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BACHELOR'S THESIS

The Impact of Macroeconomic News on the Price of Financial Assets

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Declaration of Authorship

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Prague, May 9, 2016

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Abstract

This thesis investigates the effect of Czech macroeconomic news announcements and Czech National Bank (CNB) communication on the price of financial assets and its volatility. As the financial assets we selected the EUR/CZK and USD/CZK exchange rates and also the Prague stock PX Index. To analyze the aforesaid effect we employed the GARCH (1,1) and EGARCH (1,1) models, each with Normal and Student's t error distribution. The main results were that the CNB's communication indeed have significant effect on the price of all three examined assets and surprisingly also tend to increase their volatility. Also the macroeconomic announcements significantly influence examined assets however significant macroeconomic indicators differ for each asset. The most influencing ones are: CPI, 1YPRIBOR and the unemployment rate. Another finding of our research was that volatility of examined time series data shows the characteristics of leverage effect, volatility clustering and persistence.

Keywords Financial market, GARCH, EGARCH, Macroeconomic news announcements, Central bank communication

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Abstrakt

Tato práce zkoumá vliv zveřejňování českých makroekonomických zpráv a komunikace České Národní Banky (ČNB) na cenu finančních aktiv a jejich volatilitu. Jako finanční aktiva jsme zvolili směnné kurzy EUR/CZK a USD/CZK a také akciový index pražské buzy PX. K analýze jsme použili GARCH (1,1) a EGARCH (1,1) modely, každý s Normálním a Studentovým rozdělením reziduí. Hlavním zjištěním bylo, že komunikace ČNB má vliv na cenu všech tří aktiv a překvapivě zvyšuje jejich volatilitu. Zveřejňování makroekonomických zpráv také významně ovlivňuje cenu a volatilitu zkoumaných aktiv, nicméně pro každé aktivum jsou významné jiné makroekonomické indikátory. Nejvíce ovlivňující indikátory jsou: index spotřebitelských cen, 1YPRIBOR a míra nezaměstnanosti. Další závěr našeho výzkumu je, že volatilita zkoumaných časových řad vykazuje známky pákového efektu, shlukování volatility a její přetrvávání.

Klíčová slova Finanční trh, GARCH, EGARCH, Zveřejňování makroekonomických zpráv, Komunikace centrální banky

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Acronyms

1YPRIBOR 1 Year Prague InterBank Offered Rate

AIC Akaike Information Criterion

ACF Autocorrelation Function

ADF augmented Dickey-Fuller test

AR Autoregressive

ARCH Autoregressive Conditional Heteroskedasticity

ARCH-LM ARCH Lagrange Multiplier test

BIC Bayesian Information Criterion

CNB Czech National Bank

CPI Consumer Price Index

EGARCH Exponential GARCH

EUR/CZK Euro-Czech koruna exchange rate

FOREX Foreign Exchange

GARCH Generalized ARCH

GDP Gross Domestic Product

MoF Ministry of Finance

NAIRU Non-Accelerating Inflation Rate of Unemployment

OLS Ordinary Least Squares

PACF Partial ACF

PDF Probability Distribution Function

PRIBOR Prague InterBank Offered Rate

PSE Prague Stock Exchange

SE Standard Error

USD/CZK United States dollar - Czech koruna exchange rate

YoY Year-over-Year

Bachelor's Thesis Proposal

Author	Jakub Říha
Supervisor	Ing. Michala Moravcová
Proposed topic	The Impact of Macroeconomic News on the Price of Financial Assets

Topic characteristics There is a fair amount of evidence that macroeconomic news and central bank communication matter for the financial markets. More attention is paid to developed markets, while emerging markets are less examined. Frequently applied models to estimate asset price volatility are autoregressive conditional heteroscedastic (ARCH) models advanced by Engle (1982) and generalized (GARCH) model developed independently by Bollerslev (1986) and Taylor (1986).I will first investigate the overall characteristics of asset price reaction to macroeconomic news and central bank communication. Then I will take a closer look at the available techniques, which measure the impact of the news announcement on the financial markets. Afterwards, the hypothesis about the news impact on the asset price and volatility will be tested. Finally, I will present empirical results and conclusion.

Hypotheses

1. Does the volatility of examined time series show the characteristics of leverage effects, volatility clustering and persistence?
2. Do macroeconomic news announcements and central bank communication have the impact on the asset price value (conditional mean)?
3. Do macroeconomic news announcements and central bank communication have the impact on the asset price volatility (conditional variance)?

Methodology As econometric models I use variations of ARCH model - GARCH and EGARCH.

Outline

1. Introduction
2. Theoretical background
3. Data characteristics
4. Methodology
5. Hypotheses & Empirical results
6. Conclusion

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Author Supervisor

Chapter 1

Introduction

The fact that macroeconomic news announcements and central bank communication influence the price of financial assets and its volatility is publicly known. However the communication of central banks has dramatically changed over the last two decades. Central banks are nowadays more open to the public to assure their transparency and independence and as a result the communication influences financial markets in more significant way than before. The effect of news announcements and central bank communication was subject of many studies however in most cases they were focused mostly on developed markets.

We aim to examine the emerging market of Czech republic, more precisely the exchange rates and the stock market. The subject of the study will be EUR/CZK and USD/CZK exchange rates and also the PX Index, thus we will investigate how are these assets affected by domestic news announcements and Czech central bank communication. The main contribution of this paper is that we explore the after crisis period - from January 2009 to December 2015 (although according to some points of view the year 2009 was still part of the crisis). To estimate the aforesaid effect we will employ two commonly used models for financial time series data the GARCH and EGARCH models which allow including independent variables about central bank communication and macroeconomic news announcements. Unlike the GARCH, the EGARCH model assumes the asymmetry of the shocks which is generally expected in financial time series (Nelson 1991). Besides central bank communication data we use five macroeconomic indicators as the independent variables - CPI, GDP, Retail Sales, 1YPRIBOR and Unemployment rate.

The thesis is structured as follows: Chapter 2 provides literature review and basic information how news announcements affect the assets prices. Chapter

3 describes individual variables and their importance to our research. Chapter 4 covers the primary analysis of the data and also the models we used. Chapter 5 discuss the hypotheses, empirical results and their clarification. Finally, Chapter 6 concludes our findings and provides ideas for future research.

Chapter 2

Expected Effect of the News & Related Literature

2.1 Estimating the Effect of Macroeconomic News Announcements

Basic economic thinking can be often enough to briefly estimate the impact of new economic data announcements on asset prices. Consider e.g. stock price and release of news indicating unexpected economic strength such as increase in personal spending. To estimate the stock price a simple method of discounted cash flow can be used. In that that case there are two basic information required - future corporate earnings & dividends and future interest rates. The stock value should match the expected dividend/cash flow which is discounted by some interest rate.

$$DCF = \sum_{i=1}^{n} \frac{CF}{(1+r)^i}$$

The expected effect of unforeseen news about stronger economy on both of them is relatively evident. With stronger economy the corporate earnings & dividends and also the interest rates are expected to rise. With faster growing economy the expectations of higher corporate earnings and therefore higher dividends are natural. The logic behind the expectations for higher interest rates is that stronger economy drives price levels higher, instigating the central bank to pursue tighter monetary policy (Faust *et al.* 2003). The final effect on stock price is however somewhat ambiguous since the investors cannot know

whether the effect on corporate earnings & dividends will be greater than the effect on interest rates which actually discount the dividends.

Boyd *et al.* (2001) studied the reaction of stock market on negative unemployment announcements and also concluded the ambiguity as the current state of economy is also relevant. Their research showed that the effect of surprised increase in unemployment rate differs during the business cycle. On average in times of economic contraction the effect on future interest rates exceeds the effect on future corporate earnings & dividends causing fall in stock prices whereas in times of economic expansion the final effect is reversed and stock prices rise. Same relationship was documented by Andersen *et al.* (2007).

Reaction of exchange rates to economic news is subtly more problematic. As described by Bartolini *et al.* (2008) if in case of positive domestic news announcements investors believe in rise of domestic imports which cause higher demand for foreign currency the domestic currency may depreciate. On the contrary Andersen *et al.* (2007) documented that positive news announcements increase the demand for domestic currency and therefore cause its appreciation. Also assuming that higher domestic inflation usually depreciates the currency, in the short run the currency may appreciate. The reason would be the central bank's monetary policy of inflation targeting. In case of excessive inflation the short-term interest rates are increased to decelerate the economy.

2.2 Related Literature

In the US Bartolini *et al.* (2008) studied how bonds, stocks and foreign exchange markets respond to nine categories of macro news such as GDP advance release, nonfarm payroll, unemployment rate, consumer price index, personal spending and others. Their findings support the opinion that positive news causes rise in asset prices and also that only GDP advance release and news about employment situation and manufacturing are important. According to the authors stock prices showed the weakest response whereas the interest rates showed the strongest ones.

In the context of uncovered interest rate parity Faust *et al.* (2003) interpreted the joint behavior of exchange rates and zero coupon interest rate given US macroeconomic announcements. The authors find that for better than expected news the dollar appreciates in the short run but either the dollar will

depreciate in the future by higher proportion than was the original appreciation or the risk premium for holding foreign currency will decrease.

The asset price itself is often not the main subject of the study. Investors also want information about risks such as market stability - its volatility. The volatility is measured as standard deviation of the returns which states the deviation from the mean (average return). Therefore assets with higher volatility are riskier and less stable. Laakkonen (2007) examined the impact of the US and European macroeconomic news on the USD/EUR volatility and concluded that the news significantly increase the volatility of exchange rates especially immediately after the announcement. Another finding of the study was that "*negative news increase volatility more than positive news. However, the impact of positive news was found to be surprisingly low*" (Laakkonen 2007).The response also differs for consisting and conflicting information on the state of economy. The consistent information increase volatility less than the conflicting ones.

To decrease the market volatility or maintain the stability the central banks must carefully chose their policies. For exchange rates the actual interventions (purchases and sales on Forex market) are a direct policy tool which allows the central bank to influence the exchange rate development. However, Fratzscher (2006) documented that such interventions tend to increase exchange rate volatility and market uncertainty. Partially same effect was documented by Tashu (2014) who examined forex interventions in Peru. According to the study by Tashu (2014) forex purchases have no effect on the currency appreciation and have negative effect on exchange rate volatility. On the contrary the author finds forex sales effective in reducing exchange rate volatility and preventing depreciation.

In the last decades monetary authorities started to use another direct tool to control the exchange rate - communication. Fratzscher (2006) finds that central bank communication decrease exchange rate volatility and market uncertainty. Further finding of the study was the increase in use of communication as a policy. US and the euro area use almost exclusively communication to alter exchange rate development while some economies like Japan use communication and actual interventions in the same ratio. The effectiveness of communication was also documented by Fratzscher (2006). Results by Fratzscher (2006) indi-

cate that communication affects forward rates in medium to long-term horizon and its effect is more persistent then the effect of actual interventions.

Macroeconomic news can also influence assets internationally. It is rational to think that large developed markets have impact on the emerging ones. Cakan *et al.* (2014) analyzed the impacts of unexpected US economic news on the volatility of twelve emerging markets. The analysis included both positive and negative news about US unemployment and inflation. The authors find that the volatility shocks are asymmetric and persistent. With good news about US unemployment the asymmetric volatility decreases in two thirds of researched countries whereas with bad news about US unemployment the asymmetric volatility increases in only one third of those countries.

2.2.1 Emerging Markets

Many studies have focused solely on emerging markets and their reaction to economic news and central bank communication. Examining the emerging market of Czech republic Fiser and Horvath (2009) find that also the timing of the communication is important since financial markets tend to give stronger response to the communication before the policy meetings than after them. In addition the authors documented that macroeconomic news releases and central bank communication have calming effect on exchange rate volatility which is consistent with Fratzscher (2006). This also supports the opinion that central bank aims to stable the market by its communication.

Hanousek *et al.* (2008) examined the reaction of Czech, Hungarian and Polish stock market on macroeconomic news releases originating in EU or in US. While news from EU affect significantly all three stock markets, news from US have effect on Czech and Hungarian markets only. The authors attribute the results to the fact that foreign investors are responsible for significant part of the traded volume. In terms of volatility the effect is lower in Czech Republic than in Hungary or Poland suggesting that Czech market is calmer.

Similar results were presented by Cai *et al.* (2009). They studied the impact of US and domestic news on nine emerging economies including Czech Republic and their research corresponds with previously mentioned trends. Except for two exchange rates (Thai and Turkish) all other show consistent reactions to news especially news originating in the US. Other findings were that exchange

rates became more sensitive in recent years and that "*good (bad) news matters more when optimism (pessimism) prevails*" (Cai *et al.* 2009) which is valid for all nine examined markets.

Since the current state of economy is crucial for estimating the impact of macroeconomic news releases, as shown by Boyd *et al.* (2001) and Andersen *et al.* (2007), one would expect significant differences in the impacts before and during the economic crisis. Egert and Kocenda (2013) analyzed the impact of news and central bank communication on exchange rates of Czech koruna, Hungarian forint and Polish zloty. The main difference in exchange rates behavior towards central banks communication during pre-crisis period and during the crisis is the magnitude of responsiveness. Before crisis there were only negligible reactions to the central bank communication (except Polish zloty). But after the crisis the currencies became more sensitive to the verbal communication and all three of them reacted in significant way. For macroeconomic news the pre-crisis behavior of examined currencies was corresponding to its expected behavior whereas during the crisis the currencies clung to the key economic indicator the real GDP growth. The authors suggest another potential explanation for these differences and that is the extent to which are these currencies traded on the international forex market.

Chapter 3

Data Description

We aim to examine the emerging market of Czech Republic, more precisely the exchange rates and the stock market. The influence of macroeconomic announcements and central bank communication on financial markets has been broadly documented by several researchers (Andersen *et al.* 2003; Ehrmann and Fratzscher 2007; Blinder *et al.* 2008) also literature survey by Cavusoglu (2010) provides evidence that macroeconomic fundamentals are truly important for exchange rates movements.

Since we examine the Czech exchange rate and stock market our dependent variables of interest are exchange rates EUR/CZK, USD/CZK and the Prague Stock Exchange PX Index. We used daily data from January 2009 to December 2015 (7 years). As independent variables we have naturally selected data about Czech central bank communication and five essential macroeconomic indicators described in section (3.5).

3.1 EUR/CZK

The EUR/CZK exchange rate is due to geographical and political reasons the most observed exchange rate in Czech Republic since the non-cash introduction of euro in 1999. The political reasons include EU membership and more importantly the commitment to join the eurozone[1] which was part of the Treaty of Accession to the European Union signed in 2003. Nevertheless on 22 December 2015 the Czech National Bank and the Ministry of Finance recommended to "*not to set euro adoption date yet*"[2] meaning that Czech Republic will not

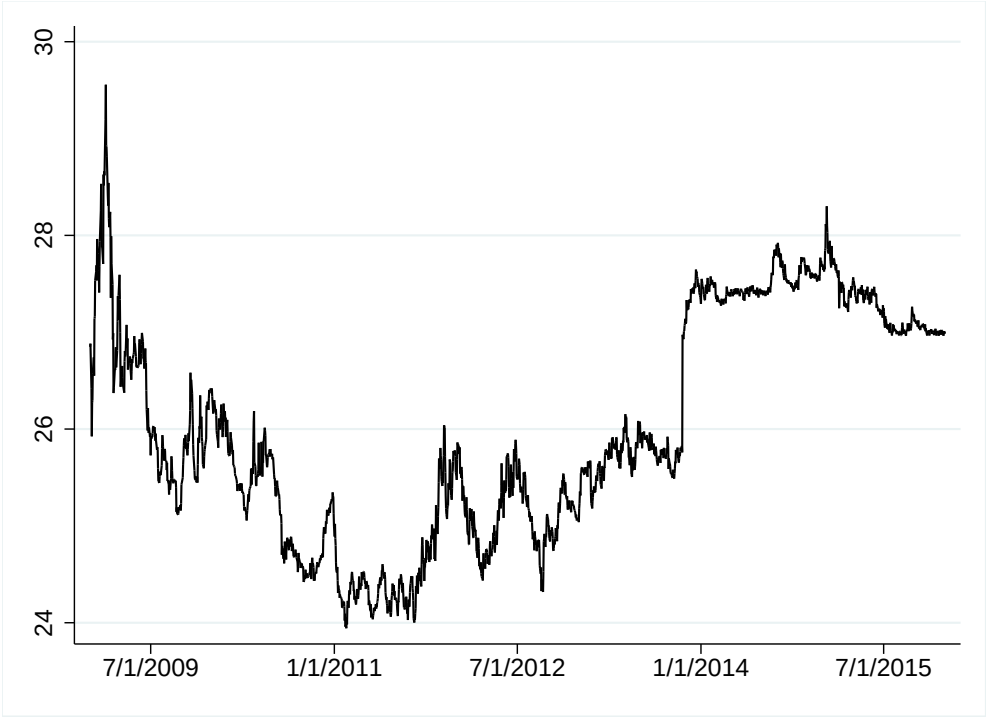
[1] Monetary union of 19 of the 28 EU member states which adopted euro as their currency

[2] http://www.cnb.cz/en/public/media_service/press_releases_cnb/2015/20151222_sladenost_2015.html

attempt to enter ERM II in 2016. The reason was the European economic and debt crisis in recent years which complicated the process of real economic convergence of the Czech Republic. However according to the CNB and MoF statement "*all the Maastricht criteria except for ERM II participation are likely to be fulfilled in the medium term*".[3]

The historical maximum of EUR/CZK was shortly after the euro introduction in 1999. On 25 March the exchange rate was 38,6 while the historical minimum was 22,97 on 21 July 2008 during the economic crisis. Naturally after the crisis the exchange rate increased back to almost 29 but only for a short period of time.

Figure 3.1: EUR/CZK



The exchange rate commitment In November 2013 the CNB decided to use the exchange rate as a main monetary policy instrument instead of interest rates. The main monetary policy objective — to fulfill the inflation target — remained the same. On 7 November 2013 the Czech national bank intervened in the forex market and Czech koruna depreciated against the euro from 25,79 to 26,85. CNB' s interventions in the forex market involve buying foreign currency and selling Czech koruna to maintain the exchange rate "*close to CZK 27 to*

[3]http://www.cnb.cz/en/public/media_service/press_releases_cnb/2015/20151222_sladenost_2015.html

the euro".[4] The CNB will not allow the koruna appreciation if the exchange rate would no longer be close to CZK 27 to the euro. Such appreciation is prevented by CNB by automatic interventions on forex market. And since the CNB is the only issuer of the Czech currency these interventions are potentially unlimited. This exchange rate commitment is however asymmetric. The CNB allows the koruna to depreciate according the supply and demand on the forex market.

3.2 USD/CZK

The exchange rate between US dollar and Czech koruna seems less important than EUR/CZK. The reason is that Czech economy is more connected to the EU than to the US even though economic data releases originating in the US also have significant effect on the Czech financial market (Hanousek *et al.* 2008). The historical minimum was 14,45 during the economic crisis on 22 July 2008 whereas the historical maximum was 42,13 in October 2000. In recent years the exchange rate was most of the time oscillating between 19 and 20 korunas per dollar but in early July 2014 Czech koruna started to depreciate and in March 2015 the US dollar breached the 25 korunas level after almost a decade. At current times the exchange rate is usually slightly under the 25 korunas per dollar level. Interesting fact might be that unlike the PX Index[5] the USD/CZK exchange rate did not suffer from any substantial shock after the terrorist attack on 11 September 2001.

[4] http://www.cnb.cz/en/faq/the_exchange_rate_commitment.html#3

[5] For PX Index see next section 3.3 - PX Index

Figure 3.2: USD/CZK

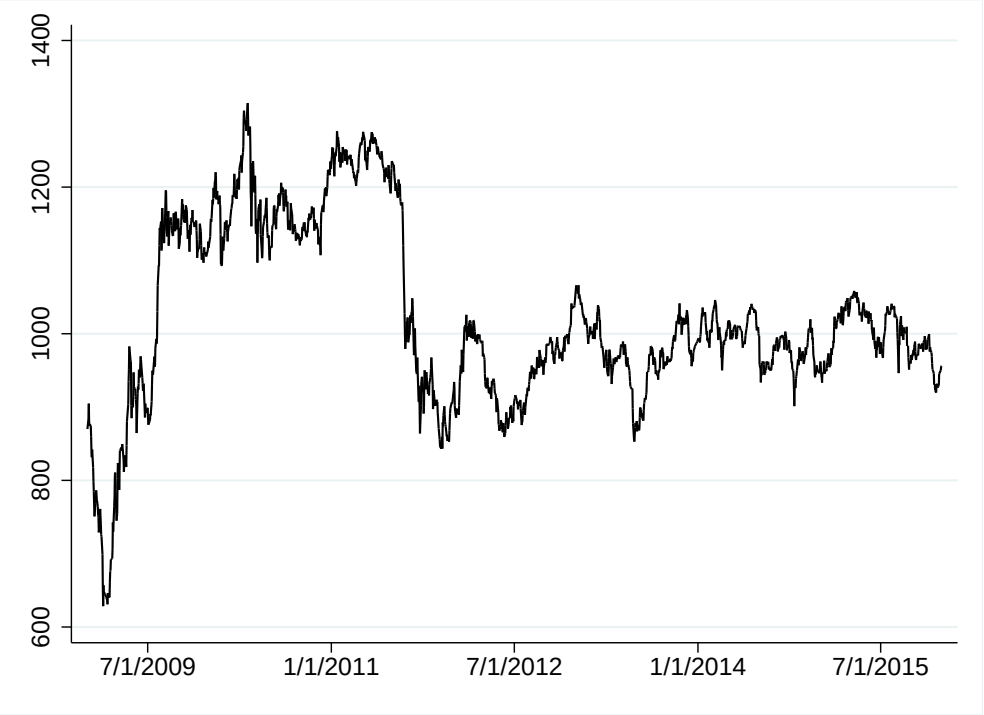
3.3 PX Index

The PX Index is official capitalization-weighted index of major stocks traded on Prague Stock Exchange (PSE). Until March 2006 the predecessor of the PX Index was the PX 50 an index which included 50 companies traded on PSE. The benchmark date for PX 50 was 5 April 1994 and its opening value was set at 1000 points. The current PX Index took over historical values of the PX 50 index and continuously followed up on them. The current PX Index base includes 13 major companies traded on PSE. The PX Index is a price index and does not take dividend returns into consideration unlike the other PSE index the PX-TR (TR stand for total returns).

After setting the initial value to 1000 points the PX 50 declined until 29 June 1995 to its bottom value of 387 points. More than three years later on 8. October 1998 the PX 50 hit its so far historical minimum of 316 points after the Russian financial crisis. Another bottom value was 320 points on 17 September 2001 as a consequence of terrorists attack on 11 September 2001. The value of 1000 points was reached for the first time on 19 November 2004 (except retroactively computed values - in that case the first breach of 1000

points was on 25 January 1994). The so far historical maximum of the PX 50/PX Index was 1936 points on 29 October 2007. Naturally during the crisis the index has significantly declined, the crisis-bottom value was 629 points on 18 February 2009. The value in last years often breaches the 1000 points level and its average value is approximately 980 points.

Figure 3.3: PX Index



3.4 Central bank communication

Over the past two decades there has been a considerable movement towards increasing communication by central banks about their view of the economy, monetary policy decisions and the targets they plan to achieve through those decisions.

Blinder *et al.* (2008) define central bank communication as "*provision of information by the central bank to the public. Given information refers to such matters as the objectives of monetary policy, the monetary policy strategy, the economic outlook, and the outlook for future policy decisions*"

Today, central bank communication is so extensive that it can be considered as a monetary policy itself because of its major impact on financial markets.

Even subjects with no interest in central banking at all have most likely ever heard or read some news originating from the central banks. However the communication was not always as extensive as we know it now, for instance Fed[6] was not publishing its interest rate decisions until February 1994.

3.4.1 Content of communication

Central bank should communicate several topics as:

1. Its main objectives and means for their achievement
2. Monetary policy decisions and motivation for those decisions
3. Economic outlook and forecast

Communicating these topics helps to control the market expectations so the central bank can affect market beliefs about its future steps. For obvious reasons central bank authorities do not reveal its strategy and decisions down to the least detail but their statements should be clear and should reveal enough so that every interested individual can understand each of the bank's action (Blinder *et al.* 2009).

3.4.2 Reasons for communication

The main reason why central banks communicate is to maintain their transparency and to meet their objectives (e.g. price stability). Also, as already mentioned, communication can influence the market beliefs or even serve as a monetary policy e.g. to alter exchange rate (Fratzscher 2006). It has been proven many times that the central bank communication matters as well as the communication's timing (e.g. Fiser and Horvath 2009).

Central banks are aware of the communication benefits and use it also to lower the noise on the market. By communicating what is the bank trying to achieve, its expected policies or possible issues in the future, the uncertainty on the market should logically decrease. On the contrary Ehrmann and Fratzscher (2009) came up with empirical evidence that communication during certain period before and after policy meetings or other important events increase the market volatility. Also misunderstanding of the communication may lead to false expectation.

[6]Federal Reserve System - central banking system in the U.S.

3.4.3 Forms of communication

The communication comes in several basic ways:

1. Press releases after policy meetings and minutes released usually 8 days after the meetings
2. Periodic reports, economic outlooks and forecasts
3. Interviews, articles and speeches of central bank's representatives

All this communication is carefully observed not only by the financial market but also by the media, general public, politicians and other subjects.

3.4.4 Czech National Bank

As stated on the CNB website[7] "*The CNB is the central bank of the Czech Republic, the supervisor of the Czech financial market and the Czech resolution authority*" and its primary objective is to maintain price stability. CNB also manages the circulation of money, oversees the payment system or maintain accounts of organizations connected to the state budget.

The supreme governing body of the CNB is Bank Board which consists of 7 members - Governor (currently Miroslav Singer), two Vice-Governors and four other Bank Board members. When deciding monetary policies on the monetary policy meetings the votes of all members have equal weight. In case that some of the members are missing and the number of present Board members is even the governor has a casting vote.

Monetary policy meetings are scheduled 8 times a year - at the beginning of February, May, August and November and at the end of March, June, September and December. On the same day after the meeting a press release with brief information about discussed issues is published. Minutes with details of the Bank Board discussion are released usually 8 days after the meeting.

3.4.5 Communication data

There are several important information about the central bank communication which are captured by following variables:

[7] http://www.cnb.cz/en/about_cnb

1. *Bank Board meeting* - Bank Board monetary policy meeting. Since the monetary policy is decided on these meetings the press release after the meeting is expected to have the greatest impact on the asset prices. *Bank Board meeting* is a dummy variable which takes value of one on days of monetary policy meetings. Information is taken from the CNB website (section "Monetary policy", subsection "CNB Board decisions").

2. *Minutes* - minutes contain details of Bank Board discussion on monetary policy meeting and are released usually 8 days after the meeting. *Minutes* is a dummy variable which takes value of one on days when minutes are released. Information is taken from the CNB website. Information is taken from the CNB website (section "Monetary policy", subsection "CNB Board decisions").

3. *Comments* - comment is defined as written or oral expression by governor or Bank Board member. This expression should be about economic outlook, exchange rates, interest rates, price stability or monetary policies. *Comment* is a dummy variable which takes value of one on days when a comment is made. Information is taken from CNB website (section "Media service", subsections "Interviews and articles" and "Speeches of CNB representatives).

4. Variable *Comment* is further divided into two dummy variables according to its author - *Comment by governor* stand for comments made by governor and *Comment by others* stand for comment made by other Bank Board members.

Another characteristic which would be useful for our research is the nature of the communication - positive, negative or neutral. Positive communication represents information implying tightening monetary policy or stronger economic outlook. Negative communication represents the opposite of positive communication. The option "neutral" contains ambiguous information or information which is about relevant topic but does not have either positive or negative nature. Unfortunately data about nature of the communication are not gathered by any institution and obtaining these data would require detail inspection of every public communication of the central bank for last seven years. Therefore we leave this topic as a subject of possible future research.

3.5 Macroeconomic Indicators

Economic news is released quite frequently but of course not all those releases are equally important. As the indicators of our interest we have chosen the main macroeconomic indicators the CPI, GDP, Retail Sales, Interest rate (1YPRIBOR) and Unemployment rate which are commonly used to evaluate certain economy.

The source of the data was the ARAD Time Series Database of Czech National Bank. The GDP data are seasonally adjusted (by the originator) so its movements reflect the true pattern in economic activity and are not affected by external factors like for example weather or holidays.

3.5.1 Consumer Price Index

CPI measures price levels changes of consumption basket of goods and services purchased by households. CPI also helps to determine the general cost of living within certain economy or its inflation rate which is important because the Czech National Bank, among other national banks, uses the monetary policy of inflation targeting. The national bank uses interest rate or interventions on forex market as a tool to reach or maintain certain inflation target. The logic behind inflation targeting is that maintaining price stability is the most effective way to support long-term economic growth. The investors can easily compare the target and reality and therefore anticipate certain central bank behavior.

The items in the consumption basket are predetermined and each item is assigned a weight to reflect the preferences of the consumer. The basket's actual price is compared to its price in a certain base year. The CPI is usually calculated as follows:

$$CPI = \frac{\sum_{i=1}^{n} price_i^a * weight_i}{\sum_{i=1}^{n} price_i^b * weight_i}$$

Where $price_i^a$ is the actual price of i-th good, $price_i^b$ is the price of i-th good in some base year and $weight_i$ is the respective weight of given good or service in the consumption basket.

The CPI indicator is published monthly in Year-over-Year form (denotes the percentage change in CPI compared to the same period in previous year) and its increase is considered to be positive news.

3.5.2 Gross Domestic Product

GDP is a monetary value of all produced goods and services within given economy. It is often used to evaluate the performance of the economy. The most common formula to compute GDP is as follows:

$$GDP = C + G + I + NX$$

C stands for consumption - that is the total amount of money spent by households on goods and services within the economy (food, rent, etc.). G stands for government spending - that is the sum of government expenditures on goods and services (military expenses, salaries of state employees, etc.). I stands for investment - the total value of all goods and services purchased to generate wealth in the future (purchase of machinery for factory, purchase of new houses by households, etc.). NX stands for net export of goods and services - net export equals all exports minus all imports.

The GDP indicator is published quarterly in Year-over-Year form and its increase is considered to be positive news.

3.5.3 Retail Sales

Retail Sales measure the total value of consumer spending in retail sector. Importance of this indicator can be easily explained - decrease in retail sales and therefore in consumption may be sign of economic recession or even depression (if the low consumption persists) but on the contrary excess in consumption may create inflationary pressure. The retail sales data are published monthly on Year-over-Year basis. Increasing retail sales is considered to be positive news.

3.5.4 PRIBOR

Prague InterBank Offered Rate is the average rate at which are banks willing to lend each other money (liquidity) on the Czech interbank money market.

This interest rate is often used as reference rate which means that majority of floating rates for corporate loans or mortgages are (partially or totally) tied to PRIBOR. In theory the lower the rate is the more loans for households are provided which causes higher personal spending.

The rate is not a product of Czech National Bank but a product of six commercial banks which can theoretically manipulate the rate for their own purposes. On March, 24 2015 the news "Hospodářské noviny" came up with such an allegation - that PRIBOR is just a fictional rate which does not have anything to do with the current money market trends. According to the news the reference banks artificially keep the PRIBOR higher than necessary to maintain their revenue from loans.[8]

We use monthly data for 1 year interest rate. In spite of the allegation discussed above the 1YPRIBOR is continuously declining for several years. The rate was 2,95% in January 2009 compared to 0,46% in December 2015. Increasing PRIBOR is considered to be negative news.

3.5.5 Unemployment

The rate of unemployment is measured as a percentage share of unemployed people in total labor force. This indicator has a great importance since it is strongly economically connected to GDP and inflation.

The relationship with GDP is described by commonly known Okun's law - an empirical observation which says that for every 1% increase in unemployment the country's GDP will be approximately 2% lower than its potential GDP and vice versa. Therefore decline or rise in unemployment rate may give us some information about the country's output. The relationship with inflation is described by Phillips curve and NAIRU (Non-Accelerating Inflation Rate of Unemployment). The Phillips curve tells us that increase in unemployment correlates with lower rates of inflation but this trade-off is only applicable in a short-term (Friedman 1968). The NAIRU refers to a rate of unemployment below which the inflation rises. If the unemployment rate is below some threshold it will cause inflationary pressure causing central bank to pursue tighter monetary policy. On the contrary high unemployment rate may cause a decrease in personal spending which again prompts the central bank to react.

[8] http://archiv.ihned.cz/c1-63732140-banky-drzi-uroky-umele-vysoko-nikdo-je-ale-ucinne-nekontroluje

The unemployment data are published monthly as a percentage described above. Decreasing unemployment rate is naturally considered to be positive news.

3.6 Dataset summary

The dataset summary table (3.1) can be found below.

Table 3.1: Dataset summary

Variable	**Form**	**Frequency**	**Source**
EUR/CZK	Close value	Daily	Metatrader Corp.
USD/CZK	Close value	Daily	Metatrader Corp.
PX Index	Close value	Daily	PSE
Bank Board meting	Dummy		CNB
Minutes	Dummy		CNB
Comments by governor	Dummy		CNB
Comments by others	Dummy		CNB
CPI	YoY	Monthy	ARAD - CNB
GDP	YoY	Quarterly	ARAD - CNB
Retail Sales	YoY	Monthly	ARAD - CNB
1YPRIBOR	Current rate	Monthly	ARAD - CNB
Unemployment	Current rate	Monthly	ARAD - CNB

Chapter 4

Methodology

4.1 Primary Analysis and Data Transformation

So far the data are in the same form as in the source, however they should be analyzed and probably also transformed to assure their required properties for further modeling.

- Sections **Stationarity**, **Serial Correlation** and **ARCH effect** concern the dependent variables
- Section **Surprise effect of the News** concerns the independent variables

4.1.1 Stationarity

Definition 4.1 (Stationarity Time series). The stochastic process $\{x_t : t = 1, 2, ...\}$ is *stationary* if for every collection of time indices $1 \leq t_1 < t_2 < ... < t_m$, the joint probability distribution of $(x_{t_1}, x_{t_2}, ..., x_{t_m})$ is the same as the joint probability distribution of $(x_{t_1+h}, x_{t_2+h}, ..., x_{t_m+h})$ for all integers $h \geq 1$. □

In other words the Probability Distribution Function (PDF) is stable over time. For financial time series the stationarity assumption is very strict and is also often violated. For that reason there is a weaker assumption of *covariance stationarity*

Definition 4.2 (Covariance Stationary Process). A stochastic process $\{x_t : t = 1, 2, ...\}$ with finite second moment $\left[E(x_t^2) < \infty\right]$ is *covariance stationary* if:

- $E(x_t)$ is constant

- $Var(x_t)$ is constant
- for any $t, h \geq 1, Cov(x_t, x_{t+h})$ depends only on h and not on t. $\square$

That means that sequence of $\{x_t\}$ oscillates around some constant value. The stationarity is important because usual assumptions and therefore testing are not valid for non-stationary time series. The non-stationarity of the series is connected to several problems as spurious correlation due to time trend or infinite shock persistence. There are several ways to determine whether the dependent variables are stationary or not.

The simplest way is to plot the data and visually analyze if they fluctuate around some constant value or not. For graphs of examined time series see appendix, figures A.1, A.2 and A.3. More precise method is to test it by augmented Dickey-Fuller test (ADF test) which is common part of most econometric software. The test is as follows:

We run OLS regression

$$\Delta x_t = \alpha + \beta t + \gamma x_{t-1} + \sum_{i=1}^{p-1} \delta_i \Delta x_{t-i} + \varepsilon_t \tag{4.1}$$

where α is constant, β is the coefficient on time trend t and p is the number of lags of the AR process. To determine how many lags should be included the F-test can be used - if the F-test shows that the δ coefficients are jointly significant we can add more lags. The null hypothesis of non-stationarity is $H_0 : \gamma = 0$ and the alternative hypothesis of stationarity is $H_a : \gamma < 0$. The Dickey-Fuller (DF) test statistics is computed as the usual t-statistics:

$$DF = \frac{\hat{\beta}}{SE(\hat{\beta})}$$

where $\hat{\beta}$ is the estimate from equation (4.1) and $SE(\hat{\beta})$ is its corresponding standard error.

As expected none of the three time series is stationary. Not only is it visible from the figures in appendix (tables A.1, A.1, A.3) but we also run the ADF test. With 3 lags included the p-values for all three variables were high enough to reject the null hypothesis. See results in table (4.1).

To deal with the non-stationarity we will transform the data to log returns. The transformation is as follows:

$$\Delta\ r_t = \Big(ln(s_t) - ln(s_{t-1})\Big) * 100 = ln(\tfrac{s_t}{s_{t-1}}) * 100, \qquad \text{for all } t \geq 2$$

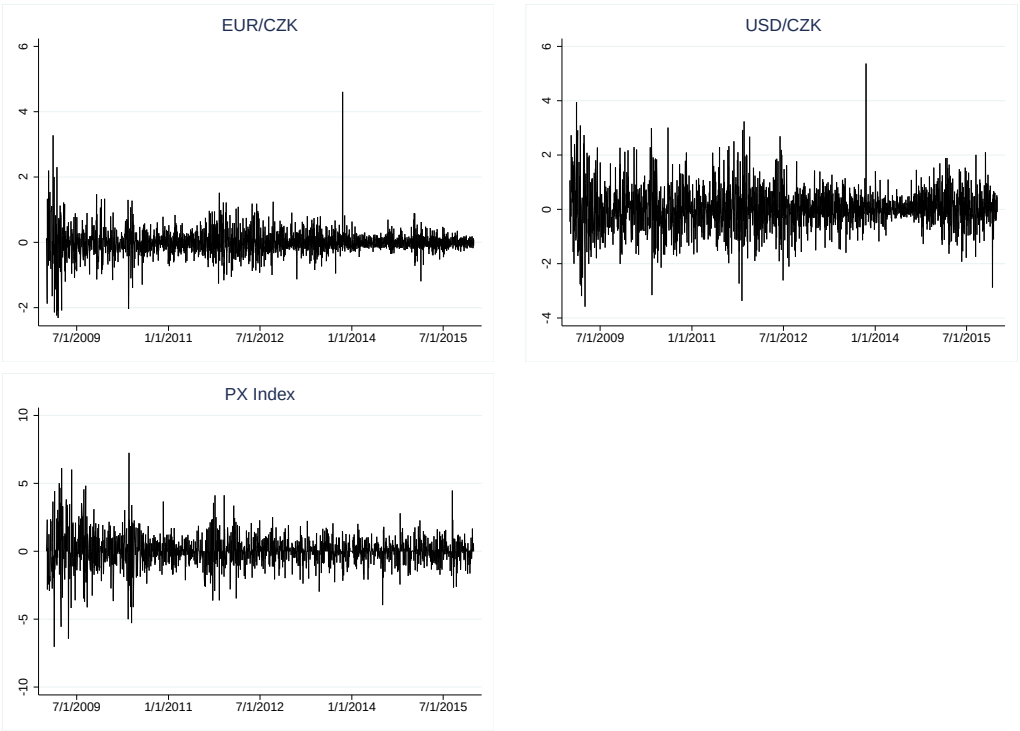
where Δr_t denotes the log returns and s_t and s_{t-1} are values of given dependent variable at time t and $t-1$ respectively.

After the transformation the p-values are all significantly smaller than 0,01 so we can reject the null hypothesis at 99% level (table 4.1). Also the graphical representation of the transformed data in figure (4.1) indicates that they all fluctuate around constant value of zero. Therefore the data are now covariance stationary and suitable for further modeling.

Table 4.1: ADF test with 3 lags

Variable	Before transformation	After transformation
EUR/CZK	0,9726	0,0000
USD/CZK	0,9853	0,0000
PX Index	0,4198	0,0002

Figure 4.1: Log returns: EUR, USD and PX Index



4.1.2 Serial Correlation

After modeling the data another characteristics should be investigated - serial correlation among residuals and also among their squared values. Having serially correlated residuals is a serious problem because the whole model is then misspecified - estimates of standard errors are biased therefore we can not decide about the significance of estimated coefficients.

To test the serial correlation we used the Ljung-Box test also known as Q-test:

$$Q = N(N+2)\sum_{k=1}^{m}\frac{1}{N-k}\hat{\rho}_k^2 \tag{4.2}$$

where N is the number of observations, m denotes the number of lags specified for the test and $\hat{\rho}_k^2$ is the squared autocorrelation coefficient of k-lag. Q follows χ^2 distribution with m degrees of freedom. Under the null hypotheses the data are independently distributed and there is no serial correlation.

4.1.3 ARCH effect

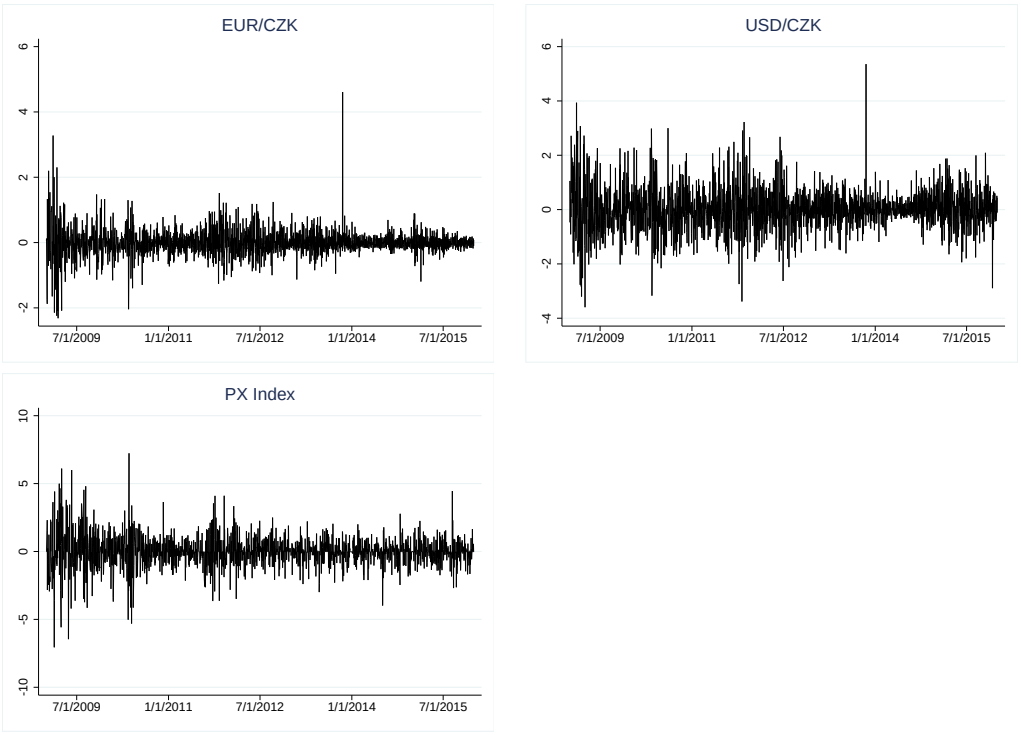
Before applying ARCH models[1] one must examine the residuals of dependent variables whether they truly evince conditional heteroskedasticity - the ARCH effect. To do that we used the ARCH-LM test proposed by Engle (1982).[2] The results can be found in table (4.2) and the residuals visualization in figure (4.2):

Table 4.2: ARCH effect

	EUR/CZK	**USD/CZK**	**PX Index**
ARCH-LM test	0,0000	0,0000	0,0000

[1] ARCH models will be described in the following section 4.2 "Models"
[2] The ARCH-LM test will be described in the following section 4.2.1 "Models - ARCH"

Figure 4.2: Residuals: EUR, USD and PX Index



The ARCH effect is significant in all three time series therefore the ARCH models are suitable for further analysis. Important is that after modeling the data with ARCH type of models, the ARCH effect must not be present anymore. The after-estimation presence of ARCH effect implies misspecified model and one should use different model (alternatively add more lags or use different error distribution).

4.1.4 Surprise Effect of the News

When estimating the influence of news announcements one should account only for their surprise effect which is the difference between the actual news and market anticipation. According to Egert and Kocenda (2013) the news surprise effect can be calculated as follows:

$$yn_{it} = \frac{(an_{i,t} - E_{t-1}[an_{i,t}])}{\partial_i}$$

where yn_{it} is the surprise effect, an_{it} is the value of scheduled announcement, $E_{t-1}[an_{it}]$ is the expected value of the announcement, ∂_i is the sample standard

deviation of the announcement. The indices i and t stand for indicators and time periods respectively.

Unfortunately, we were not able to find reliable source of forecasts (expected values of the announcements) for the whole examined time period. For that reason we use past values instead of forecasts:

$$yn_{it} = \frac{(an_{i,t} - an_{i,t-1})}{\partial_i}$$

where $an_{i,t-1}$ is the value of announcement in the previous time period.

4.2 Models

Since the time series data evince conditional heteroskedasticity it is advisible to use model which can deal with it. Models frequently applied on financial series data are models from ARCH (Autoregressive Conditional Heteroskedasticity) family. ARCH model was originally presented by Engle (1982) who also won the Nobel Memorial Prize in Economic Sciences for this method. The ARCH model was later developed independently by Bollerslev (1986) and Taylor (1986) and the new GARCH (Generalized ARCH) model was introduced. GARCH models capture volatility clustering which is an important characteristic of financial time series. The Class of GARCH models contains several extensions of the original GARCH model and one of them will be later described and also applied in this paper.

4.2.1 ARCH

The ARCH (q) is nonlinear model with q lags and consists of two equations. The Mean equation (4.3) and the Conditional Variance equation (4.4):

$$y_t = \alpha_0 + \varepsilon_t \tag{4.3}$$

$$\sigma_t^2 = \gamma_0 + \sum_{i=1}^{q} \gamma_i \varepsilon_{t-i}^2 \tag{4.4}$$

where y stands for mean, σ^2 is variance of ε term, ε term is independent and identically distributed random variable with Normal distribution $\varepsilon \sim N(0, \sigma^2)$.

The terms $\gamma_i \varepsilon_{t-i}^2$ are the ARCH terms. The mean equation can have several forms (e.g. AR(q) process) and the distribution of the error terms does not necessarily have to be Normal.

To confirm the aforesaid presence of conditional heteroskedasticity Engle (1982) introduced the ARCH-LM (Lagrange Multiplier) test:

1. Run the OLS regression to estimate autoregressive model AR(q) where q is the length of ARCH lags

$$y_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i y_{t-i} + \varepsilon_t \tag{4.5}$$

   and save the residuals $\hat{\varepsilon}_t$

2. Run the OLS regression of squared residuals on a constant and q lagged values

$$\hat{\varepsilon}_t^2 = \hat{\alpha}_0 + \sum_{i=1}^{q} \hat{\alpha}_i \hat{\varepsilon}_{t-i}^2 \tag{4.6}$$

Under the Null hypothesis, $H_0 : \alpha_i = 0$ for all $i \in \{1, ..., q\}$, there is absence of ARCH effect. The alternative hypothesis is that if the ARCH effects are present at least one of the estimated α_i coefficients must be significantly different from zero.

For further information about ARCH model see Engle (1982).

4.2.2 GARCH

GARCH (q,p) is generalization of previous ARCH model and allows for both lags in conditional variance - we have ARCH term and GARCH term in the Variance equation. Again the model consists of two equations - the Mean equation, identical to the ARCH Mean equation (4.3) described in previous section and the Variance equation (4.7):

$$\sigma_t^2 = \gamma_0 + \sum_{i=1}^{q} \gamma_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \gamma_j \sigma_{t-j}^2 \tag{4.7}$$

If there are no ARCH or GARCH effect present the total sum of all γ_i and γ_j coefficients should be equal to zero which implies that the residual variance is equal to γ_0.

GARCH model as well as its extension allow including independent variables in both Mean and Variance equation. However the same variable cannot be included in both of the equations simultaneously. Since the properties of GARCH and ARCH are in general very similar standard ARCH-LM test described earlier is valid for GARCH model as well.

After fitting the model one should determine its quality. Some of the most important diagnostics are:

- Ljung-Box test (Q-test) to check for serial correlation among residuals and among their squared values
- ARCH-LM test to see whether the ARCH effect was eliminated
- Significance of the coefficients
- Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). Smaller AIC and BIC indicate better fitting model (useful when deciding whether to include/exclude some independent variable in/from the model)

For further information about GARCH model see Bollerslev (1986).

4.2.3 GARCH Extension

EGARCH (1,1)

Exponential GARCH presented by Nelson (1991) has the ability to capture the leverage (asymmetry) effect.[3] The asymmetry of the model is described by the coefficient γ_2 in Variance equation (4.8). Again the extension concerns only the Variance equation (4.8):

$$\ln(\sigma_t^2) = \gamma_0 + \gamma_1 \left(\frac{|\varepsilon_{t-1}|}{|\sigma_{t-1}|} - \sqrt{\frac{2}{\pi}} \right) + \gamma_2 \frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \gamma_3 \ln(\sigma_{t-1}^2) \qquad (4.8)$$

[3]Leverage effect - volatility after positive shock is lower than volatility after negative shock of the same magnitude

coefficient γ_1 describes the ARCH term which represents the magnitude of the shocks and the coefficient γ_3 describes the GARCH term which represents the conditional variance.

We assume that our time series data will show characteristics of leverage effect therefore the EGARCH is expected to estimate better results than GARCH

Chapter 5

Hypotheses and Empirical results

5.1 Hypotheses

1. Does the volatility of examined time series show the characteristics of leverage effects, volatility clustering and persistence?

2. Do macroeconomic news announcements and central bank communication have the impact on the asset price value (conditional mean)?

3. Do macroeconomic news announcements and central bank communication have the impact on the asset price volatility (conditional variance)?

5.2 Empirical results

We used software STATA version 13.0 for the computations. For modeling conditional mean and conditional variance we used the GARCH(1,1) and EGARCH(1,1) models with two different error distributions - Normal (Gaussian) distribution and Student's t distribution.

5.2.1 Leverage effects, volatility clustering and persistence

Leverage effect

Leverage effect refers to the tendency of an asset's volatility to be negatively correlated with news influencing the asset price — negative news for asset prices mean higher volatility, and vice versa. Because of limited dataset we could not precisely measure the different effect of good news and bad news therefore the presence of leverage effect. Nevertheless we measured the effect

of macroeconomic indicators improvement and deterioration on the asset price volatility. The easiest way to do so is to filter out only the days when good/bad news are announced and calculate the standard deviation of returns on these days.

To confirm the presence of leverage effect the standard deviation of returns on "good days"[1] must differ from standard deviation of returns on "bad days".[2] Logically, if the standard deviation of returns on "bad days" is greater/smaller than on "good days" it means that the effect of bad news is greater/smaller than the effect of good news. When the standard deviations are identical or very similar there is no presence of leverage effect. The results are in table (5.1) below:

Table 5.1: Standard deviation - leverage effect

	EUR/CZK	**USD/CZK**	**PX Index**
Good news	0,004906	0,009246	0,012160
Bad news	0,003315	0,007614	0,016112

According to the results for EUR/CZK and USD/CZK returns, the effect of good news on volatility is greater than the effect of bad news. For stock returns the result is reverse, hence the leverage effect is present only for stock returns.

Volatility clustering and persistence

Volatility clustering is a trend when changes in prices cluster together which leads to the persistence of these price changes. In other words large changes in price tend to be followed by large changes in price and small changes in price tend to be followed by small changes in price. To detect the volatility clustering and persistence in the time series data we simply detect the ARCH effects (table 5.2) or inspect the time series visually (figure (4.2) in section 4.1.3 "ARCH effect").

It is evident from the ARCH-LM test statistics above that the ARCH effects are present therefore examined time series show the characteristics of volatility clustering and persistence.

[1] "Good days" stand for days when positive movement of macro indicator is announced
[2] "Bad days" stand for days when negative movement of macro indicator is announced

Table 5.2: ARCH effect

	EUR/CZK	USD/CZK	PX Index
ARCH-LM test	0,0000	0,0000	0,0000

5.2.2 Impact of news announcements and CNB's communication on the asset price value and on its volatility

To describe the impact on the asset price value and its volatility, the best fitting model and error distribution for each dependent variable should be chosen according the following criteria:

- ARCH term elimination
- Significance of coefficients
- Economic sense of estimated coefficients
- Serial correlation in residuals

The models for estimating impact on the asset prices are specified as follows:

GARCH(1,1)

$$\Delta r_t = \mu + \sum_{i=1}^{4} \alpha_i CNB_{it} + \sum_{j=1}^{5} \beta_j MI_{jt} + \varepsilon_t \tag{5.1}$$

$$\sigma_t^2 = \gamma_0 + \gamma_1 \varepsilon_{t-1}^2 + \gamma_2 \sigma_{t-1}^2 \tag{5.2}$$

where (5.1) is the mean equation and (5.2) is the variance equation. CNB refers to the central bank communication data and MI refers to our five macroeconomic indicators.

EGARCH(1,1)

$$\Delta r_t = \mu + \sum_{i=1}^{4} \alpha_i CNB_{it} + \sum_{j=1}^{5} \beta_j MI_{jt} + \varepsilon_t \tag{5.3}$$

$$\ln(\sigma_t^2) = \gamma_0 + \gamma_1 \left(\frac{|\varepsilon_{t-1}|}{|\sigma_{t-1}|} - \sqrt{\frac{2}{\pi}} \right) + \gamma_2 \frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \gamma_3 \ln(\sigma_{t-1}^2) \tag{5.4}$$

where (5.3) is the mean equation and (5.4) is the variance equation.

The models for estimating impact on the asset price volatility are specified as follows:

GARCH(1,1)

$$\Delta r_t = \mu + \varepsilon_t \tag{5.5}$$

$$\sigma_t^2 = \gamma_0 + \gamma_1 \varepsilon_{t-1}^2 + \gamma_2 \sigma_{t-1}^2 + \sum_{i=1}^{4} \alpha_i CNB_{it} + \sum_{j=1}^{7} \beta_j MI_{jt} \tag{5.6}$$

where (5.5) is the mean equation and (5.6) is the variance equation.

EGARCH(1,1)

$$\Delta r_t = \mu + \varepsilon_t \tag{5.7}$$

$$\ln(\sigma_t^2) = \gamma_0 + \gamma_1 \left(\frac{|\varepsilon_{t-1}|}{|\sigma_{t-1}|} - \sqrt{\frac{2}{\pi}} \right) + \gamma_2 \frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \gamma_3 \ln(\sigma_{t-1}^2) + \sum_{i=1}^{4} \alpha_i CNB_{it} + \sum_{j=1}^{7} \beta_j MI_{jt} \tag{5.8}$$

where (5.7) is the mean equation and (5.8) is the variance equation.

Note: From now on, if not specified otherwise, by "mean equation" we understand the equation which captures the impact on the asset price value i.e. (5.1) or (5.3), and by "variance equation" we understand the equation which captures the impact on asset price volatility i.e. (5.6) or (5.8).

EUR/CZK

GARCH (1,1) - GARCH model with Normal error distribution gave us significant results for the mean equation and also for the variance equation. In both cases the significant variables were concerning only the central bank communication. Furthermore in both equations the ARCH and GARCH terms were significant which indicates well specified model. However we failed to eliminate the ARCH effect from the variance equation. Hence, we estimated the GARCH

model with Student's t error distribution, nevertheless we failed to eliminate the ARCH effect again.

EGARCH (1,1) - While estimating EGARCH with Normal error distribution we found significant variables concerning central bank communication and also news announcements. Even the EARCH term, EGARCH term and the asymmetry component (EGARCH_A term) were significant. However according to the ARCH-LM test we failed to eliminate the ARCH effect in both mean and variance equation. For this reason we find this model to be inconvenient. Another option is EGARCH model with Student's t error distribution. Results from this estimation are shown in table (5.3). For both mean and variance equation the ARCH effect was successfully eliminated. In addition, for both the equations the EARCH, EGARCH and EARCH_A terms are significant which implies well specified model. Since the asymmetry component is significant there is presence of asymmetric shocks.

Naturally we selected the **EGARCH (1,1) model with Student's t error distribution** as the best fitting model for EUR/CZK returns.

Table 5.3: EUR - EGARCH (1,1) with Student's t error distribution

	Variable	Coefficient			Variable	Coefficient	
Mean eq.	Bank Board meeting	0,00025		**Mean eq.**	Constant	-0,00008	
	Minutes	-0,00003					
	Comments by governor	-0,00079	**	**Variance eq.**	Bank Board meeting	0,38945	*
	Comments by others	0,00070	***		Minutes	0,06929	
	CPI YoY	-0,00015			Comments by governor	0,40206	*
	GDP YoY	-0,00106			Comments by others	0,54969	***
	Retail sales YoY	-0,00031			CPI YoY	0,10634	*
	1YPRIBOR	-0,00724	**		GDP YoY	-0,79347	
	Unemployment	-0,00144	**		Retail sales YoY	0,18293	
	Constant	-0,00010	*		1YPRIBOR	-0,23166	
					Unemployment	0,41582	
Variance eq.	EARCH	-0,10232	**		Constant	-0,21956	
	EARCH_A	0,75846	***		EARCH	-0,10429	**
	EGARCH	0,98861	***		EARCH_A	0,71803	***
	Constant	0,03044			EGARCH	0,97246	***
	No of observations	2099			No of observations	2099	
	ARCH - LM	0,8699			ARCH - LM	0,7517	

Note: *** denotes significance at the 1% level, ** denotes significance at the 5% level, * denotes significance at the 10% level

Results from table (5.3) show that comments by CNB's representatives have ambiguous effect on the EUR/CZK returns. While comments by governor tend to decrease the returns, comments by other Bank Board members tend to increase them. The magnitude of those effects is practically the same. Also 1YPRIBOR and unemployment rate announcements significantly influence the returns. However since the decrease in both 1YPRIBOR and unemployment rate is a positive news, improvement of these indicators actually increase the returns which makes sense economically.

Central bank communication in all its forms except minutes also significantly increase the volatility of the returns which strongly contrast with a lot of previous research e.g. with Fiser and Horvat (2010). The explanation can be given by different market behavior after the financial crisis, additionally Ehrmann and Fratzscher (2009) claim that communication during some period before and after monetary policy meetings or other important events increase the market volatility. Therefore after accounting for timing of the communication the results can be different.

As for the macroeconomic indicators only the CPI announcements affects the volatility — if higher than expected CPI is announced the volatility increase. Positive domestic news, such as growth of CPI, can cause currency depreciation by rise in domestic imports implying higher demand for foreign currency (Bartolini *et al.* 2008). On the contrary positive news may also increase demand for domestic currency thus the currency appreciation (Andersen *et at.* 2007). This ambiguous effect of positive news announcement on the exchange rate can be one of the clarifications of the result.

USD/CZK

GARCH (1,1) - Results given by GARCH model with Normal error distribution were quite satisfying. We obtained significant ARCH and GARCH terms in both equations, moreover according to the ARCH-LM test we eliminated the ARCH effect. In variance equation only the Bank Boards meetings were significant whereas in mean equation also the comments by Bank Board members (not by governor) and the CPI were significant. For GARCH with Student's t distribution we found insignificant ARCH terms and persisting ARCH effect, thus we concluded this model to be unsuitable.

EGARCH (1,1) - Even though we got significant results, none of the EGARCH model estimation generated significant EARCH and EARCH_A (asymmetry component) terms. Not only does this imply misspecified model but also no presence of asymmetry in shocks, thus no need for using EGARCH model. In addition, according to the ARCH-LM test the ARCH effects were still present after the estimations.

As a consequence of the above mentioned we selected the **GARCH (1,1) model with Normal error distribution** as the best fitting model for USD/CZK returns. Results from this estimation are shown in table (5.4) below:

Table 5.4: USD - GARCH (1,1) with Normal error distribution

	Variable	Coefficient			Variable	Coefficient	
Mean eq.	Bank Board meeting	0,00348	***	**Mean eq.**	Constant	0,00014	
	Minutes	0,00026					
	Comments by governor	-0,00191		**Variance eq.**	Bank Board meeting	2,24658	**
	Comments by others	0,00093			Minutes	0,52537	
	CPI YoY	0,00071			Comments by governor	-0,72081	
	GDP YoY	-0,00008			Comments by others	1,92903	**
	Retail sales YoY	-0,00047			CPI YoY	3,08556	*
	1YPRIBOR	-0,00171			GDP YoY	-1,64932	
	Unemployment	0,0006			Retail sales YoY	0,45382	
	Constant	0,00005			1YPRIBOR	-8,35178	
					Unemployment	-2,19080	
Variance eq.	ARCH	0,1105	***		Constant	-0,98753	***
	GARCH	1,04997	***		ARCH	0,1187	***
	Constant	0			GARCH	0,81366	***
	No of observations	2099			No of observations	2099	
	ARCH - LM	0,1163			ARCH - LM	0,1781	

Note: *** denotes significance at the 1% level, ** denotes significance at the 5% level, * denotes significance at the 10% level

The results for mean equation indicate only positive effect of Bank Board meetings on the USD/CZK returns. As for the variance equation, the results are again in contrast with the statement that central bank communication lowers the volatility - press releases after monetary meetings and comments by Bank Board members (except the governor) increase the volatility. The reasons are the same as for the EUR/CZK returns — first, according to Ehrmann and Fratzscher (2009), in some periods the communication does not have the calming effect on volatility, and second, different market behavior after the world financial crisis. So again, after accounting for the timing of the communication the results can be different.

Also the announcements of CPI have significant effect on the volatility (causing its increase) which is consistent with the EUR/CZK results. Economical explanation is the same as for the EUR/CZK - ambiguous effect of positive domestic news on the exchange rate creates higher volatility.

The conditional volatility of USD/CZK and EUR/CZK returns is influenced by almost the same variables in the same direction. This results indicate that movements of these two exchange rates are closely connected which is a rational and expected conclusion.

PX Index

GARCH (1,1) - When estimating the mean and variance equation by the GARCH model with both Normal and Student's t error distribution we obtained convenient results - significant ARCH and GARCH terms indicating well specified model and significant variables in both equations. Nevertheless according to the ARCH-LM test the ARCH effects were still present after all GARCH estimations.

EGARCH (1,1) - The EGARCH estimation with Student's t error distribution generated insignificant EARCH terms in both mean and variance equation. In addition, there was only one significant variable (CPI) in the mean equation and no significant variable in the variance equation. That would mean that macroeconomic news announcements and central bank communication have no effect on stock price volatility. Although Bartolini *et al.* (2008) claim that news announcement have weak effect on the stock price and its volatility it would be precipitate to say that there is no effect at all. Much better results were given while using Normal error distribution. All the EARCH, EGARCH and EGARCH_A (asymmetry component) terms were significant which implies well specified model and also presence of asymmetric shocks, furthermore the ARCH effects were successfully eliminated.

Based on the aforesaid information we selected the **EGARCH (1,1) model with Normal error distribution** as the best fitting model for the stock returns. The results are in table (5.5).

Table 5.5: PX Index - EGARCH (1,1) with Normal error distribution

	Variable	Coefficient			Variable	Coefficient	
Mean eq.	Bank Board meeting	-0,00107		**Mean eq.**	Constant	0,00024	
	Minutes	-0,00296	*				
	Comments by governor	0,00117		**Variance eq.**	Bank Board meeting	0,04996	
	Comments by others	-0,00178			Minutes	0,25307	**
	CPI YoY	0,01100	**		Comments by governor	-0,12027	
	GDP YoY	-0,00968			Comments by others	0,40894	***
	Retail sales YoY	0,00387	**		CPI YoY	-0,09792	
	1YPRIBOR	-0,00568			GDP YoY	0,15031	
	Unemployment	0,00162			Retail sales YoY	0,08288	
	Constant	0,00048			1YPRIBOR	-0,31773	***
					Unemployment	0,98556	*
Variance eq.	EARCH	-0,04871	*		Constant	-0,59590	
	EARCH_A	0,47367	***		EARCH	-0,05903	**
	EGARCH	0,86356	***		EARCH_A	0,40555	***
	Constant	-1,21789	**		EGARCH	0,93897	***
	No of observations	1451			No of observations	1451	
	ARCH - LM	0,1163			ARCH - LM	0,1016	

Note: *** denotes significance at the 1% level, ** denotes significance at the 5% level, * denotes significance at the 10% level.

The stock returns are positively influenced only by announcements of CPI and Retail sales. Logically, positive domestic news have positive impact on the stocks — for instance higher than anticipated retail sales indicate higher personal spending so growth in corporate earnings therefore also growth in stock prices is consequent. On the contrary, releasing the minutes from the monetary meetings have decreasing effect on the returns.

Minutes releases also increase the volatility as well as comments by Bank Board members (except the governor). As for macroeconomic indicators, positive unemployment announcement[3] lowers the volatility while positive 1YPRIBOR announcement[4] tends to raise it. Both of these effects make economic sense - higher employment means healthier economy thus less uncertainty, on the other hand lower 1YPRIBOR means more affordable loans which can cause higher indebtedness of the corporate sector making it more risky and volatile.

Interesting fact is that according to the results the raise in GDP not only lowers the stock returns but also increases the volatility which is complete opposite of general expectation that reasonable growth in GDP indicates economic stability and strength therefore steady rise in stock prices and lower uncertainty on the market. However results for GDP were statistically insignificant so the GDP's effect is not a concern.

[3]Positive unemployment announcement means its decrease
[4]Positive 1YPRIBOR announcement means its decrease

5.2.3 Limitations

While testing our hypotheses we faced following limitations:

1. Since we have no data about the nature of the central bank communication (positive, negative or neutral), we could not distinguish the effect of positive and negative communication.

2. Similar problem arose for macroeconomic news - we do not have data about the market expectation of macroeconomic indicators so we also could not precisely measure the effect of good or bad news. However instead of expected value of certain indicator its previous value was used so we could at least measure the effect of improvement or deterioration of the indicator.

3. Use of daily data - intraday data would give more precise results not only when detecting the presence of leverage effect in the first hypothesis but also in all other estimations.

Chapter 6

Conclusion

This thesis discuss how are the daily returns of EUR/CZK, USD/CZK and PX Index affected by Czech national bank communication and Czech macroeconomic news announcements — announcements of CPI, GDP, Retail sales, 1YPRIBOR and Unemployment rate. The main subject of the research was the impact on the conditional mean and on the conditional variance, moreover we discuss the key properties of the conditional variance (volatility) - presence of leverage effect, volatility clustering and persistence.

In the first part of the thesis, we summarized the literature which is concerned with topics similar to ours. The main message given by this literature review is that the central bank communication generally lowers the noise in the financial markets and that its timing is also important. Additionally, that macroeconomic news announcements also have significant impact specially announcements of key indicators like GDP or unemployment rate. There were also several studies contrasting these statements e.g. Ehrmann and Fratzscher (2009) who claim that in certain time periods before and after important events the central bank communication increases the volatility. Also Boyd *et al.* (2001) say that depending on the business cycle good news announcements can have both positive and negative impact on the stock prices.

In the second part of the thesis, we presented the most common techniques to measure the impact of central bank communication and news announcements on the price and volatility of financial assets. Then we employed the GARCH and EGARCH models each with two error distributions - Normal (Gaussian) and Student's t.

The empirical results show the presence of volatility clustering and persis-

tence which are anticipated findings, additionally the stock returns also evince the presence of leverage effect. The effect of central bank communication was however unexpected. For all three examined returns the central bank communication significantly increases the volatility, usually by press releases after monetary meetings or by comments of CNB representatives. We attribute this results to different market behavior after the world financial crisis and also to the fact that we do not take into account the timing of the communication. The central bank communication also have significant effect on the mean of the returns, however each of the returns is affected by different form of the communication and in a different way.

The effects of macroeconomic news announcements are quite diverse but generally speaking the effects are following: for EUR/CZK returns the decrease in 1YPRIBOR and unemployment increases the conditional mean and rise in CPI increases the volatility, for USD/CZK returns none of the macroeconomic indicators influence the conditional mean and only the CPI has rising effect on the volatility, and for Prague stock returns the increases in CPI and retail sales have positive impact on the conditional mean, and decrease in 1YPRIBOR and unemployment rate increases respectively decreases the volatility.

Nevertheless there several possibilities for future research which can produce more precise results. First, more frequent (intraday) data would be better not only for detecting the leverage effects in volatility of the returns but also for all estimations in this thesis. Second, adding timing of the communication and its nature (positive, negative or neutral) could also help to obtain better results. And third, dividing the dataset to more time periods (e.g. before/after CNB's intervention) would help to better understand the behavior of the financial series or to document the change in their behavior.

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Appendix A

Selected Figures and Tables

Figure A.1: EUR/CZK

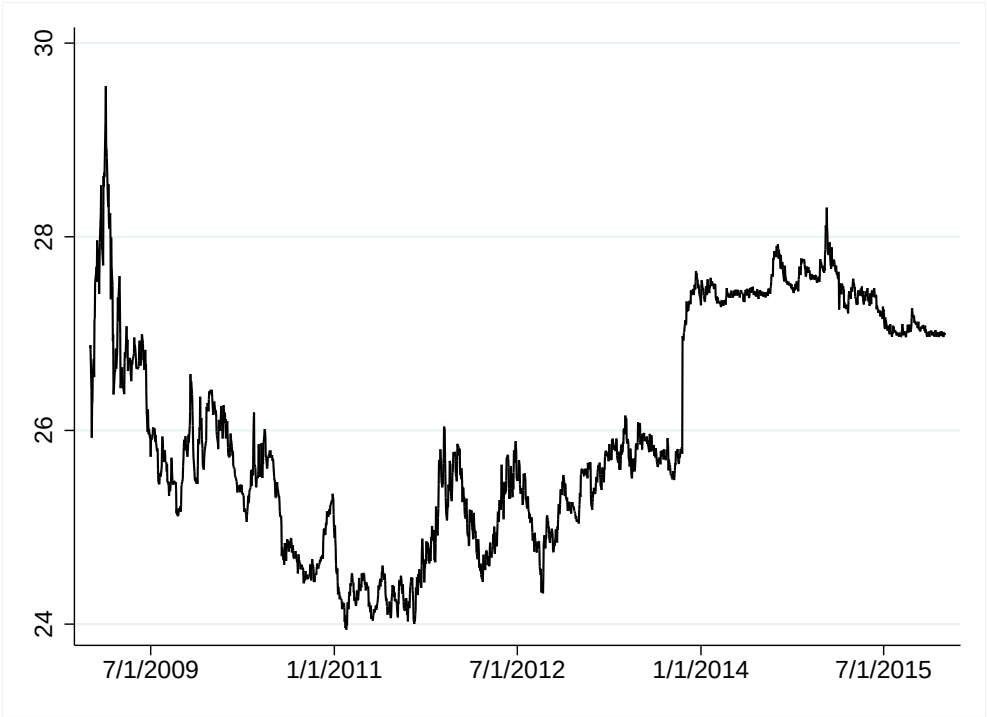

Figure A.2: USD/CZK

Figure A.3: PX Index

Results of the Ljung-Box tests in following tables refer to the best fitting model and error distribution for each variable:

- For EUR/CZK - EGARCH (1,1) with Student's t error distribution
- For USD/CZK - GARCH (1,1) with Normal error distribution
- For PX Index - EGARCH (1,1) with Normal error distribution

Table A.1: Ljung-Box test for serial correlation - EUR/CZK

	Mean equation	**Variance equation**
Residuals	0,1343	0,1261
Squared residuals	1,0000	1,0000

Source: author's computations.

Table A.2: Ljung-Box test for serial correlation - USD/CZK

	Mean equation	**Variance equation**
Residuals	0,9762	0,9389
Squared residuals	0,1028	0,1111

Source: author's computations.

Table A.3: Ljung-Box test for serial correlation - PX Index

	Mean equation	**Variance equation**
Residuals	0,9968	0,9990
Squared residuals	0,1412	0,6620

Source: author's computations.