

*Table 2*. Regression results for a model with year over year changes.

| Model 2: Fixed-effects, using 252 observations<br>Included 4 cross-sectional units<br>Time-series length: 63<br>Dependent variable: Inflation | | | | | |
|---|---|---|---|---|---|
| | *Coefficient* | *Std. Error* | *t-ratio* | *p-value* | |
| Const. | 0.617082 | 0.590943 | 1.0442 | 0.2974 | |
| Reserves_change | 13.1768 | 2.06054 | 6.3948 | <0.0001 | *** |
| Long_IR | 0.232906 | 0.106239 | 2.1923 | 0.0293 | ** |
| Short_IR | 0.138551 | 0.0854387 | 1.6216 | 0.1062 | |
| Unemployment | 0.00374005 | 0.068451 | 0.0546 | 0.9565 | |
| GDP_growth | 0.0307812 | 0.0397363 | 0.7746 | 0.4393 | |
| Oil_price | 0.110726 | 0.268172 | 0.4129 | 0.6801 | |
| Wages | −18.7162 | 6.12775 | −3.0543 | 0.0025 | *** |
| Indust_input_p | −0.738147 | 0.40809 | −1.8088 | 0.0717 | * |
| Food_price | 4.07796 | 0.623704 | 6.5383 | <0.0001 | *** |
| LSDV R-squared 0.590581<br>Akaike criterion 694.6363 | | | | | |

### 3.2.3 Fixed effects model with year over year changes and an inclusion of lags.

This model is very similar as the previous one, but here independent variables were lagged by 2 quarters. After research half a year was chosen as an optimal time for determinants of inflation to take effect in Baumeister and Benati (2010) empirical analysis therefore same period was chosen in this study as well. Results were similar as in previous model, but this time GDP growth was found to have a significant positive impact on inflation rate (*Table 3*). Coefficients of other variables have not changed too much and R-squared was found to be higher. Also from theoretical point of view lags make sense, because independent variables are not expected to take effect immediately, therefore this regression is considered to be more precise than the one without time lags. However coefficients of average wages and long term interest rates remained with unusual signs.

Long term interest rates might indicate not only returns on financial assets, but also expectations of countries economic health in the future and possible risks. In economic theory interest rates should inversely correlate with an inflation rate, because lower rates encourage people to spend money instead of saving and vice versus. But in a model higher 10 years government bond yields were found to have a positive impact on inflation rate. The reason might be because these yields are connected not only with consumer preferences to save or spend money. Risks and long term expectation can be important as well. If country becomes less stable and future prospects are considered to be negative, even very low interest rates might not increase spending and inflation.

Negative sign on average wages variable can be explained with other independent variables taking positive effect of wages. Regression was done with an inclusion of only wages

as independent variable (Appendix C). It shows that the positive change of average year over year wage level leads to a higher rate of inflation. But in a regression below a sign of wages coefficient was negative. An explanation for this would be that other variables like GDP growth take into account same positive effects and explain them even better.

*Table 3*. Regression results for a model with year over year changes and an inclusion of lags.

| Model 4: Fixed-effects, using 244 observations<br>Included 4 cross-sectional units<br>Time-series length: 61<br>Dependent variable: Inflation | | | | | |
|---|---|---|---|---|---|
| | *Coefficient* | *Std. Error* | *t-ratio* | *p-value* | |
| const | 0.0470113 | 0.611191 | 0.0769 | 0.9388 | |
| Reserves_change_2 | 16.2522 | 1.95195 | 8.3261 | <0.0001 | *** |
| Long_IR_2 | 0.256826 | 0.105228 | 2.4407 | 0.0154 | ** |
| Short_IR_2 | 0.129749 | 0.0777819 | 1.6681 | 0.0966 | * |
| Unemployment_2 | 0.0519842 | 0.0666586 | 0.7799 | 0.4363 | |
| GDP_growth_2 | 0.113887 | 0.0370853 | 3.0709 | 0.0024 | *** |
| Oil_price_2 | 0.473106 | 0.243913 | 1.9397 | 0.0536 | * |
| Wages_2 | −19.0667 | 5.69102 | −3.3503 | 0.0009 | *** |
| Indust_input_p_2 | 0.00791273 | 0.374408 | 0.0211 | 0.9832 | |
| Food_price_2 | 3.28669 | 0.568582 | 5.7805 | <0.0001 | *** |
| LSDV R-squared 0.663162<br>Akaike criterion 624.5768 | | | | | |

### 3.2.4 Fixed effects model with levels and an inclusion of lags.

In this model all variables were transformed into real levels or indices. This type of model was chosen to observe if total asset purchases have an effect on price levels and in a way to track quarter over quarter effects (in previous models most of the variables were measured as year over year changes). Therefore inflation rate was changed into price level, GDP growth - into

real GDP index, etc. Only level of reserves was measured as a percentage of nominal GDP. Also all independent variables were lagged by 2 quarters to give them enough time to take an effect. Knowing that in most of the cases there will be a quite obvious increasing trend (e. g. positive inflation would mean a constantly increasing price levels) time trend variable was included. Additionally expecting that price levels might also depend on past values of itself, lag of this variable was used to catch that effect. Interest rates and unemployment rates were excluded from this model, because these variables were not transformable into levels or indices.

In a model several variables coefficients were found to be significant and all of them had expected signs (*Table 4*). R-squared was very high because of time trend and a lag of dependent variable therefore this model shouldn't be seen as superior to previous one only because of this indicator. Reserves variable which measures QE again was significant and had a positive impact on price level. Also wages and industrial inputs prices ("Industrial_input_p") contributed to higher price index. Lagged value of price index also had a very significant positive coefficient. Only negative coefficient on time trend might seem quite strange, but it just means that variables on the right side of the equation were increasing at the faster rates than dependent variable.

*Table 4*. Regression results for a model with levels and an inclusion of lags.

| Model 4: Fixed-effects, using 244 observations<br>Included 4 cross-sectional units<br>Time-series length: 61<br>Dependent variable: Price_index (Inflation) | | | | | |
|---|---|---|---|---|---|
| | *Coefficient* | *Std. Error* | *t-ratio* | *p-value* | |
| Const. | 0.0222298 | 0.0157533 | 1.4111 | 0.1595 | |
| Reserves_2 | 0.0439956 | 0.00954439 | 4.6096 | <0.0001 | *** |
| GDP_2 | 0.00987301 | 0.0169895 | 0.5811 | 0.5617 | |
| Oil_price_2 | −1.4009e-05 | 3.85992e-05 | −0.3629 | 0.7170 | |
| Wages_2 | 0.0341911 | 0.0156525 | 2.1844 | 0.0299 | ** |
| Indust_input_p_2 | 0.000132247 | 2.71508e-05 | 4.8708 | <0.0001 | *** |
| Food_price_2 | −7.24785e-05 | 4.9688e-05 | −1.4587 | 0.1460 | |
| Price_index_2 | 0.938681 | 0.0167984 | 55.8791 | <0.0001 | *** |
| Time | −0.000202092 | 9.0154e-05 | −2.2416 | 0.0259 | ** |
| LSDV R-squared | | | 0.998167 | | |
| Akaike criterion | | | −1758.732 | | |

### 3.3 Panel data analysis

Several tests and panel analysis methods were used to observe possible limitations of a model or to find the most suitable regression. Last two models from the previous part “3.2 Regression results” were found to explain highest share of inflation variation therefore these models were analyzed more comprehensively.

**3.3.1 Panel diagnostics.** Several tests were used to find out the most appropriate panel model. Firstly for the pooled OLS model with year over year changes and an inclusion of lags panel diagnostics have shown that both random effects and fixed effects models were more suitable than pooled OLS. Afterwards using STATA statistical software Hausman test was executed (gretl was not able to perform this test) to decide between fixed and random effects

model. It have shown that fixed effects model should be chosen (Appendix D). Exactly the same tests were done for the model with levels. Results have shown that fixed effects is the most appropriate method as well (Appendix E).

**3.3.2 Heteroskedasticity.** Wald test was performed for the same two models to check if the units have a common error variance. In this test very low p-value was observed for both models which indicates that there is a heteroskedasticity problem (Appendix F). There was an attempt to solve it with an inclusion of robust standard errors, but results haven't changed significantly. Non constant error variance in this study might be due to financial crisis factor and it might mean that statistical tests on significance would be less reliable.

**3.3.3 Normality of residuals.** In gretl normality of residuals test was used to observe if errors are normally distributed. For the model with year over year changes p-value of this test was higher than 0.05 which means that hypothesis that errors are normally distributed can't be rejected. However for the other model with levels p-value was extremely low which indicates that normality assumption is violated (Appendix G).

### 3.4 Limitations of the models and recommendations for future analyses

Although this empirical analysis might provide some insight on QE impact on inflation, but its results should be taken carefully. These would be the most important limitations of this analysis and recommendations how it might be improved:

1. Most of the other similar researches use VAR (Vector Autoregressive) models instead of RE, FE or Pooled OLS. VAR models account for linear interdependencies therefore it might be more suitable for this analysis.

2. Heteroskedasticity problem was found in both most suitable models. This means that error variance is not constant and that make the models less accurate.
3. In the model with levels errors were found to be not normally distributed.
4. Central banks' reserves show not only QE, but also credit easing impacts. Analysis might be repeated using the size of whole central banks' balance sheet or yield spreads as a measurement of QE.
5. Other variables which were not included in this analysis like exchange rates or money supply might help to explain inflation as well.
6. Some independent variables might not only have an impact on inflation, but also might be affected by inflation e. g. lower interest rates should have a positive impact on inflation levels, but these interest are decreased only when inflation is already low. There was an attempt to solve this problem with an inclusion of lags, but it might still exist.
7. Financial crisis might have effected whole dynamics how inflation is determined. In more extended analysis all models might be repeated with an inclusion of dummies which would be equal to 1 if time period is until the crisis and/or during the crisis.
8. This analysis doesn't provide any conclusions about QE effects in every economy separately. All measured economies are quite different and impacts of unconventional monetary policy tools might differ as well.
9. Independent variables might be interdependent. Even though Variance Inflation Factor have not shown significant collinearity problems in OLS models it was not possible to implement it in main fixed effects models. Real GDP might be related with average wage levels and QE (therefore reserves too) was proven to have an impact on long term yields.

Despite all these limitations this analysis have shown that macroeconomic indicators can explain quite a big share of inflation variation. In main models QE policy was found to have a significant positive impact on inflation rate which means that it helped to sustain healthy price growth for the economy (because in measured economies inflation before the QE was lower than targeted rates). Even though for different economies these effects might be different analysis confirmed the results of most of the other scientific papers that QE contributed to faster economic recovery during the global financial crisis and in its aftermath.

# Conclusions

In this paper macroeconomic effects of QE were analyzed in 4 economies: US, UK, Japan and Eurozone. Firstly general information about QE and other monetary policy tools was provided. Then implementation of QE was explained in different economies following with an overview of consequences of QE and the most important economic indicators related to unconventional monetary policy. In the second part a lot of attention was paid to inflation – economic factor targeted by most of the central banks' monetary policies. Afterwards there was an analysis of the other scientific papers investigating the impacts of QE. In the third part using regression analysis there was an attempt to measure if QE had a significant impact to inflation rates in examined economies. All the results can be summarized as following:

1. QE in 4 analyzed economies was implemented differently and not at the same time.
2. Investigated economic factors show that 4 economies have some special characteristics (like low unemployment and low inflation in Japan and high unemployment in Eurozone) and might have been in slightly different economic cycles during the implementation of QE. That could be the reason of different effectiveness of this policy.
3. After the financial crisis a sharp fall in money multiplier and gradual decrease of money velocity was observed – that explains why QE policy was not as effective as it could have been.
4. Risks and dangers associated with QE include possible diminishing marginal effects, credit market malfunction, "monetization of debt", hyperinflation in the future and some others.

5. However most of the authors of empirical analyses conclude that QE had a positive impact on inflation rate, GDP growth and economic recovery in general since financial crisis started.
6. Regression analysis have shown that it is very difficult with panel methods (Pooled OLS, RE, FE) to make an accurate inflation model. Therefore several limitations should be taken into account when evaluating its results, but both main models have shown that QE had a positive impact on inflation rate.

All in all this thesis have shown that in times of economic crisis, fall of consumption and investment unconventional measures were necessary. QE was one of this kind of monetary policies and it helped to prevent deeper recession by increasing inflation and GDP growth. On the other hand long term consequences of this policy are still questionable and there are some risks involved, therefore in the future QE should be used only when there is a real necessity.

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# Appendices

## Appendix A

*Table 5*. Variables in models with year over year changes (Model 1, Model 2 and Model 3).

| **Variable** | **Number format**[2] | **Calculation method** |
|---|---|---|
| Inflation | Percentage | Percentage change from the previous year |
| Reserves | Real number | Change of the share of nominal GDP |
| Long term interest rates | Percentage | - |
| Short term interest rates | Percentage | - |
| Unemployment rate | Percentage | - |
| Real GDP | Percentage | Percentage change from the previous year |
| Oil prices | Real number | Percentage change from the previous year |
| Average wages | Real number | Percentage change from the previous year |
| Industrial inputs prices | Real number | Percentage change from the previous year |
| Food prices | Real number | Percentage change from the previous year |

[2] In this column "percentage" means that 1% would be used in a regression as 1, whereas in case of "real number" – as 0.01

# Appendix B

*Table 6*. Variables in model with levels and indices (Model 4).

| **Variable** | **Number format** | **Calculation method** |
|---|---|---|
| Inflation (price level) | Real number | Index (1999 Q4 = 1) |
| Reserves | Real number | Share of nominal GDP |
| GDP | Real number | Index (1999 Q4 = 1) |
| Oil price | Real prices | - |
| Wages | Real number | Index (1999 Q4 = 1) |
| Industrial inputs price | Real number | Index (2005 = 100) |
| Food price | Real number | Index (2005 = 100) |

# Appendix C

*Table 7*. Regression with lagged wages variable

Model 3: Fixed-effects, using 244 observations
Included 4 cross-sectional units
Time-series length = 61
Dependent variable: Inflation

| | *Coefficient* | *Std. Error* | *t-ratio* | *p-value* | |
|---|---|---|---|---|---|
| Const. | 1.26336 | 0.135377 | 9.3321 | <0.0001 | *** |
| Wages_2 | 10.9054 | 5.25632 | 2.0747 | 0.0391 | ** |

| | | | |
|---|---|---|---|
| Mean dependent var | 1.498927 | S.D. dependent var | 1.424446 |
| Sum squared resid | 316.9534 | S.E. of regression | 1.151592 |
| LSDV R-squared | 0.357169 | Within R-squared | 0.017692 |
| LSDV F(4, 239) | 33.19815 | P-value(F) | 5.10e-22 |
| Log-likelihood | −378.1345 | Akaike criterion | 766.2691 |
| Schwarz criterion | 783.7549 | Hannan-Quinn | 773.3114 |
| rho | 0.848250 | Durbin-Watson | 0.307848 |

# Appendix D

Panel diagnostics for the model with year over year changes and an inclusion of lags.

Residual variance: 166.081/(244 - 13) = 0.718965

Joint significance of differing group means: F(3, 231) = 14.535 with p-value 1.05067e-008

(A low p-value counts against the null hypothesis that the pooled OLS model is adequate, in favor of the fixed effects alternative.)

Breusch-Pagan test statistic:

LM = 30.4753 with p-value = prob(chi-square(1) > 30.4753) = 3.38141e-008

(A low p-value counts against the null hypothesis that the pooled OLS model

is adequate, in favor of the random effects alternative.)

Omitting group means regression: insufficient degrees of freedom

*Figure 10*. Hausman test for the model with year over year changes and an inclusion of lags

```
. hausman fixed random
```

| | Coefficients (b) fixed | (B) random | (b-B) Difference | sqrt(diag(V_b-V_B)) S.E. |
|---|---|---|---|---|
| Reserves_c~e | 16.2522 | 17.37091 | -1.118715 | . |
| Long_IR | .2568259 | .6688579 | -.412032 | .0598066 |
| Short_IR | .1297487 | -.0163193 | .146068 | .0249191 |
| Unemployment | .0519842 | .1092687 | -.0572844 | .0575223 |
| GDP_growth | .1138871 | .1832775 | -.0693904 | . |
| Oil_price | .4731064 | .3662351 | .1068713 | . |
| Wages | -19.06667 | -9.611783 | -9.454887 | . |
| Indust_inp~p | .0079127 | -.6255241 | .6334368 | . |
| Food_price | 3.28669 | 3.024732 | .261958 | . |

```
                b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(9) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       55.99
                Prob>chi2 =      0.0000
                (V_b-V_B is not positive definite)
```

# Appendix E

Panel diagnostics for the fixed effects model with levels and an inclusion of lags

Joint significance of differing group means:

F(3, 232) = 25.8259 with p-value 1.88116e-014

(A low p-value counts against the null hypothesis that the pooled OLS model

is adequate, in favor of the fixed effects alternative.)

Breusch-Pagan test statistic:

LM = 6.25584 with p-value = prob(chi-square(1) > 6.25584) = 0.0123785

(A low p-value counts against the null hypothesis that the pooled OLS model

is adequate, in favor of the random effects alternative.)

Omitting group means regression: insufficient degrees of freedom

*Figure 11*. Hausman test for the model with levels and an inclusion of lags

```
. hausman fixed random
```

| | ——— Coefficients ——— | | | |
|---|---|---|---|---|
| | (b) fixed | (B) random | (b-B) Difference | sqrt(diag(V_b-V_B)) S.E. |
| Reserves | .0439956 | .0432662 | .0007294 | . |
| GDP | .009873 | .0094131 | .0004599 | .0081058 |
| Oilprice | -.000014 | -.0000155 | 1.49e-06 | . |
| Wages | .0341911 | .0155807 | .0186104 | .0129028 |
| Indust_inp~p | .0001322 | .0001463 | -.000014 | . |
| Food_price | -.0000725 | -.0000936 | .0000211 | . |
| pricelvllag2 | .938681 | 1.019574 | -.0808933 | .0147615 |
| Date | -.0002021 | -.0004091 | .000207 | .0000323 |

```
                b = consistent under Ho and Ha; obtained from xtreg
    B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test:  Ho:  difference in coefficients not systematic

          chi2(8) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                  =       83.35
        Prob>chi2 =      0.0000
        (V_b-V_B is not positive definite)
```

# Appendix F

Wald tests for heteroskedasticity.

Model with year over year changes and an inclusion of lags.

```
Distribution free Wald test for heteroskedasticity -
  Null hypothesis: the units have a common error variance
  Asymptotic test statistic: Chi-square(4) = 60.1771
  with p-value = 2.66266e-012
```

Model with levels and an inclusion of lags

```
Distribution free Wald test for heteroskedasticity -
  Null hypothesis: the units have a common error variance
  Asymptotic test statistic: Chi-square(4) = 70.1619
  with p-value = 2.09808e-014
```

# Appendix G

Normality of residuals. Model with year over year changes and an inclusion of lags.

| Test for null hypothesis of normal distribution: |
|---|
| Chi-square(2) = 2.330 with p-value 0.31199 |

Normality of residuals for the fixed effects model with levels and an inclusion of lags

| Test for null hypothesis of normal distribution: |
|---|
| Chi-square(2) = 129.244 with p-value 0.00000 |