Charles University in Prague

Faculty of Social Sciences
Institute of Economic Studies

RIGOROUS THESIS

The Czech National Bank Communication: GARCH analysis of 3M PRIBOR rate and Czech 10Y government bonds

Author: **Mgr. Pavel Karas**

Year of rigorous defence: **2014**

Declaration of Authorship

Prohlašuji, že jsem rigorózní práci vypracoval samostatně a použil pouze uvedené prameny a literaturu.

I do hereby declare that I have written this thesis independently using only listed sources.

Prague, January 16, 2014

Pavel Karas

Acknowledgement

I would like to express my gratitude to my diploma supervisor, Roman Horváth, whose helpful comments, materials and constructive suggestions enabled me to complete the diploma thesis from which this rigorous thesis is compiled.

I am also grateful to my diploma opponent, Aleš Maršál, for helpful tips and comments on how the diploma thesis can be improved in order to be published as a rigorous one.

Last but not least, I wish to acknowledge with thanks the comments received from the editor and two anonymous referees of the Czech Journal of Economics and Finance for their suggestions that improved the published paper.

To my beloved wife Markéta

Contents

Rigorous Thesis Introduction

The presented rigorous thesis is an elaboration of my diploma thesis defended at the Institute of Economic Studies (Faculty of Social Studies, Charles University in Prague) in June 2013. The whole text has been revised and some parts of it have been modified, rewritten or removed completely. This revision reflects my diploma thesis referees' suggestions, new remarks and new resources as well as more precise definition and more consistent organization of the text.

This rigorous thesis is separated into two parts – diploma thesis reflecting referees' suggestions (Part I. Diploma Thesis) and an article published based on my 2013's diploma thesis (Part II. Published Article).

Part I.: Diploma Thesis contains the defended master thesis with incorporated referees' suggestions and my revisions. In this diploma thesis, I focus on the effects of the Czech National Bank Communication on the volatility of the 3M PRIBOR and the yield of the Czech 10-year government bonds. It is structured as follows. The first chapter provides the literature review describing the development in how central banks have behaved, from total discretion to transparency, and stating the recent empirical findings. The next chapter discusses the role of central banks' communication in general and the end of the chapter is focusing on the Czech National Bank. The following chapter describes the methodology and the data that have been used. It also provides the results of the econometric analysis and discusses the results.

The revision of the diploma thesis reflects referees' suggestions. Firstly, the title of the thesis was changed to correspond better to the studied subject and grammatical errors and typos have also been corrected.. Secondly, I have extended the motivation of the thesis, see the Introduction, for better reader's understanding what I am trying to say in my thesis. Then, I have added academic papers that deal with the effect of announcements on the bond markets

(e. g. Ederington & Lee 1993, Fleming & Remolona 1997, Goldberg & Leonard 2003), see section 1.3.1.

Moreover, one of the referee's questions was why in my study any news (inflation, report, minutes and comment) has impact on bond prices. As stated in many papers, the surprise is what moves the prices. This surprise is captured in a release all of the studied variables (inflation report, minutes or comments). I wanted to enlarge the literature studying the effects of news to bond price volatility; it was confirmed that these announcement shocks have an impact on volatility. I conclude that markets incorporate public information into prices, see the discussion in Part II.

Finally, why have not I used the higher frequency data but daily daily? The incorporation of information takes time. Let us imagine the situation that e. g. governor makes an interview and expresses his very own point of view on the state of economy. Expectations are then formed during time, markets are processing this information. After a while, Bank Board meeting takes place and the "state of economy" is shown in the adjustment of 2W repo. The markets then adjust their expectations and so one. This is not a one-minute operations, therefore I suppose that daily data are sufficient enough to capture the pattern.

Part II.: Published Article contains the enclosed published article. According to the given rules for the rigorous theses presented at the IES, this represents the sufficient enlargement of the diploma thesis. The paper was published as:

> Horváth, R. & P. Karas (2013): "Central Bank Communication and Interest Rates: The Case of the Czech National Bank." *Czech Journal of Economics and Finance (Finance a úvěr)*, 63(5): 454–464,

and can be found on this website:

`http://journal.fsv.cuni.cz/mag/article/show/id/1285`.

English resumé

Over the last two decades, the communication from central banks to public has become an important mean of managing monetary policy. Communication is therefore an important and powerful part of central bank's toolkit. Why is it so? How does it come that a central banker says only one sentence and this moves e. g. exchange rate by some points? How are the interest rates affected by central bank talks? These questions and more ones are the issues I would like to explain in this rigorous thesis.

This rigorous thesis consists of two parts. The first part is the defended diploma thesis where some referees' suggestions have been incorporated and the whole text has been revised and grammatical errors and typos have been corrected. The second part is created by an article that both me and my diploma thesis supervisor Mr. Horváth have published in Czech Journal of Economics and Finance's paper.

There are a lot of different strategies how and by what means central banks can communicate with professionals and broad public. One can therefore ask what constitutes an optimal communication strategy. The answer to this question is not easy and authors agree that there is hardly any optimal answer. Therefore, I discuss different communication strategies and how the transmission of information works. This thesis mainly refers to the Czech National Bank (CNB). Thus, I describe the CNB's primary objective, the price stability, as well as other goals and tasks. I focus on the communication channels the CNB uses to share the main information. Lastly, I talk its policy instruments over.

The core of this thesis is the analysis of volatilities of the short-term and long-term interest rates in the Czech Republic, that are caused by the communication, by using the GARCH, the TGARCH and the EGARCH modelling framework. I have compilled a unique database of dummy variables capturing

the release of the Inflation reports, the Bank Board meetings, minutes and comments provided by the Bank Board members to media. Moreover, Bank Board members' comments are classified as positive, negative or neutral concerning the economic outlook and the whole state of the Czech economy.

I have found that the CNB communication tends to decrease the volatility of interest rate, i. e. this supports the assertion that the central bank aims to decrease the noise in the financial markets. Written communication, as captured by the monetary policy minutes and the Inflation reports, exerts a calming effect on the financial markets. I did not manage to find this calming effect for oral communication. This can be explained by the fact that listeners may not be sure about the content of the oral comment. The timing of the communication also matters, since comments made closer to the monetary policy meeting a stronger effect on interest rate volatility.

Institut ekonomických studií UK FSV
Teze RIGORÓZNÍ práce

Tyto teze tvoří přílohu „Přihlášky ke státní rigorózní zkoušce“

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Předpokládaný název rigorózní práce v češtině:
Komunikace České národní banka: GARCH analýza 3měsíčních PRIBOR sazeb a českých 10 letých vládních dluhopisů

Předpokládaný název rigorózní práce v angličtině:
The Czech National Bank Communication: GARCH analysis of 3M PRIBOR rate and Czech 10Y government bonds

Předpokládaný termín předložení práce:
Únor/2014

Pedagog, s nímž byly teze konzultovány:
Horváth, Roman, IES FSV UK

Charakteristika tématu a jeho dosavadní zpracování žadatelem:

Tato rigorózní práce bude vycházet z mé práce diplomové, kterou jsem obhájil na IES FSV UK v červnu 2013. Cílem práce je prozkoumat, jak různé typy komunikace České národní banky (vydání publikace Zpráva o inflaci, oznámení o zasedání bankovní rady diskutující o nastavení dvoutýdenních úrokových měr, komentáře členů bankovní rady v médiích o výhledu české ekonomiky atd.) ovlivňují volatility tříměsíčního PRIBORu a desetiletého vládního dluhopisu. Dále budu analyzovat, jak na volatilitu působí načasování komentářů členů bankovní rady. Data jsou analyzována pomocí tří typů GARCH modelů, a to GARCH(1,1), EGARCH(1,1) a TARCH(1,1). V poslední řadě rozdělím komentáře na pozitivní a negativní ve smyslu zlepšení nebo zhoršení makroekonomického výhledu. Každý z těchto modelů totiž vysvětluje data z jiných úhlů. Vytvořím vlastní soubor dat obsahující nula-jedničkové proměnné popisující, zda komunikace nastala, nebo ne. Data pro analýzu pocházejí převážně ze stránek ČNB a jedná se o denní data. Závěrem práce bude zjistit, jak jednotlivé typy komunikace ovlivňují volatilitu.

Předpokládaný cíl rigorózní práce, původní přínos autora ke zpracování tématu, případně formulace problému, výzkumné otázky nebo hypotézy:

Zaměřím se na českou Centrální banku a empiricky prozkoumám mladé téma diskutované v literatuře. Použiji úrokové míry namísto směnných kurzů (což je běžná praxe v akademické literatuře).

Zkoumané otázky:

1. Vliv komunikace na volatilitu – snižuje ji nebo zvyšuje?
2. Má načasování komunikace vliv? A jaký?
3. Jaký vliv mají různé formy komunikace (zasedání bankovní rady, Zpráva o inflaci, komentáře členů bankovní rady v novinách, ...)?

Předpokládaná struktura práce:

Introduction – vymezení tématu, postup zpracování, použité metody
1. Literature review
    1.1 Development in thinking – popis změny vnímání toho, co by centrální banky měly a neměly publikovat široké veřejnosti
    1.2 Recent empirical findings – shrnutí nejdůležitějších poznatků v literatuře, a to jak v české, tak ve světové
2. Central bank communication
    2.1 Definition of communication
    2.2 Model of communication
    2.3 Why what and how – proč, o čem a jak centrální banky komunikují
    2.4 The Czech National Bank – kapitola shrnující Českou národní banku
3. Analysis of the volatility
    3.1 Methodology – hlavní použité metody analýzy a jejich definice
    3.2 The data set – popis sběru a hlavních rysů použitých dat
    3.3 The model – popis použitého modelu
    3.4 3M PRIBOR – analýza 3 měsíčního PRIBORu
    3.5 Czech 10Y Bond – analýza českého 10 letého vládního dluhopisu
4. Conclusion – shrnutí a interpretace výsledků
Bibliography
Appendices – přílohy s výsledky regrese, výstupy z programu, důkazy použitých vět atd.

Vymezení podkladového materiálu a metody (techniky) jeho zpracování:

Použitá data za období leden 2007 až prosinec 2012:
– 3 měsíční referenční sazba PRIBOR a výnos českého 10 letého státního dluhopisu
– Dummy proměnné: datum zasedání bankovní rady, datum komentáře členů bankovní rady v médiích, vydání Zprávy o inflaci
– Proměnná interpretující komentáře členů bankovní rady v hodnotách:
    -1 – negativní ekonomický výhled, inklinace k uvolnění monetární politiky
    0 – neutrální výrok, zavádějící, nepřesný obsah
    +1 – pozitivní ekonomický výhled, inklinace k zpřísnění monetární politiky

Metody zpracování:
– GARCH(1,1), EGARCH(1,1) a TARCH(1,1) analýza v programu Eviews 6

Základní literatura:

ANDERSSON, M., H. DILLÉN, & P. SELLIN (2006): „Monetary policy signaling and movements in the term structure of interest rates." Journal of Monetary Economics 53(8): pp. 1815–1855. – *Zkoumají, jak různé signály monetární politiky ovlivňují časovou strukturu úrokových měr. Výsledkem je, že komunikace centrální banky je nezbytnou součástí monetární politiky.*

BLINDER, A. S., M. EHRMANN, M. FRATZSCHER, J. DE HAAN, & D.-J. JANSEN (2008): „Central Bank Communication and Monetary Policy: A Survey of Theory and Evidence." Journal of Economic Literature 46(4): pp. 910–945. – *Poskytují průzkum literatury zabývající se komunikací centrální banky a jejím vlivem. Komuniace může být důležitým a mocným nástrojem, protože „hýbe" s finančními trhy, zlepšuje předvídatelnost rozhodnování a pomáhá k dosažení makroekonomických cílů.*

BLINDER, A. S., C. GOODHART, P. HILDEBRAND, D. LIPTON, & C. WYPLOSZ (2001): „How Do Central Banks talk?" International Center for Monetary and Banking Studies/Centre for Economic Policy Research. – *První z publikací, v níž se autoři pokouší dojít k závěru, co by měla centrální banka publikovat a jakými prostředky. Dokládadá to na komunikační strategii čtyř světových centrálních bank (FED, ECB, Bank of England, Bank of Japan a Reserve Bank of New Zealand).*

BÖHM, J., P. KRÁL, & B. SAXA (2012): „The Czech National Bank's monetary policy in the

media.“ European Journal of Political Economy 28(3): pp. 341–357. – *Zkoumají, jak je komunikace České národní banky vnímána a interpretována českými médii, a to čtyřmi seriózními novinami.*

EHRMANN, M. & M. FRATZSCHER (2007a): „Communication by Central Bank Committee Members: Different Strategies, Same Effectiveness?“ Journal of Money, Credit and Banking 39(2-3): pp. 509–541. – *Zkoumá strategii a efektivitu FEDu, Bank of England a ECB. Efektivita komunikace není nezávislá na procesu rozhodování. Závěrem je, že nejspíše neexistuje jeden nejlepší přístup či metoda komunikační strategie.*

EHRMANN, M. & M. FRATZSCHER (2007b): „The timing of central bank communication.“ European Journal of Political Economy 23(1): pp. 124–145. – *Komunikace centrálních bank je považována za nástroj, jakým připravit trhy na nadcházející rozhodnutí. Proto se komunikace zintenzivňuje ve dnech před zasedáním bankovních rad.*

FILÁČEK, J., L. KOMÁREK, & P. KRÁL (2007): „Why Central Bankers Should Disclose: Interest Rate Forecast.“ Czech Journal of Economics and Finance (Finance a úvěr) 57(11-12): pp. 558–576. – *Diskutují teoretické a empirické aspekty publikování odhadů a předpovědí úrokových sazeb.*

FIŠER, R. & R. HORVÁTH (2010): „Central Bank Communication and Exchange Rate Volatility: A GARCH Analysis.“ Macroeconomics and Finance in Emerging Market Economies 3(1): pp. 25–31. – *Prostřednictvím GARCH modelů analyzují efekty komunikace České národní banky, makroekonomickcý zpráv a změn úrokových sazeb na volatility směnných kurzů. Komunikace má „tišící“ efekt na volatilitu směnných kurzů. Finanční trhy reagují na komunikaci, proto je důležité dbát na správné načasování.*

HAYO, B. & M. NEUENKIRCH (2011): „Bank of Canada communication, media coverage, and financial market reactions.“ Economics Letters. – *Pomocí GARCH modelu zkoumají, jak komunikace Bank of Canada a mediální zpravodajství o ní ovlivňuje kanadský trh s dluhipisy a akciemi. Závěrem je, že oficiální komunikace ovlivňuje trh s dluhopisy, zatímco média ovlivňují více trh s akciemi.*

JANSEN, D. & J. DE HAAN (2006): „Does ECB communication help in predicting its interest rate decisions?“ – *Zkoumají užitečnost komunikace ECB na predikování jejího rozhodování ohledně úrokových sazeb za použití probit modelů založených na Taylorově pravidle.*

ROZKRUT, M., K. RYBIŃSKI, L. SZTABA, & R. SZWAJA (2007): „Quest for central bank communication: Does it pay to be talkative?“ European Journal of Political Economy 23(1): pp. 176–206. – *Komunikace centrálních bank v České republice, Maďarsku a Polsku ovlivňuje chování finančních trhů. Nicméně tento efekt se liší mezi analyzovanými zeměmi.*

Diplomové a disertační práce k tématu:

FIŠER, R. (2008): „Vliv komunikace České národní banky na směnný kurz: důkaz GARCH modelem.“ Bakalářská práce (Bc.). Praha: Univerzita Karlova, Fakulta sociálních věd, Institut ekonomických studií. Vedoucí: doc. Roman Horváth, Ph.D.

LOCOMAN, E. (2011): „Central Bank Communication: Comparison between the Czech National Bank and the National Bank of Moldova.“ Diplomová práce (Mgr.). Praha: Univerzita Karlova, Fakulta sociálních věd, Institut ekonomických studií. Vedoucí: doc. Mgr. Tomáš Holub, Ph.D.

VAŠKO, D. (2012): „Central bank communication on financial stability.“ Diplomová práce (Mgr.). Praha: Univerzita Karlova, Fakulta sociálních věd, Institut ekonomických studií. Vedoucí: doc. Roman Horváth, Ph.D.

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Bibliographic Record

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Part I.

Diploma Thesis

Abstract

This thesis analyzes the effect of the Czech National Bank's (CNB) communication on the interest rate volatility (PRIBOR reference rate). Starting with the literature survey about the central bank communication in the world, I focus on the literature that concerns the CNB. To model the CNB's communication, I use the GARCH(1,1), EGARCH(1,1) and TGARCH(1,1) models. I have created a unique data set containing the dummy variables for the CNB communication. The results are as follows: (a) the CNB's communication tends to decrease the volatility, (b) timing of the communication has a key role as the comments closer to the meeting have bigger calming effect, and that (c) there is no clear effect concerning the comments of the Bank Board members in the media.

JEL Classification	E43, E44, E52, E58
Keywords	Czech National Bank, monetary policy signaling, central bank communication, the term structure of interest rates, GARCH analysis

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Academic Year	2012/2013

Abstrakt

Tato diplomová práce analyzuje efekt komunikace České národní banky (CNB) na vývoj úrokových sazeb (referenční sazbu PRIBOR). Předkládám průzkum literatury týkající se komunikace centrálních bank, a to nejen ve světě, ale zaměřuji se hlavně na CNB. K modelování komunikace CNB používám modely GARCH(1,1), EGARCH(1,1) a TGARCH(1,1). Vytvořil jsem datový soubor obsahující dummy proměnné popisující komunikaci centrální banky. Výsledky jsou následující: (a) komunikace centrální banky snižuje volatilitu, (b) důležitou roli hraje i načasování komunikace, protože komentáře blíže k datu zasedání Bankovní rady mají spíše uklidňující efekt na volatilitu a (c) komentáře členů Bankovní rady v médiích mají nejasný efekt na volatilitu.

Klasifikace JEL	E43, E44, E52, E58
Klíčová slova	Česká národní banka, signalizování pomocí monetární politiky, komunikace centrální banky, časová struktura úrokových měr, GARCH analýza

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List of Acronyms

AIC	Akaike Information Criterion
AR	Autoregressive model
ARCH	Autoregressive Conditional Heteroskedasticity
ARCH-LM	Lagrange Multiplier test
BIC	Bayesian information criterion
CNB	Czech National Bank; Česká národní banka
EGARCH	Exponential GARCH
GARCH	General ARCH
MA	Moving Average model
OLS	Ordinary Least Squares
PRIBOR	Prague InterBank Offered Rate
SIC	Schwarz Information Criterion
TARCH	Threshold GARCH

Master Thesis Proposal

Author	Mgr. Pavel Karas
Supervisor	doc. Bc. Roman Horváth, M.A., Ph.D.
Proposed topic	The Czech National Bank Communication: GARCH analysis of 3M PRIBOR rate and Czech 10Y government bonds

Topic Characteristics I would like to investigate how the Czech National Bank's various monetary policy signals such as repo rate changes, inflation reports, speeches by and minutes from monetary policy meetings affect the term structure of interest rates.

This thesis would also assess the effectiveness of monetary policy communication of the CNB. I would like to come to the conclusion which of the previously mentioned monetary policy signals do affect the yield curve and in what sense. Moreover, I would like to find out what is the role, if any, of statements in predicting the next policy move.

Hypotheses

1. Does CNB communication have any effect on the term structure of interest rates?
2. Which types of news are more relevant?
3. What are the effects from various signaling channels on the structure of interest rates?
4. How large are the impacts on short-term interest rates and long-term ones?
5. How important is it to control for publication of relevant economic news?

Methodology I would like to use the Autoregressive Conditional Hazard Model (ACH model) derived by Hamiltion and Jorda (2002) because the policy rate is changed irregularly in time and we are uncertain about when the policy rate will be changed next, given information available today. As Anderson et al. (2004) suggest,

the unexpected movements in the term structure are driven by changes in expectation of future short-term interest rates and unexpected changes in the term premia. We will use their model, too.

Outline

1. Introduction
2. Central banking – theoretical background
3. Description of the model
4. Empirical results
5. Conclusion and recommendation

Core bibliography

1. Andersson, M., Dillén, H. & Sellin, P. (2006): "Monetary Policy Signaling and Movements in the Swedish Term Structure of Interest Rates", *Journal of Monetary Economics*, pp. 1815–1855.
2. Blinder, A.S., Ehrmann, M., Fratzscher, M., De Haan, J. & Jansen, D.-J. (2008): "Central Bank Communication and Monetary Policy: A Survey of Theory and Evidence." *National Bureau of Economic Research.*
3. Bomfim, A.N. (2003): "Monetary Policy and the Yield Curve". *Board of Governors of the Federal Reserve System, Finance and Economics Discussion Series 2003-15 (February).*
4. Buttiglione, L., Giovane, P.D. & Tristani, O. (199**7**): "Monetary Policy Actions and the Term Structure of Interest Rates: A Cross-Country Analysis." *Banca d'Italia. Servizio studi.*
5. Demiralp, S., Kara, H. & Özlü, P. (2011): "Monetary policy communication under inflation targeting: Do words speak louder than actions?" *TUSIAD-Koc University Economic Research Forum.*
6. Égert, B. & Kočenda, E. (2012)**:** "The impact of macro news and central bank communication on emerging European forex markets". *University of Paris West - Nanterre la Défense, EconomiX.*
7. Hamilton, J.D. & Jorda, O. (2000): "A Model for the Federal Funds Rate Target." *National Bureau of Economic Research, Inc.*
8. Rosa, C. (2011): "The high-frequency response of exchange rates to monetary policy actions and statements." *Journal of Banking & Finance* **35(2)**: pp. 478–489.

Author

Supervisor

Introduction

The past recent years have changed the practice of how central banks are communicating with the public. This thesis describes this movement towards a greater independence and transparency. We can also see a shift in via to whom the banks communicate, from individuals to committees. We also observe an increasing number of central bank talks in the media, as well as regular comments of members of Bank Boards.

In this thesis I will empirically study quite a young topic: the central bank communication and its effects on financial markets. The communication is one way of how the central bank can assess uncertainty about future rates and therefor affect their level and volatility. Since the Czech National Bank (CNB) explicitly targets inflation, I focus on the interest rate and the government bonds instead of the exchange rate as it is more common practice in the recent literature. Apart from the daily 3M PRIBOR reference rate, I am studying the Czech 10-year government bond. There is so much literature about this subject concerning lots of central banks all over the world, but there is none literature that studies Czech National Bank's talks and their effects.

I have created an extensive data set on how the CNB communicates the economic outlook and its implications for monetary policy to the public. More specifically, the data set contains unity values for the days when the Inflation report, the most important document published by the CNB, is released and for the days when the minutes, approximately a 1000-words-long document, is issued. Moreover, I have scrutinized the comments provided by members of the CNB Bank Board and assigned different values ($+1$ or -1) to given comments. The analysis takes into account the timing of the CNB communication, because it is believed that comments made closer to the Bank Board meeting have higher impact. The effects of these variables are analyzed using the mean and variance equations of the GARCH, the EGARCH and the TGARCH models.

Previous research has pointed up the role of the timing of central bank communication. As a consequence, my hypothesis to be tested are: (i) whether the Czech central bank's communication affects the interest rate (volatility), (ii) whether its communication becomes more potent as the monetary policy meeting approaches, and (iii) whether, in contrast to most of the previous literature, its communication affects not only short-term, but also long-term interest rates.

The main findings of this thesis can be summarized as follows. First, I found that the CNB communication tends to decrease the volatility of interest rate as well as the government bond yield, i. e. this supports the view that the central bank aims to decrease the noise in the financial markets. Comments made closer to the date of the Bank Board meeting (a timing of the communication) have a more calming effect on the volatility. Thus, the CNB does a great job, because its communication timing decreases the volatility. There is not a clear pattern concerning comments. This can be explained by the fact that listeners may not be sure about the content of the comment. Another explanation is that the members' comments are more individualistic with opposing signals or opinions on the current or future situation.

The remainder of this paper is structured as follows. Chapter 1 provides the literature review describing the development in how central bank have behaved, from total discretion to transparency, and stating the recent empirical findings. Chapter 2 discusses the role of central banks' communication in general and the end of the chapter is talking about the Czech National Bank. Chapter 3 describes the methodology and the data. It also provides the results of the econometric analysis and discusses the results. Finally, Conclusion includes the concluding remarks as well as ideas for further research.

Chapter 1
Literature review

This chapter provides a literature review. First of all, I will describe the development in thinking by stating the milestones that have changed the perception of how central banks should behave. Apart from the recent openness and the independence of central banks, the transparency plays an important role because it manages the monetary policy effectiveness and the democratic accountability.

I also present the recent empirical findings in literature regarding how macroeconomic announcements and communication influence asset prices, money and bond markets, exchange rate, interest rates and so on. At the end of this chapter, some papers concerning the CNB's communication, e. g. through media, are mentioned there.

1.1. Development in thinking

Ehrmann & Fratzscher (2007a) state that the recent past has been a witness of a change in how central banks all around the world are performing their monetary policy. Along with a trend toward a greater openness, there has been a movement toward a decision-making by committees rather than individuals, as well as a strong emphasis on a central bank transparency.

There were times, prior to the 1990s, when central banks did not talk publicly about their decisions and actions performed. They were "shrouded in mystery" (Blinder *et al.* 2008) and it was generally believed that they should not be talkative at all. Karl Brunner (1981, p. 5) writes:

> "Central Banking ... thrives on a pervasive impression that ... [it] is an esoteric art. ... The esoteric nature of the art is moreover revealed by an

> inherent impossibility to articulate its insights in explicit and intelligible words and sentences."

Ten years later, there were debates about how central banks should behave in order to improve its decisions and the monetary policy as a whole. Alan Blinder (1999, pp. 70-72) expressed a view of what central banks should be like:

> "Greater openness might actually improve the efficiency of monetary policy ... [because] expectations about future central bank behavior provide the essential link between short rates and long rates. ... By making itself more predictable to the markets, the central bank makes market reactions to monetary policy more predictable to itself. And that makes it possible to do a better job by managing the economy."

More recently, Michael Woodford (2001, pp. 12 and 16-17) emphasizes the necessity for a higher transparency. He concludes that:

> "... successful monetary policy is not so much a matter of effective control of overnight interest rates ... as of affecting ... the evolution of market *expectations* ... [Therefore,] *transparency is valuable* for the effective conduct of monetary policy ... this view has become increasingly widespread among central bankers over the past decade."

What have we learnt from these three papers? We can clearly see the sharp progression here: from the 1981's disapproval of central bankers' rejection to communicate to 2001's claim that the core of monetary policy is the art of managing expectations via the central banks' communications. The presented development can be, without any exaggerations, called a "revolution in thinking" (Blinder 2009).

1.2. Transparency

The previous paragraphs are talking a lot about the transparency. Transparency can be understood as "much is known by many"[1] or as "behaving and operating in such a way that it is easy for others to see what actions are performed"[2]. Woodford (2001) claims that "transparency is valuable for effective conduct of monetary policy" (p. 16). Central banks know that. They have become more transparent in the last fifteen years and put a much higher importance on their communications.

[1] According to: http://www.investopedia.com/, accessed April 12, 2013.
[2] According to: https://en.wikipedia.org/, accessed April 9, 2013.

Locoman & Holub (2011) discuss this subject much deeper. They define different types of the monetary policy transparency:

1. Political transparency,
2. Economic transparency,
3. Procedural transparency,
4. Policy transparency,
5. Operational transparency.

We will not describe these types in a detail, but we will state different look at the transparency. An interested reader can also find an exhaustive list of relevant literature in their paper.

Let me start with the definition of transparency in the context of central banking. "A central bank is transparent when it provides at all times sufficient information for the public to understand the policy regime, to check whether the bank's actions match the proclaimed regime and to pass a judgment on its performance" (Blinder *et al.* 2001).

In fact, there are two reasons for openness: *effectiveness of monetary policy* and *democratic accountability*. Policy effectiveness is raised when the broad public can anticipate the bank's actions with a confidence. Transparency reduces uncertainty and limits the costs associated with decisions which turn out to have been based on mistaken expectations. These two rationales are not completely independent of each other but will be treated separately in the following paragraphs.

1.2.1. Monetary policy effectiveness

The secrecy was a characteristic of central banks which accompanied both their internal operations and their external communication. The literature findings nevertheless prove that the monetary policy is most effective when the markets correctly anticipate it. There are three features of the effective monetary policy signaling (Blinder *et al.* 2001):

1. *"Monetary policy mostly acts through variables that are driven by market expectations*." The very short-interest rate is controlled by central banks. The Czech national bank controls the 2W repo rate. As noted by Blinder (1999), these short-term interest rates have a trivial impact on the

economy. Longer-term interest rates, asset prices and the exchange rate, to the contrary, constitute powerful and marked influences. The link between short-term interest rate and these financial variables involves expectations.

2. *"The channel from interest rates to the real economy and inflation involves price and wage setting."* Transparency goes hand in hand with credibility (Locoman & Holub 2011). The credibility improves the effectiveness, acceptability and speed of monetary policy (De Haan *et al.* 2004). If it is not obvious what a central bank wants to achieve, the adjustment of the market participant's behavior (price and wage setting) is slow.

3. *"Transparency also reduces the cost of policy changes."* Central bankers are aware that sudden changes in policy confuse the public and, consequently, may harm their credibility. Therefore, the public must clearly understand the policy regime.

Thus, central banks are better off if they reveal completely and truthfully their chosen policy regime and the procedures put in place to enforce such a regime. Everything ought to be communicated to the broad public unless a case can be made that some confidentiality is desirable under the particular circumstances that prevail (Blinder *et al.* 2001).

1.2.2. Democratic accountability

Being a public institution, a central bank must be fully accountable for all its procedures and actions. A communication is in the center of accountability because any central bank cannot operate successfully unless it uses a broad support. Central bank is accountable to different groups (citizens, media, governments or financial markets) with different knowledge and interests.

It is not a secret that an average *citizen* typically does not understand monetary policy. He does not care about the price stability, but he cares about the inflation. Ordinary citizen does not read Inflation reports, therefore, media should take its place here and take control and inform them.

Media face two problems when dealing with monetary policy. Firstly, they need to create and maintain an interest in a technical subject. Secondly, media need to diversify their sources of information and analysis. When making the

statements clear to ordinary citizens, media must understandably explain central bank's actions and intentions. "Simplification and pedagogy are essential ingredients here, but the risk is to lose nuance, a key ingredient in central bank communication" (Blinder *et al.* 2001).

There are also *governments* and parliaments there and they are, on the other hand, very interested in monetary policy since economic conditions are often playing an important role during elections. Governments have a clear view of what central banks should do. This conflict of interests is therefore solved by the central bank independence.

Money does matter to *financial markets*. A key responsibility of central banks is ensuring the stable price and the health of the financial system (Bernanke 2004). The volatility makes financial markets while it is disliked by public. Moreover, minutes and seconds play a big role for the financial market while public is limited with time that takes monetary policy to have real effects on economy, i.e. several months.

We should not forget other involved watchers. These can be found in financial institutions or in academia. Their role can be friendly or hostile. They can be friends while clarifying and justifying central banks actions. They can be foes because they can be critical, they can outguess some actions that a central bank wants to hide etc.

1.3. Recent empirical findings

1.3.1. Foreign literature review

This thesis is based on the extensive literature discussing how macroeconomic announcements (e. g. unemployment data or release of the CPI index) are incorporated in asset prices. McQueen & Roley (1993) study the responsiveness of stock prices. Fleming & Remolona (1999) and Thornton (1998) write about money and bond markets. Last but not least, Andersen *et al.* (2003) and Faust *et al.* (2007) study behavior of exchange rates.

Further works highlighted the asymmetries and time variations. Andersen *et al.* (2003) show that the bad news has a greater impact on the exchange rate than the good news. Andersen *et al.* (2007) and Laakkonen & Lanne (2010) add that the news effects are dependent on business cycles. Gilbert *et al.* (2010)

find a smaller responsiveness to macroeconomic announcements that should be revised in the future, and in particular a substantially larger reaction to news with more information content about monetary policy decisions by the Federal Open Market Committee.

Ehrmann & Sondermann (2012) study the reaction of United Kingdom macroeconomic announcements and Bank of England's Inflation Report on short-term interest rates (2M, 3M, 6M and 12M British zero-coupon bonds). They argue that the reaction of financial markets to news cannot be studied in isolation, as there can be important interdependences: one piece of news does not only have direct effects on asset prices and market volatility, but it can also alter the relative importance of other pieces of news.

The relation between the central bank communication and the reaction of bond markets is also studied in many papers (see e. g.Andersen *et al.* 2007, Balduzzi *et al.* 2001 or Jones *et al.* 1998). It is confirmed that the bond (prices, trading volume and bid-ask spreads) are sensitive to scheduled macroeconomic announcements. The effects, however, vary significantly according to maturity. Kim *et al.* (2004), for instance, prove that news related to the internal economy are important for the bond markets.

The evolution in technologies has enabled to use high-frequency data. Ederington & Lee (1993) examine the impact of scheduled macroeconomic news announcements (the employment report, the CPI and the PPI) on interest rate and foreign exchange futures markets (T-Bond, Eurodollar and deutsche mark futures markets) by using high-frequency data. Fleming & Remolona (1997) also use high-frequency data on bond markets and they find that bond prices react largely to the arrival of public information about the economy. They also suggest that the price and trading reactions reflect the differences of information content in different announcements under different market conditions. When analysing the U.S. and German sovereing bond markets, Goldberg & Leonard (2003) find that the largest moves in yields are associated with announcements on labour market conditions, real GDP growth and consumer sentiment.

1.3.2. Literature concerning the CNB

Rozkrut *et al.* (2007) evaluate the communication strategies of the Czech National Bank, the National Bank of Hungary and the National Bank of Poland. They found that a communication largely differs among these banks, and that

policy makers' words do not often correspond with their deeds. They provide an evidence that central banks' talks influence market expectations of future policy decisions. The consistency of policy maker's statements (the extend to which their words correspond with their prospective deeds), communication strategy and the committee structure, see subsection 2.3.3, influence the impact of central banks' talks on predictability of monetary policy decisions.

Böhm *et al.* (2012) analyze the coverage of monetary policy of the CNB in media during the period of 2002 – 2007. They studied articles in four most relevant Czech daily broadsheets[3]. They found out that the surprise in setting the interest rate was perceived neutrally in the media. This is interpreted such that the surprise, that has been believed to play an important role in managing the expectations, is part of a standard monetary policy. Next, regardless of the direction of the move, the changes in interest rates are appreciated by the media. The media does not like rising inflation and dislike disinflation. Accelerating GDP growth is perceived as good. They conclude that "despite being perceived neutrally, an unexpected CNB interest rate decision... attracted the attention of the media. Similarly, interest rate changes .. were in principle extensively covered in the media".

Filáček *et al.* (2007) confirm that the inflation-targeting regime has brought the transparency of central banks into special focus as they are highly dependent on the market perception of their policy decisions and communication. They argue that under such a regime, it is important for the central bank to disclose interest rate forecast. Market expectations are moving closer to the CNB's. This enhances the accountability and credibility of the CNB's forecasts as well as it improves the efficiency of its monetary policy conduct. Filáček & Saxa (2012) add that the private analysts do coordinate their forecasts for the interest rate and inflation according to the CNB's forecasts. On the other hand, they conclude that there is no or limited evidence that such a coordination exists for the exchange rate and the GDP growth.

Bulíř *et al.* (2007) and Bulíř *et al.* (2008) are interested in the inflation targeting and the communication of central banks of Chile, the Czech Republic, Hungary, Poland, Thailand and Sweden. They find that inflation targets, inflation forecasts and verbal assessments of inflation factors contained in quarterly inflation reports provided a consistent message during the years 2000 – 2005.

[3]The broadsheets used in their paper are Mladá fronta Dnes, Právo, Hospodářské noviny and Lidové noviny.

Fišer & Horváth (2010) analyze the effects of the CNB communication, macroeconomic news and interest rate differential on exchange rate volatility using the GARCH model. They present that the communication has a "calming" effect on the volatility of exchange rate. Moreover, they discover that the timing of the communication does matter as the financial markets respond more to the communication before the policy meetings rather than after them.

Chapter 2
Central bank communication

In the following text, I define the communication of central banks mentioning what it is, why central banks talk and how the transmission of the signals is performed. I mention not only benefits, but also disadvantages of communication. I describe the model of communication. At the end of this chapter, I analyze the Czech National Bank, stating what sort of communication and what policy instruments the CNB can use.

2.1. Definition of communication

Central bank communication can be defined 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" (Blinder *et al.* 2008).

Central bank talking is a key concept of how central banks are trying to make themselves understood. Many authors agree that the trend nowadays is towards great openness and transparency. Transparency is based on both policy effectiveness and democratic accountability (Blinder *et al.* 2001). The more transparent and accountable central bank is, the more independent it should be.

One important tool for achieving transparency and thereby accountability, that were both discussed above, is the communication with the public. A lot of authors (Andersson *et al.* 2006, Blinder 2009, Ehrmann & Fratzscher 2007a, Eijffinger & Tesfaselassie 2007, Hayo & Neuenkirch 2011, Rosa 2011 or Ehrmann & Sondermann 2012) discuss different communication techniques and

sources that are used for different types of recipients. I will try to summarize them later.

To paraphrase economic "who, what and how", we will seek answers to questions "why central banks talk", "what they say" and "how they do it". Before answering these questions, let me present a model of communication.

2.2. Model of communication

The model of central bank communication was summarized by Filardo *et al.* (2008). This model is based on the work of Shannon (1948). The model is shown on fig. 2.1. Let us describe individual parts of the picture. The following text is based on the paper of Filardo *et al.* (2008).

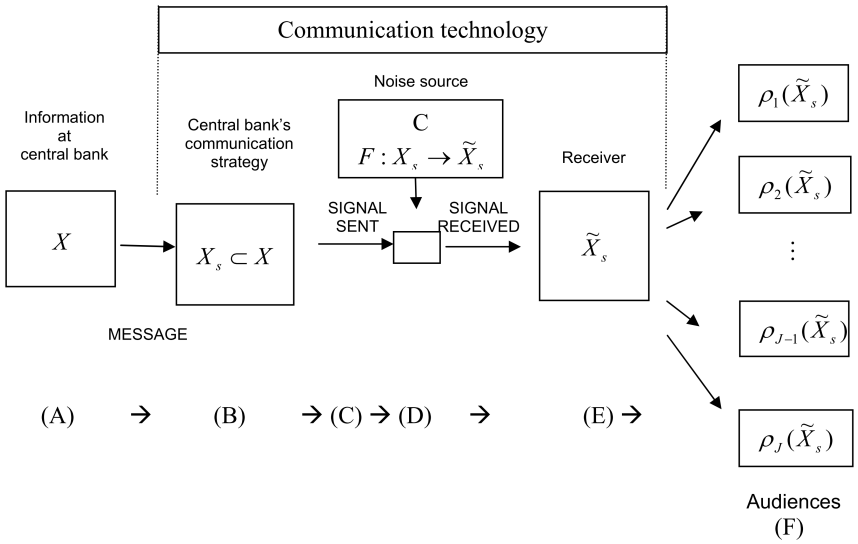
Point (A) describes the stock of information about monetary policy X that is about to be shared with a broad public. The provided message should contain such information as the policy framework, the decision making process, the policy decision, assessments of the economy, likely future actions etc.

Point (B) represents the situation in which the central bank has to choose its communication strategy judiciously. Therefore, the provided information X is reduced to $X_s \subset X$ that will be finally disclosed. More information does not always mean better (Bernanke 2004), it does not improve clarity of sent message (Filardo *et al.* 2008). Releasing too much information may overwhelm the receivers who can become more confused about the intentions of the central bank.

Point (C) describes how the message is transmitted. Many theories of monetary policy assume that transmission of the signal from the central bank to the public is almost magical. In reality, there are number of ways, including press conferences, releases of minutes, speeches, interviews, written statements, reports, background documents or research working papers.

Point (D) states that regardless of how carefully a central bank has created its message, there is a possibility for miscommunication. This possibility can arise from a number of causes: bad timing or miscalibration of messages to different audiences. Thus, instead of information X_s we get a noisy information $\widetilde{X}_s$. The end result can be a serious confusion of the signals from the central bank.

Fig. 2.1: Model of central bank information transmission



Source: Filardo *et al.* (2008, Graph 1, p. 3)

Points (E) and (F) show that a wrong interpretation of the signals by the intended recipients is always possible. This is caused by the fact that the different groups of recipients are seeking different types of information. The received information $\widetilde{X}_s$ is sorted by its importance for them, $\rho_i\left(\widetilde{X}_s\right)$, $i = 1, \ldots, J$. Moreover, the recipients have different abilities to absorb, to interpret or to pay attention to the details in the monetary policy. These fact also reduce the effectiveness of a communication strategy.

According to Blinder (2009), the bank should reveal enough about its analysis, actions and internal deliberations so that every interested person can understand each of monetary decisions. There are at least four recipients of central bank talks – the markets, the media, the politicians, and the broad public – to whom the message has to be clear and consistent. If there are some discrepancies in communications, it can lead to severe damages; we will discuss them later.

Now, let us answer the three questions mentioned above one by one. In the following section, I am presenting the reasons why central banks should communicate in a loud and clear voice, what they should and should not say and how their communication should be done.

2.3. Why, what and how

2.3.1. Why

Central banks directly control a single short-term interest rate, 2W repo rate in the case of the CNB. That is why this short-term one can be used as a lever to influence more important asset prices and yields (stock prices, government and corporate bond yields, mortgage rates). Central bank influences expectations of future short-tem rates, r^e_{t+j} in eq. (2.1), which, in turn, influence long-tem rates and other financial-market prices (e. g. bonds), R_t in eq. (2.1). These prices then influence other macroeconomic variables (e. g. inflation oroutput). This allows the central banks to influence the overall course of the economy (Bernanke 2004).

From a basic financial theory, we know that there is a link between short-term interest rates and longer-term rates (e.g. Treasury bond yields, mortgage rates). The link is based on the market expectations about the future short-term rates. For example, Bomfim (2003) demonstrated that the shape of the term structure of Treasury yields can be effectively described by a two-factor model: the first factor corresponds to the current setting of the funds rate and the second factor closely approximates expectations of a medium-term monetary policy.

As described in the previous paragraph, interest rates on longer-term instruments should reflect the expected sequence of future overnight rates. So, the n-day rate should be, approximately:

$$R_t = \alpha_n + \frac{1}{n} \cdot \left(r_t + r^e_{t+1} + r^e_{t+2} + \ldots + r^e_{t+n-1} \right) + \varepsilon_{1t}, \tag{2.1}$$

where r_t is the current overnight rate, r^e_{t+1} is today's expectation of tomorrow's overnight rate (and so on for $t+2$, $t+3$, ...), α_n is a term premium and the error term ε_{1t} indicates that the term premium might be stochastic.

Equation (2.1) describes the *expectations theory of the term structure*. Although the theory explains the simultaneous movement of rates, and also the relationship between the long and short terms well, it does not say anything about why the yield curve has an upward slope most of the time, that is, why longer term maturities command a higher interest rate in comparison to the

short term.[1]

This theory is sometimes used to explain the yield curve but it has proven to be inaccurate in practice as interest rates tend to remain flat when the yield curve is normal. In other words, expectations theory often overstates future short-term interest rates.[2]

Benefits of communication

Andersson *et al.* (2006) state that financial markets react to information on the outlook provided by central banks. This is because central banks usually give a lot more resources to forecasting and estimating of the underlying state of economy than a private sector forecasters. Kohn & Sack (2003) argue that private agents do pay bigger attention to economic pronouncements of their central bank, especially if the bank is credible and is established as an effective forecaster.

Since we all are living in a non-stationary world, where learning is natural, and where there is either non-rational expectations or asymmetric information between a central bank and general public, the central bank communication counts. The real world is changing constantly. That is why learning by and about the central bank never ends.

Therefore, learning about the central bank communication is a crucial factor. The public has to learn about parameters the central banks are using in their calculations. Bernanke (2004) points out that the adaptive learning in macroeconomics plays an important role as learning changes the "nature of the optimal monetary policy" (p. 4). He also adds that "communication by central bank may play a key role in helping to improve economic performance".

The essential message that any central bank should express to the public is its *policy regime* – what is trying to achieve, how it goes about doing so and its probable reactions to the contingencies that are likely to occur. Of course, we need to have in our mind that no central bank can express in advance its reactions on every contingency nor to reveal every details about its operations.

[1] According to: http://www.forextraders.com/, retrieved Dec 31, 2012
[2] According to: http://www.investopedia.com/, retrieved Dec 31, 2012

Downside to communication

On the other hand, a lot of authors also express the disadvantages of communication. Bernanke (2004), for instance, warns that a lot of information is not always better. Blinder *et al.* (2008) add that poorly designed or poorly executed communications can do more harm than benefit. This is because irrelevant or badly communicated information may create more noise, and can even compromise the integrity and quality of policy-making process itself.

Communication can be undesirable and damaging under certain circumstances. Ehrmann & Fratzscher (2009) define the *purdah*[3] period and they show that any communication during this period leads to an excessive market volatility. This period differs in time span but can be defined as "some time before policy meetings or other important events and some time after". For Federal Reserves, they established its period to be 7 days before and 3 day after Federal Open Market Committee meetings, as well as before the chairman's semiannual testimony to Congress.

The "cacophony problem", see Blinder *et al.* (2008), arises when monetary policy decisions are announced by a committee rather than by a single person because too many voices might confuse rather than enlighten the public – especially when these messages are conflicting.

Reasons for communication

The central banks' mandate is first and foremost to *achieve price stability.* The process started with the Reserve Bank of New Zealand in 1989 and has spread to countless central banks (Blinder *et al.* 2001). Central banks can control interest rates only at the shorter end of the maturity spectrum, but monetary policy affects the economy through its impact on the longer-term interest rates as well as on asset prices and exchange rates. The link is the market expectations working through the term structure of interest rates: transmitting the central bank's command to the economy.

Communication really matters (Blinder *et al.* 2001). The same authors state one concrete example: from early 1996 to mid-1999 in the USA. Because of the Fed's greater openness, the bond market began to anticipate the central

[3] The word "purdah" originally comes from Urdu and Hindi, and literally means "curtain," referring to the practice of preventing men from seeing women (see, e.g., Wikipedia, http://en.wikipedia.org/, Dec 31, 2012).

bank's actions better than it had in the past. Fed left the federal funds rate virtually unchanged, but bond rates were moving up (when it looked like the economy was in danger of overheating) and down (when it looked like there was little such danger). Thanks to Fed's communication, the bond market was doing the Fed's work for it.

2.3.2. What

Different groups are interested in different messages provided. The communication takes different forms in different times and places. A central bank generally talks about at least four aspects of monetary policy:

1. the overall objectives and strategy,
2. the motives behind a particular policy decision,
3. the economic outlook,
4. future monetary policy decisions.

Talking about objectives and strategy

First, and perhaps foremost, central banks need to make clear their long-run objectives. An independent central bank should be given a clearly-defined mandate by its government (Blinder *et al.* 2008). A central bank should provide theirs quantifications, at least for two reasons. First, numerical targets help to maintain accountability. Second, a quantitative objective helps to formulate expectations of economic agents.

Economic agents do not have to know the precise policy rule a central bank uses for its own calculations. Instead, agents learn about this rule by watching what the central bank does and listening to what is says.

Talking about methods

Central banks should reveal a great deal about their methods – including their forecasts, the models used to derive them and to explore alternative policies, and the precise methods of implementing policy changes.

Talking about forecasts

Forecasts are any forward-looking information that central banks provide. It can consist of central bank's assessment of future inflation and economic activity as well as future monetary policy decisions. Central banks differ in opinions whether and how they communicate such information.

Periodic reports typically provide their assessment of expected future inflation. This holds for inflation targeting central bank. However, central banks that are not targeting inflation also release their inflation forecasts (Bulíř *et al.* 2008, Česká Národní Banka 2004).

Central banks should reveal at least the broad contours of their forecasts (e.g. the paths of major variables like output, employment and prices) as often as those forecasts are made.

There are three reasons for publishing forecasts:

1. information should be revealed unless there is a persuasive reason to withhold it,
2. monetary policy is apt to work better when a central bank keeps markets better informed,
3. the central bank can explain its actions to the public better by using the forecast as a background for its decisions.

Talking about models

Most central bank watchers will care only about the bank's basic view of how the economy works and how it thinks monetary policy affects output and prices. Well-chosen words supplemented by a few key numbers may be sufficient.

Talking about decisions

Prompt and clear announcements of monetary policy decisions can lower the noise by creating news and eliminating any potential guessing on the side of economic agents.

All decisions should be publicly announced as soon as they are made, with no informational advantage to select 'insiders'. The next step would be to publish conditional plans for future monetary policy. However, hardly any central banks formulate such plans, even for internal use.

2.3.3. How

The most important thing is whether monetary policy decisions are made by a *single individual*, or as it is increasingly the norm, by a *committee* – and if by a committee, whether decisions are presented as achieved by consensus (*collegial committee*) or by individuals voting for their own preferences (*individualistic committee*).

Central banks can use different types of communication:

1. statements – issued shortly after the meeting
2. minutes – following statements some week later with a fuller explanation
3. forecasts
4. 'bias' statements
5. speeches – purpose ought to be to enlighten rather than befuddle

Collegial committees should strive to convey a consistent message. Emitting a conflicting signal may confuse markets, making the central bank less transparent.

Individualistic committee should air their differences of opinions in public as *required* by transparency. Hearing conflicting view may of course confuse central bank watchers. But, in an individualistic committee, the cacophony of voices is part of the underlying reality.

2.4. The Czech National Bank

The Czech National Bank's role and powers are described in Act No. 6/1993 Coll. on the Czech National Bank of 17 December 1992[4]. Another source for this section is the CNB's website[5] (hereinafter "the website").

The primary objective is to maintain a price stability. It should also oversee the stability of the financial system, ensure smooth circulation of money and smooth payments and support the balanced and smooth development of the Czech financial market[6]. To fulfill the primary objective, the CNB is given the right to set monetary policy of the Czech Republic.

[4] Available online at www.cnb.cz/en/legislation/acts/download/act_on_cnb.pdf, Accessed March 9, 2013.
[5] Visit: http://www.cnb.cz/, accessed March 9, 2013.
[6] See: http://www.cnb.cz/en/about_cnb/mission.html, accessed March 11, 2013.

The supreme governing body is the Bank Board[7] of the Czech National Bank. It sets monetary policy and the instruments for implementing this policy, and decides upon the fundamental monetary policy measures of the Czech National Bank and measures in the area of financial market supervision. This Bank Board has another functions such as approving the budget of the CNB and so on, see Article 5 of the Act for more information. The Bank Board consists of seven members, comprising the Governor of the Czech National Bank, two Vice-Governors of the Czech National Bank and four other members of the Bank Board of the Czech National Bank who are appointed for a term of six years and relieved from the office by the President of the Czech Republic. For the list of current members of the CNB Bank Board see the website[8].

2.4.1. CNB's communication

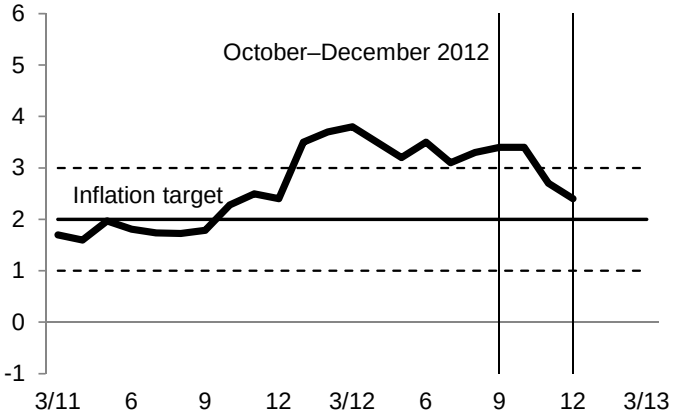
I have already discussed the issue of the central bank communication in section 2.3 of this chapter. In order to reach a high level of accountability, an independent bank must also be transparent. This is achieved mainly by communicating several types of information, see subsection 2.3.2.

Generally, the CNB Bank Board meets eight times a year[9], exceptionally at extraordinary meetings. These meetings are planned at the beginnings of February, May, August and November and at the ends of March, June, September and December. During the meeting it is decided on whether there should be an increase, decrease or no change to two-week repo rate. The results of the votes are made public at 1 p.m., and at 2.30 p.m. there is a press conference. At the press conference, the CNB releases the ratio of the votes cast, a brief digest of the information which the Bank Board based its discussion on, and a list of the risks pertaining to the current forecast according to the Bank Board members. At around 3 p.m., the presentation given at the press conference is made public. Since May 2007, the CNB provides audio recordings, and since December 2009, it provides also videos from the press conferences on its website, usually one hour after the press conference.

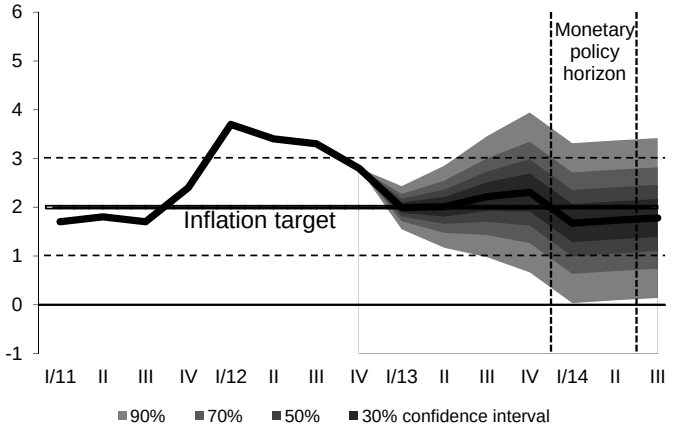
Minutes, a brief description of Bank Board's discussion, are made public eight days, in average, after the meeting. Since 2008, minutes state names of

[7] http://www.cnb.cz/en/about_cnb/bank_board/, accessed March 11, 2013.
[8] http://www.cnb.cz/en/about_cnb/bank_board/bank_board_members/index.html, accessed March 11, 2013.
[9] This holds since 2008, before that they used to meet every month.

Fig. 2.2: The CNB and its inflation target: fulfillment and forecast



(a) Fulfillment of the inflation target of CNB in the period from March 2011 to March 2013



(b) The CNB's forecasts for inflation at the monetary policy horizon, published in February 2013

Source: Inflation Report IV/2012, sekce Měnové politiky CNB

the Board members and their decisions about the interest rate changes. For more information on minutes, see Apel & Grimaldi (2012).

Detailed transcripts of the monetary Bank Board meetings and the inputs for the Bank Board's decisions on monetary issues (the Situation Report on Economic and Monetary Developments and the Monetary Policy Recommendation) are published six years later (available in the Czech version only).

The CNB also publishes a lot of publications and these are also available online on its website. The Inflation Report is without any doubts the most important document. It is published four times a year (February, May, August and November). Section I of the Inflation Report is a summary, section II

contains a description of the Czech National Bank's new quarterly macroeconomic forecast, and section III presents its assessment of past economic and monetary developments. The inflation forecast and the assumptions underlying it are published with the aim of "making monetary policy as transparent, comprehensible, predictable and therefore credible as possible".

The CNB also releases publications on Monetary policy (Inflation reports, Central bank monitoring and Global economic outlook), on Financial stability (Financial stability reports, Stress testing), on Supervision (Financial market supervision reports) and also its Annual reports (Financial and Annual Reports and Financial statements). Apart from publications, the CNB also provides press releases, different presentations and interviews provided by the employees of the CNB, all is available on the website.

2.4.2. Policy instruments

As it has already been mentioned, the CNB's primary goal is to maintain the price stability, and since 1998 it is done by inflation targeting. Until April 2001, the inflation target was represented by net inflation. Since then, it is represented by a growth in consumer price index (CPI) and by a target trajectory in a continuous band.

On fig. 2.2 a), there is the development of the inflation since December 2010. Inflation was in the tolerance band of $2\,\% \pm 1\,\%$. We can see that in December 2011, the inflation crossed the 3% border and was about it until November 2012. In December 2012, the inflation was slightly about 2 %. The forecast of inflation development, fig. 2.2 b), expects that the inflation will be in the tolerance band.

Here, I present the main instruments the CNB is using for monetary policy:

- **Open market operations**
  Open market operations are used for steering interest rates in the economy. They are mostly executed in the form of *repo operations*. According to their aim and regularity, they can be divided into the following categories:
  - The main monetary policy instrument takes the form of *repo tenders*, i.e. a sale and repurchase agreement backed by a collateral. The basic duration is 14 days (2W repo rate).

- The supplementary monetary instrument is the *three-month repo tender*, when the CNB is accepting liquidity for a three-month period.
- *Fine-tuning instruments* (foreign exchange operations and securities operations) are used to smooth the effects of unexpected liquidity fluctuations on interest rates.

▷ **Automatic facilities**
Automatic facilities are used for providing and depositing liquidity overnight.

- The *deposit facility* is a non-collateralized standing facility used by banks to make overnight deposits. The deposits are re-numerated at the discount rate, which generally provides a floor for short-term interest rates on the money market.
- The *marginal lending facility* provides banks with overnight liquidity from the CNB in form of repo operations. The interest rate applied to this facility is the lombard rate, which is a ceiling for short-term interest rates on the money market.

▷ **Extraordinary facilities**
Introduced in August 2008, extraordinary liquidity-providing repo operations with two-week and three-month maturities are aimed at "fostering the functioning of the government bond market". Since January 2011, the liquidity-providing repo operation with two-week maturity remains.

▷ **Minimum reserves**
Every bank, building society and foreign bank branch that has a banking license in the Czech Republic or intends to operate in the Czech Republic on the basis of the "Single License" has to put a specified volume of liquid funds on its account with the CNB.

Chapter 3
Analysis of the volatility

In this thesis, I am going to analyze the impact of the CNB communication on the 3M PRIBOR rate and the Czech 10Y bond yield volatilities. Now, I would like to talk about the PRIBOR reference rate. The CNB publishes the PRIBOR rates[1] on its website. PRIBOR is the abbreviation to Prague InterBank Offered Rate. It represents the interest rate at which banks provide loans to each other in the Prague interbank market (well-known examples of similar types of interest rates are e. g. LIBOR or EURIBOR).

The PRIBOR is fixed on a daily basis, generally in the morning. The CNB has its own rules for a fixing of reference interest rates[2]. The article 6 of these rules states the process of calculation of reference interest rates. To make long story short, the reference banks (there are 7 banks eligible to submit the quotations for the calculation) submit the quotations and the calculation agent (Czech Forex Club) calculates the mathematical arithmetic mean rounded to the nearest hundredth for different maturities (from overnight to 1 year).

3.1. Methodology

3.1.1. Concept of stationarity

Definition 1 (**Stationary Time Series**). A time series $\{x_t\}$ is said to be *strictly stationary* if the joint distribution of $\{r_{t_1}, \ldots, r_{t_k}\}$ is identical to

[1] Available on the CNB web page: http://www.cnb.cz/en/financial_markets/money_market/, accessed March 26, 2013.

[2] For more information see the document "Rules for reference banks and the calculation (fixing) of reference interest rates (PRIBID and PRIBOR)" from May 2006, available online: http://www.cnb.cz/en/financial_markets/regulations/, accessed March 26, 2013.

$\left\{r_{t_{1+t}}, \ldots, r_{t_{k+t}}\right\}$ for all t, where k is an arbitrary positive integer and $(t_1, \ldots, t_k)$ are positive integers. A time series $\{x_t\}$ is said to be *weakly stationary* if both mean of x_t and covariance between x_t and x_{t-l} are time-invariant:

$$\begin{aligned} \mathbb{E}\{x_t\} &= \mu, \\ \operatorname{var}\{x_t\} &= \gamma_0 < \infty, \\ \operatorname{cov}\{x_t, x_{t-l}\} &= \gamma_l. \end{aligned}$$

□

In other words, the stationarity requires a distribution of time series to be constant under a time shift; weak stationarity, which is assumed more often, requires only a fluctuation with a constant variation around a constant level. If a time series process is non-stationary, it is often difficult to analyze it by a simple model.

We need to care about stationarity for different reasons. The most important one is that non-stationary time series influences its behavior and properties; persistence of shocks will be infinite. Moreover, the standard assumptions and thus testing are not valid for non-stationary series.

In most cases, a non-stationary time series has a trend. Regressing a trending variable against another one, for example against time, leads to a regression we call a spurious. It suggests a strong statistical relationship where, in reality, no economic relationship may exist. What are the tests to reveal non-stationarity?

The first type of tests is an informal procedure. It consists of a visual identification of a mean and variance that are fixed in time. The second type is based on the fact that the value of the autocorrelation function of a stationary series falls as the number of lags becomes large. The Ljung-Box Q-statistics is tested against the null hypothesis that the autocorrelation coefficients are zero. Unit-root tests are the third type that try to estimate whether ρ in an $AR(1)$ process $y_t = \rho y_{t-1} + \varepsilon_t$ is strictly less than one or not. In the following text, all the tests are described.

Definition 2 (**Autocorrelation with lag k**). The k-th order autocorrelation coefficient is defined as

$$\rho_k = \frac{\operatorname{cov}\{x_t, x_{t-k}\}}{\operatorname{var}\{x_t\}} = \frac{\gamma_l}{\gamma_0}.$$

□

The autocorrelation function (ACF) at lag k describes the level of interdependency (correlation) between series values that are k intervals apart.

The autocorrelation is tested by the Portmanteau test with the null hypothesis $H_0 : \rho_k = 0$ against alternative $\neg H_0$, where ρ_k, $k = 1, \ldots, K$, represents autocorrelation of random error of the model for a lag k. Test statistics is

$$Q = T \cdot \sum_{i=k-1}^{K} \hat{\rho}_k^2,$$

with χ^2 distribution with $(K - p - q)$ degrees of freedom.

Another test is e. g. Ljung-Box test described by

$$LB = n \cdot (n + 2) \cdot \sum_{k=1}^{h} \frac{\hat{\rho}_k^2}{n - k},$$

where n is the number of observations, h is the number of lags under test, k is the current lag and $\hat{\rho}_k^2$ is the autocorrelation at the current lag. The null states that the data are independently distributed.

Example (**Random walk**)**.** The random walk is a time series y_t for which

$$y_t = y_{t-1} + \varepsilon_t,$$

where $\mathbb{E}\{\varepsilon_t\} = 0$, $\text{var}\{\varepsilon_t\} = \sigma_\varepsilon^2$ and $\mathbb{E}\{\varepsilon_t \varepsilon_s\} = 0$, for $t \neq s$. Even though $\mathbb{E}\{y_t\} = 0$, the random walk is not stationary, because $\text{var}\{y_t\} = t \cdot \sigma_\varepsilon^2$, i. e. variance is time-dependent. In order to make the random walk process stationary, we can first difference this process:

$$w_t = \Delta y_t = y_t - y_{t-1} = \varepsilon_t,$$

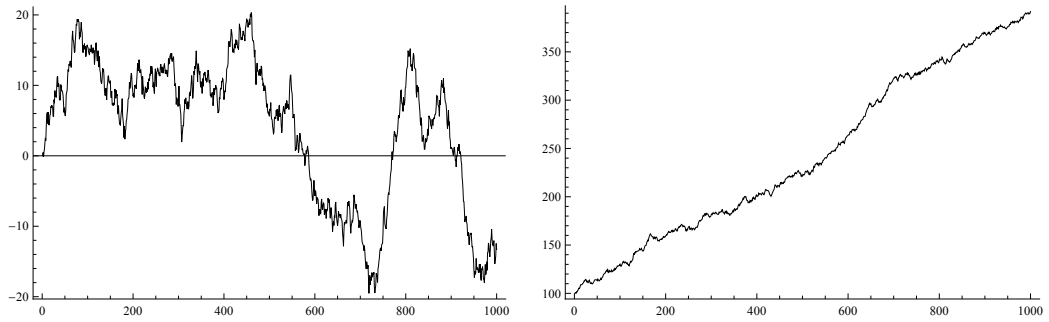
where w_t is a stationary process since ε_t is assumed to have a constant mean and variance, i. e. to be independent of time. The process for ε_t is an important building block of time series models and is referred to as a white noise process. The presented random walk is without a drift. If we want a drift in the process, the y_t series would be

$$y_t = \mu + y_{t-1} + \varepsilon_t,$$

where ε_t is a white noise and μ is a drift. Figure 3.1 presents the random walks without (a) and with (b) a drift. □

Definition 3 (**Testing for unit roots in a first order *AR* model**)**.** Let y_t is $AR(1)$ process, $y_t = \delta + \theta y_{t-1} + \varepsilon_t$, where $\theta = 1$ corresponds to a unit root. We will use the Dickey-Fuller test with the null hypothesis that $\theta = 1$, i. e. the

Fig. 3.1: Examples of random walk processes



(a) without a drift: $y_t = y_{t-1} + \varepsilon_t$ (b) with a drift: $y_t = \mu + y_{t-1} + \varepsilon_t$, $\mu = 0.25$

Source: Own simulations, Mathematica 9.0.1.0

null hypothesis is that the series y_t is not a stationary series. We define the Dickey-Fuller statistics as

$$DF = \frac{\hat{\theta} - 1}{SE\left(\hat{\theta}\right)},$$

where $SE\left(\hat{\theta}\right)$ denotes the usual standard error. The 1% and 5% critical values for the Dickey-Fuller test can be found e. g. in Verbeek (2008, p. 269). □

Testing for unit roots in higher order AR model is obtained by a extending the Dickey-Fuller test procedure. We then perform so-called augmented Dickey-Fuller tests (ADF tests).

Definition 4 (**Lag operator**)**.** The lag operator, denoted by L, is defined by

$$L^p x_t = x_{t-p},$$

with p being an integer. □

Definition 5 (**Lag polynomial**)**.** The polynomial

$$\Phi(L) = \left(1 - \rho_1 L - \rho_2 L^2 - \ldots - \rho_p L^p\right)$$

is called the lag polynomial. □

3.1.2. ARIMA

For modeling data series, we use two common concepts of conditional mean – the autoregressive model, AR, and the moving-average model, MA.

AR model

The $AR(p)$ process is described by

$$y_t = \mu + \sum_{i=1}^{p} \rho_i \cdot y_{t-i} + \varepsilon_t, \tag{3.1}$$

where p is the lag parameter of the observed variable, y_t is the random observed variable at time t depending on the previously realized values of y_{t-i}, ρ_i is the parameter, μ is the mean and ε_t the white noise.

We can write a general $AR(p)$ as

$$\Phi(L) y_t = \mu + \varepsilon_t,$$

where $\Phi(L)$ is a lag polynomial.

Proposition 1. *The $AR(p)$ process is stable (stationary) if the roots of the lag polynomial lie outside the unit circle, i. e. if all roots of the equation (3.1) are less than one in modulus.* □

MA model

The $MA(q)$ process is described by

$$y_t = \mu + \sum_{i=1}^{q} \theta_i \cdot \varepsilon_{t-i} + \varepsilon_t, \tag{3.2}$$

where q is the number of lags of the error term, y_t is the random observed variable depending on the previously realized values of error term ε_{t-i}, θ_i is the parameter, μ is the mean and ε_t is the white noise.

Equivalently, using the lag operator, $MA(q)$ process can be written as

$$y_t - \mu = \left(1 + \theta_1 L + \theta_2 L^2 + \ldots, \theta_q L^q\right) \varepsilon_t = \Theta(L) \varepsilon_t.$$

Proposition 2. *A $MA(q)$ is stationary for every sequence $\{\theta_n\}_{n=1}^{q}$.* □

$MA(q)$ models are always weakly stationary, because they are a finite linear combination of a white noise with $\mathbb{E}\{y_t\} = \mu$, .

Theorem 1. *The $MA(\infty)$ is stationary if the coefficients are absolute summable, i. e. if*

$$\sum_{i=0}^{\infty} |\theta_i| < \infty. \qquad \square$$

ARMA model

$ARMA$ model combines AR and MA models into a compact form, eq. (3.1) and (3.2), respectively. The $ARMA(p, q)$ process is given by

$$y_t = \mu + \sum_{i=1}^{p} \rho_i \cdot y_{t-i} + \sum_{i=1}^{q} \theta_i \cdot \varepsilon_{t-i} + \varepsilon_t. \tag{3.3}$$

$ARMA(p, q)$ model can be rewritten as

$$\Phi(L)\, y_t = \mu + \Theta(L)\, \varepsilon_t.$$

Proposition 3. *The $ARMA(p, q)$ model is stationary provided the roots of the $\Phi(L)$ polynomial lie outside the unit circle.* $\square$

ARIMA model

We are about to add a parameter d representing the order of integration.

Definition 6. A process is said to be integrated of order d, $I(d)$, if it becomes stationary after being differentiated d times. $\square$

$ARIMA(p, d, q)$ model written using a lag operator is

$$\Phi(L)\, \Delta^d y_t = \Theta(L)\, \varepsilon_t,$$

where Δ^d means that a series y_t has been differentiated $d-$times. If Δy_t is described by a stationary $ARMA(p, q)$ model, we say that y_t is described by an autoregressive integrated moving average model of order p, 1, q, or in short an $ARIMA(p, 1, q)$ model. If we need to differentiate a series $d-$times, then we speak about an $ARIMA(p, d, q)$ model.

3.1.3. ARCH family of models

As the financial data time series show heteroskedasticity, Akgiray (1989), a model dealing with conditional heteroskedasticity must be used. Bollerslev (1986) introduced the general autoregressive conditional heteroskedasticity, $GARCH$, model which is a generalization of the autoregressive conditional heteroskedasticity, $ARCH$, model originally presented by Engle (1982), the 2003 Nobel prize winner[3].

ARCH model

The $ARCH\,(q)$ model consists of a mean equation (y_t) and a variance equation (h_t):

$$\begin{aligned} y_t &= \varepsilon_t \sqrt{h_t} \\ h_t &= \alpha_0 + \sum_{i=1}^{q} \alpha_i \cdot \varepsilon_{t-i}^2, \end{aligned} \tag{3.4}$$

where q is the length of the $ARCH$ lags, ε terms are independent, standard normal variables with $\varepsilon \sim N\,(0, h_t)$, $\alpha_0 > 0$, $\alpha_i \geq 0$ and h stands for variance[4]. If $\sum_{i=1}^{q} \alpha_i < 1$, the process is weakly stationary with constant unconditional variance

$$\sigma^2 = \frac{\alpha_0}{1 - \sum_{i=1}^{q} \alpha_i}.$$

From (3.4), one can see that the $ARCH$ determines the error variance at time t according to the information known at time $t-1$, i.e. the value is conditional on past information. The $ARCH$ can deal with the inherent uncertainty associated with different forecast periods. The $ARCH$ therefore allows the variance to change over time and be predicted by past errors.

Engle proposed the Lagrange Multiplier test, the *ARCH-LM test*, to affirm the presence of the conditional heteroskedasticity. This test is proceeded

[3] The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2003 was shared by two econometricians. Robert F. Engle III received it "for methods of analyzing economic time series with time-varying volatility (ARCH)" . Clive W.J. Granger was acknowledged "for methods of analyzing economic time series with common trends (cointegration)". Source: http://www.nobelprize.org/, Accessed March 8, 2013.

[4] Generally, the variance is denoted by σ^2. Notation h is the standard notation for financial series. Further in the text, these two notations are considered to have the same meaning.

as follows (Engle 1982, p. 1000):

1. Run the OLS regression[5] and save residuals.
2. Regress the squared residuals on a constant and p lags and test TR^2 as a χ^2_p.

Under the null hypothesis, $\alpha_1 = \alpha_2 = \cdots = \alpha_p = 0$, i.e. no $ARCH$ effect. This test is already incorporated in almost every econometric software.

Choosing the best fitting model, we have to rely on our professional judgment and experience. There is no clear way what is the best model like. Generally speaking, we have information criteria or log-likelihood. We need to satisfy a parsimony, low information criteria or high log-likelihood and the estimated parameters should be significant.

GARCH model

The $GARCH$ extends the $ARCH$ in a way that allows for both lags in conditional variance and a more flexible lag structure. The $GARCH\,(p,q)$ is described as

$$\begin{aligned} \varepsilon &\sim N\,(0, h_t) \\ h_t &= \alpha_0 + \sum_{i=1}^{q} \alpha_i \cdot \varepsilon^2_{t-i} + \sum_{j=1}^{p} \beta_i \cdot h_{t-j}, \end{aligned} \tag{3.5}$$

where $p \geq 0$ and $q > 0$ are lengths of the $GARCH$ and the $ARCH$ terms, respectively, $\alpha_0 > 0, \alpha_i \geq 0, i = 1, \ldots, q$ and $\beta_j \geq 0, j = 1, \ldots, p$. For $p = 0$ the process reduces to the $ARCH\,(q)$ process.

The $GARCH\,(p,q)$ model is stationary with a finite variance if $\sum_{i=1}^{q} \alpha_i + \sum_{j=1}^{p} \beta_i < 1$. If this condition is not fulfilled, we should use an iterated $GARCH$, $IGARCH$, where we apply the substitution $\beta = (1 - \alpha)$ in eq. (3.5). The closer to 1 this summation is, the higher a persistence of shocks in volatility is.

Diagnostic checking of the fitted $GARCH$ model, the estimation should follow, as in the $ARCH$,

[5] Ordinary Least Squares regression

- ▷ the best model minimizes Akaike Information Criterion, *AIC*, Schwarz Information Criterion, *SIC*, or Bayesian Information Criterion, *BIC,*
- ▷ there should no longer be any significant volatility clustering,
- ▷ parsimony and significance of coefficients.

The $GARCH$ model as well as its extensions is very flexible and we can include external regressors relevant to the volatility modeling into either mean or variance or both equations. In practice, the $GARCH\,(1,1)$ specification often performs very well (Verbeek 2008, p. 299).

GARCH extensions

The $GARCH$ can deal with common financial data time series characteristics such as thick tails and volatility clustering but it has its disadvantages, Jánský & Rippel (2011). Therefore it is suggested to use different models that take into consideration asymmetries in volatility of return. The exponential GARCH, $EGARCH$, model by Nelson (1991) and the threshold GARCH, $TGARCH$, model by Zakoian (1994) belong to the most popular models.

The $TGARCH\,(1,1)$ is defined as

$$\sigma_t^2 = \omega + \gamma_1 u_{t-1}^2 + \gamma_1^- u_{t-1}^2 I_{(u_{t-1}<0)} + \beta_1 \sigma_{t-1}^2, \tag{3.6}$$

where $I_{(\cdot)}$ denotes an indicator function which equals 1 for past innovations with a negative effect. Asymmetric effect is covered by the $TGARCH$ model if $\gamma_1^- > 0$.

The $EGARCH\,(p,q)$ is defined as

$$\ln \sigma_t^2 = \bar{\omega}' z_t + \sum_{i=1}^{q} \left[\alpha_i \left(|\varepsilon_{t-i}| - \sqrt{2/\pi} \right) + \gamma_i \varepsilon_{t-i} \right] + \sum_{j=1}^{p} \beta_j \ln \left(\sigma_{t-j}^2 \right). \tag{3.7}$$

In estimating the central bank communication effect, I will follow the structure proposed by Horváth (2012):

1. Fitting $ARIMA$ model for the time series. Then check, whether the residuals resemble the white noise process. If they do, the model was chosen correctly.
2. Testing for the $GARCH$ effects presence in residuals from the $ARIMA$ model using the *ARCH-LM* test.

3. Estimating the *GARCH* model and plot the generated variance series against the residuals.

3.2. The data set

In the following section, I will describe the data set used in this thesis. I use EViews[6] for the data analysis and further for their modeling. The data were mainly downloaded from the CNB website as it is considered as the main source of information for financial markets for the period from January 2007 to December 2012. The data for the Czech 10-year bond yield were downloaded from the Stooq.com[7]. I have collected a total of 1496 observations of daily data.

The main interest is to investigate the effectiveness of central bank communication and therefore the use of daily data are justified (Jansen & De Haan 2006). The absorption of provided information in the communication takes time. Evans & Lyons (2005) provide evidence that currency markets are not responding to news instantaneously but it may take several days until the news are fully incorporated.

In the text below, I provide a basic description of the used data. `PRIBOR` and `Yield10Y` are the dependent variables, the remaining variables are explanatory. The description is given in tab. 3.1.

DEPENDENT VARIABLES:

$\texttt{PRIBOR}_t$ daily data on three-month PRIBOR, Prague InterBank Offered Rate. It is the interest rate at which banks provide loans to each other on the Czech interbank market.

$\texttt{Yield10Y}_t$ Czech 10 year bond yield

EXPLANATORY VARIABLES:

$\texttt{IR}_t$ dummy variable describing the release of the Inflation Report:

$$\texttt{IR}_t = \begin{cases} 1 & \text{on all days the Inflation Report is released,} \\ 0 & \text{otherwise.} \end{cases}$$

[6] EViews 6, Enterprise Edition - Jun 3, 2008 build.
[7] Available at http://www.stooq.com/q/?s=10czy.b.

$\texttt{minutes}_t$ dummy variable describing the munder certain circumstancesinutes:

$$\texttt{minutes}_t = \begin{cases} 1 & \text{on all days the minutes are released,} \\ 0 & \text{otherwise.} \end{cases}$$

$\texttt{comments}_t$ dummy variable showing whether there was a comment on the day or not. Comment is defined here as the oral or written expression of the member of the Bank Board concerning the interest rates, economic outlook, inflation or the exchange rate. These data come from the CNB website ("Media service – Interviews, articles" and "Media service – Speeches, conferences, seminars – Speeches"):

$$\texttt{comments}_t = \begin{cases} 1 & \text{on all days comment is made,} \\ 0 & \text{otherwise.} \end{cases}$$

$\texttt{direction}_t$ dummy variable capturing the direction[8] of the comment:

$$\texttt{direction}_t = \begin{cases} +1, & \text{positive comment,} \\ -1, & \text{negative comment,} \\ 0, & \text{otherwise.} \end{cases}$$

$\texttt{timing}_t$ describes the influence of the Bank Board comment that is stronger as the comment appears nearer the date of Bank Board meeting. A comment that occurs on the day of the Bank Board's meeting has value of 45, the comment from previous day has a value of 44, value of 43 on two days before the meeting and so on[9]. In consequence, comments closer to monetary policy meeting get greater weight.

In their paper, Rozkrut *et al.* (2007) used the comments of all members as well as separately by the governor. They also assigned different value to the statements (+1 for statements in favor of monetary policy or stronger economic outlook, and −1 for statements signaling easing of monetary policy or weaker economic outlook).

In this thesis, I do not just put unity value to the day of the relevant comment, but I also value the direction of the comment, i. e. whether it is a positive comment (+1), meaning enhancing the economic outlook, or whether it is a negative comment, meaning worsening of the situation (-1). I do not

[8] "Positive comment" represents the improved economic outlook or inclination of tightening monetary policy and "negative comment" represents the weaker economic outlook and inclination of easing monetary policy. I am aware that the coding of this variable is, to a certain extent, subjective and I therefore exclude this variable from some regression specifications to evaluate the stability of our results.

[9] The value of 45 is decided on the fact that the Bank Board's meetings are held eight times a year. There are 360 days a year, so $360 \div 8 = 45$.

Tab. 3.1: Descriptive statistics

	$\texttt{PRIBOR}_t$	$\texttt{Yield10Y}_t$	$\texttt{comments}_t$	$\texttt{minutes}_t$	$\texttt{timing}_t$	$\texttt{IR}_t$
Mean	2.13	4.04	0.11	0.04	3.98	0.02
Maximum	4.52	5.42	1.00	1.00	45.00	1.00
Minimum	0.50	1.84	0.00	0.00	0.00	0.00
Std. deviation	1.16	0.77	0.31	0.18	10.25	0.13
Skewness	0.62	-0.74	2.56	5.08	2.51	7.70
Kurtosis	1.90	3.29	7.53	26.81	7.94	60.35
Observations	1496	1496	1496	1496	1496	1496

Source: Own calculation

Tab. 3.2: Correlation matrix among communication variables

$\texttt{comments}_t$	$\texttt{minutes}_t$	$\texttt{timing}_t$	$\texttt{IR}_t$	
1.00	-0.01	0.67	0.15	$\texttt{comments}_t$
	1.00	-0.05	-0.02	$\texttt{minutes}_t$
		1.00	-0.01	$\texttt{timing}_t$
			1.00	$\texttt{IR}_t$

Source: Own computation

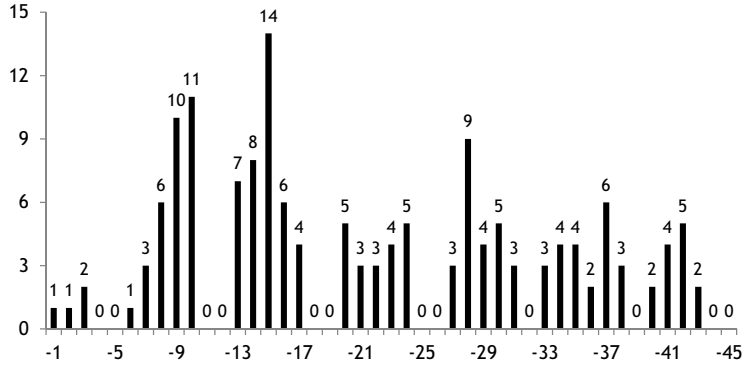
distinguish the comment according to who provided that comment (a regular member or the governor).

Contrary to Kohn & Sack (2003) or Reeves & Sawicki (2007), I am not modeling any surprise component of the communication. At the end of the Conclusion, there is a list of possible changes to the model and suggestions for further research.

Table 3.1 provides a descriptive statistics of key variables. Several issues are noteworthy. Czech central bank communication occurs on about every tenth day on average. Minutes occur more than monthly, as the frequency of monetary policy meeting is more than monthly (there are in average 8 Bank Board meetings a year). Inflation reports are published 4 times a year, approximately in the same period each year (February, May, August and November).

Table 3.2 provides the correlation between variables. We can see that there are no strong connections between variables. Correlations close to ± 1 represent strong relationships; correlations close to 0 mean small relationship. Almost all the correlation are close to zero. Only correlation between $\texttt{comment}_t$ and $\texttt{timing}_t$ is almost 0.67. This means that there is some positive correlation, indeed. But since the value is not close to $+1$, the relationship is not strong. Therefore, we are not tied up by the multicollinearity problems when

Fig. 3.2: Frequency of the CNB communication before the Bank Board meeting



Notes: Graph represents the number of $\texttt{comments}_t$ before the day of the Bank Board meeting. Legend to the graph: "-1" for a day before the meeting (Wednesday), "-2" for two days before the meeting (Tuesday), "-3" for three days before the meeting (Monday), "-4" and "-5" are four and five days before the meeting (Sunday and Saturday), respectively, etc.

Source: Own computation

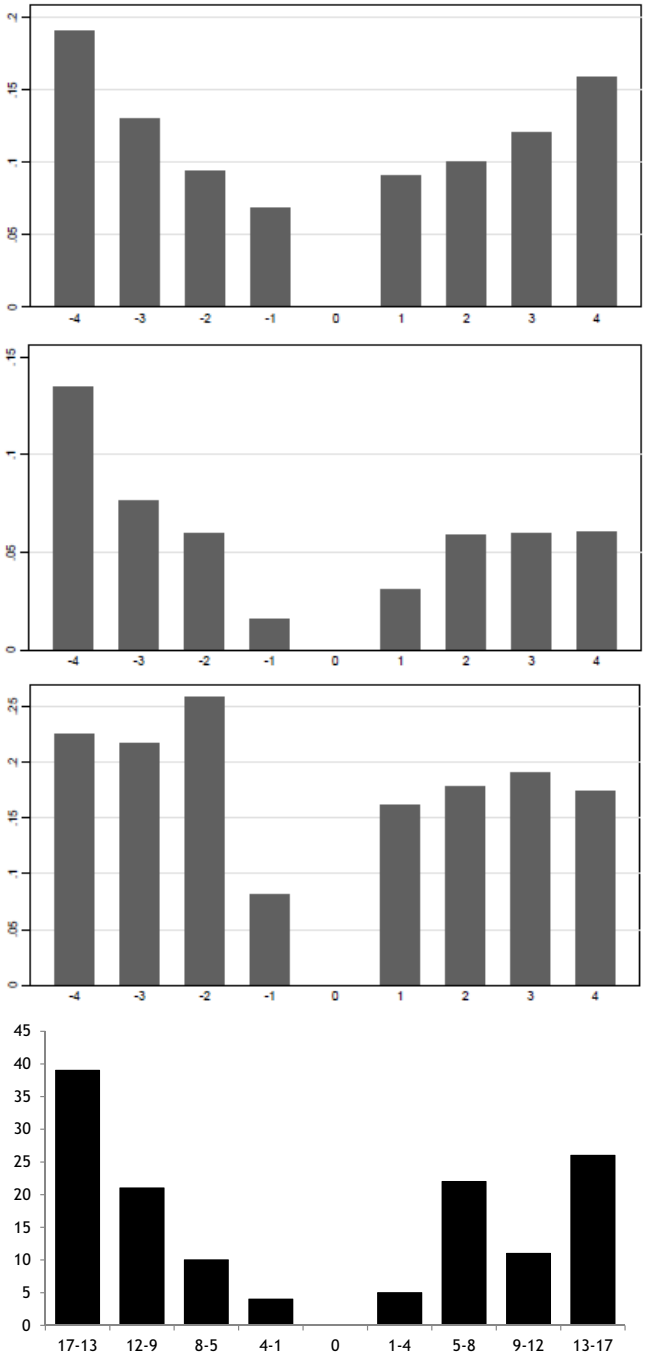
estimating the model.

Figure 3.2 presents the frequency of central bank communication. As the monetary policy meeting is typically held on Thursday, the results indicate that the frequency of communication is much lower in the week of the monetary policy meeting is held (see the frequencies on the days 1-3 in fig. 3.2). There is a rare communication during the weekend; occasionally there were some comments made during Sundays when a member of Bank Board was talking in a television discussion show "Otázky Václava Moravce"[10], but this happened mainly in 2009 during the crisis (3 comments in total). Another finding is that there were more comments about the economic outlook and reactions of rates to the economic crisis. The communication is most intense a week (days 6 – 10), two weeks (days 13–17) and three weeks (days 20–24) before the policy meeting.

This finding is analogous to the evidence of the Bank of England, European Central Bank and the U.S. Federal Reserve (see Ehrmann & Fratzscher 2007b), where communication is more common, as the meeting comes closer. On the other hand, in contrast to these central banks, the CNB communication is not frequent after the monetary policy meeting (days 30-45 in fig. 3.2). I suppose that this reflects the fact that the CNB puts more effort into explaining their interest rate decision and risk scenarios at the press conference just

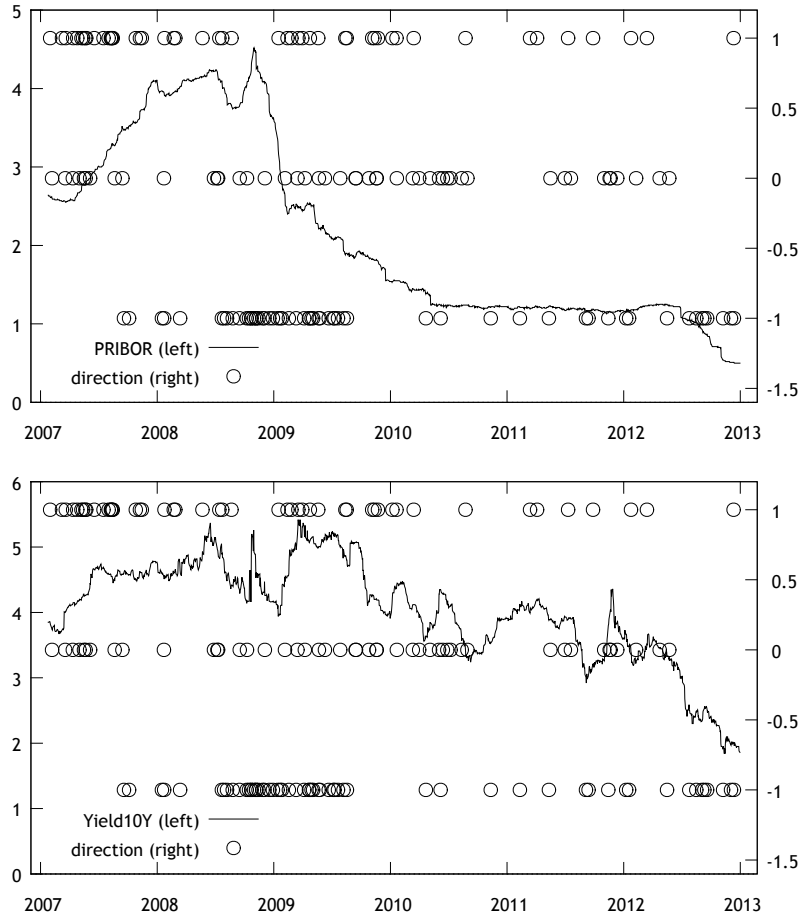
[10] The Czech discussion show broadcasted since January 2, 2005, every Sunday at 12 o'clock on ČT1 channel, available online: http://www.ceskatelevize.cz/ivysilani/1126672097-otazky-vaclava-moravce/

Fig. 3.3: Frequency of communication around meetings



Notes: The first three figures are from Ehrmann & Fratzscher (2005), last one is my own own computation. Horizontal axes in the first three pictures represent the aggregation of data from four days (i. e. bar "-1" contains days 4, 3, 2 and 1 before a meeting, "1" contains days of 1, 2, 3 and 4 after a meeting, and so on). Last figure states the day of the meeting ("0") and days before (descending order) and after (ascending order).

Fig. 3.4: Distribution of comments ($\texttt{direction}_t$)



Note: Comparison of the $\texttt{PRIBOR}_t$ and $\texttt{Yield10Y}_t$ curves with the variable $\texttt{direction}_t$, stating the direction of communication, i. e. the value of "1" represents the improved economic outlook or inclination of tightening monetary policy, "0" is the neutral statement, "−1" is weaker economic outlook or inclination of easing monetary policy. See text for further explanation.

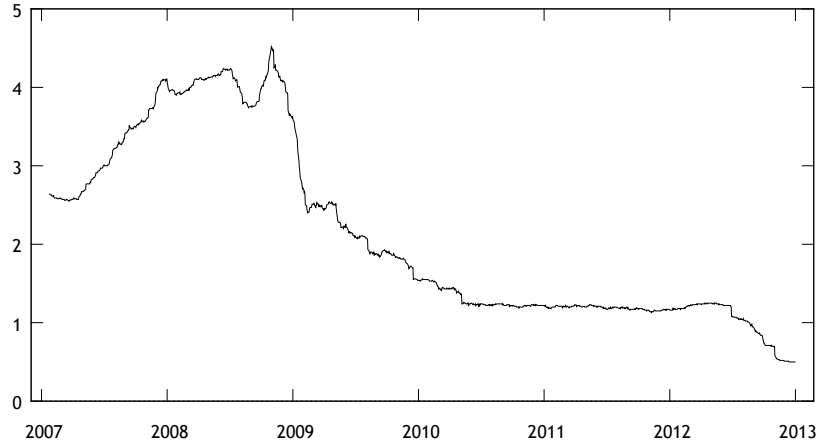
Source: Own processing

after the monetary policy meeting was held.

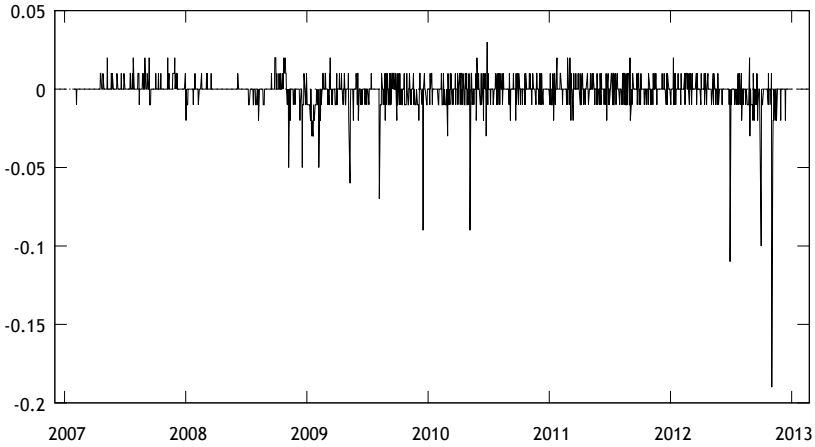
Another figure, fig. 3.3, represents the frequency of communication before and after the meeting of (from top) the Federal Reserve's FOMC, the Bank of England's MPC, the European Central Bank's Governing Council and the CNB's Bank Board. We can see that there is a common communication behavior of these four banks. They talk a lot approximately fifteen days before the meeting with the decreasing tendency as the meeting comes closer. On the other hand, there is a small frequency of talks in the following two weeks after the meeting.

Figure 3.4 provides an overview of the distribution about the monetary

Fig. 3.5: $\texttt{PRIBOR}_t$ plots

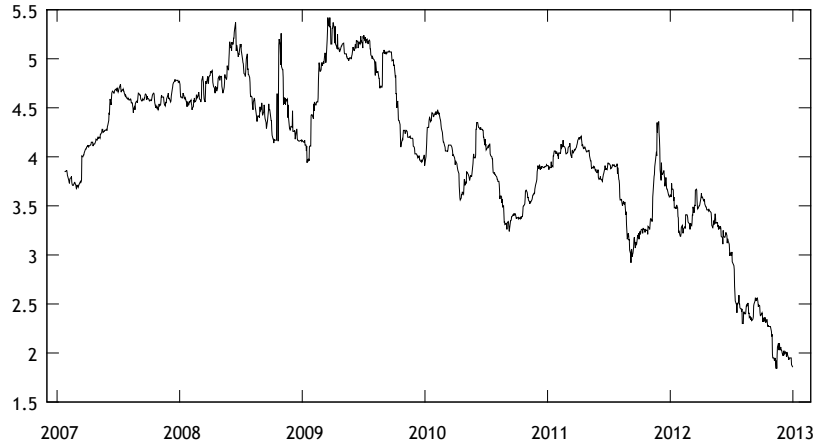


(a) Time series plot

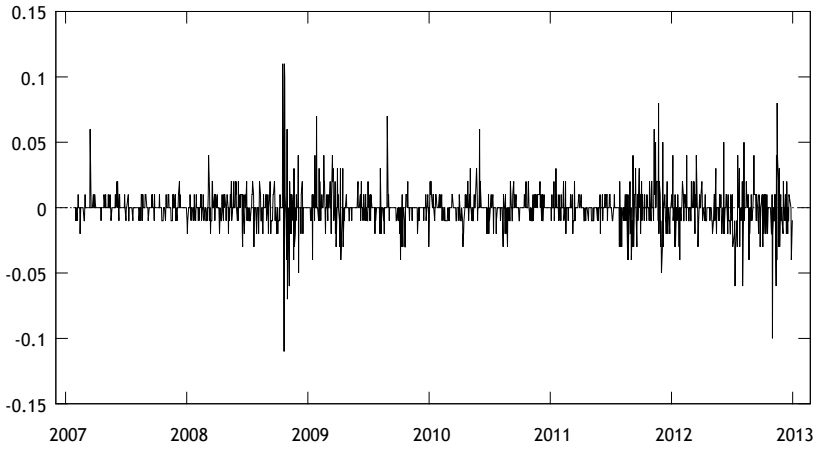


(b) Returns plot
Source: CNB's website

Fig. 3.6: `Yield10Y`$_t$ plots



(a) Time series plot



(b) Returns plot

Source: Stooq.com, http://www.stooq.com/q/?s=10czy.b

policy inclination and the economic outlook (variable $\texttt{direction}_t$) over the whole period of 2007 – 2012. The communication intensifies in the period of changes, specially in the period 2008 – 2009. On the other hand, the communication is low in periods of small or no changes, period 2010 – 2012.

Figures 3.5 a) and 3.6 a) show time series plots of $\texttt{PRIBOR}_t$ and $\texttt{Yield10Y}_t$, respectively. It is obvious that the series are not stationary from both the graphs. This finding is also confirmed by the Augmented Dickey-Fuller test with p-values of 0.59 and 0.52, respectively. Therefore I calculated the log returns[11]. These are shown on fig. 3.5 b) and 3.6 b). All the famous "stylized facts" are present on these returns plots, e. g. a volatility clustering or a leptokurtic distribution. ADF tests confirm the stationarity with p-values lower than 1 %. For complete tables of these tests see appendix B.

3.3. The model

In this section, I will firstly define the used models. I will try to provide an answer to what effect the Czech National Bank's communication has on the volatility of the interest rate.

It follows from the definition of our variables capturing the central bank communication that we focus on whether the central bank talk to the markets rather than on interpreting the content of its communication. Therefore, the central bank communication variables are included only in the variance equation and interest rate is assumed to follow random walk.

The central bank communication variables such as the dummy variable for the publication of inflation report do not affect the mean equation but only volatility equation. Clearly, adding these dummies into the mean equation makes no sense. However, it makes sense to include the variable $\texttt{direction}_t$ into the mean equation given the definition of the variable – communication good outlook for the economy is likely to increase the interest rate. This is a standard approach in the literature.

As it is also a standard approach in volatility modeling, I use the $GARCH$ model and its extensions. In the variance equations, I estimated different types of the CNB communication one by one, specifications (1) – (3), then their pairs, specifications (4) – (6). After that I estimated a whole model, specification (7).

[11] Log returns of variable X_t in time t are defined as $x_t = \log(X_t) - \log(X_{t-1})$.

Specification (8) is little different, there is a change in the mean equation, I have added the $\texttt{direction}_t$ variable, see its description above. The reasons for these model specifications (equations (1) – (8)) are given in the previous paragraph.

3.3.1. GARCH model

My baseline specification is the $GARCH\,(1,1)$ process for the interest rate return. This model is chosen due to the parsimony. I have also estimated the $GARCH$ models with higher lags, but I have not proved their significance. The model is therefore specified as follows:

$$\Delta r_t = \mu + \upsilon\,(\texttt{direction}_t) + \xi_t, \tag{3.8}$$

$$\sigma_t^2 = \gamma + \alpha\xi_{t-1}^2 + \beta\sigma_{t-1}^2 + \phi_i \sum_{i=1}^{n} CB_{it} + \rho IR_t, \tag{3.9}$$

where r_t denotes the log of interest rate, Δr_t is therefore the first difference of logarithms. The variable $\texttt{direction}_t$ is added in the mean equation (3.8) only in one case, specification (8) in table A.3. The error term, ξ_t, of the mean equation (3.8) is assumed to have a conditional variance, σ_t^2, specified by variance equation (3.9). The conditional variance equation (3.9) includes the constant, γ , the $ARCH$ term, ξ_{t-1}, and the $GARCH$ term, σ_{t-1}^2 and the variables capturing the effect of central bank communication, $\texttt{CB}_{it}$. The model is estimated via maximum likelihood using the BHHH algorithm for optimization, and is estimated for all business days in the sample, i. e. also for days when neither Inflation report is issued not the CNB communication is made[12].

The $\texttt{IR}_t$ variable in equation (3.9) is also a mean of the CNB communication and should therefore be a part of a bundle of CB variable. Nevertheless, it is separated to show (and draw your attention) that I use the Inflation report in all the regressions but the variables contained in the CB variable change in different specification and make different combinations (see e. g. tab. A.3). This also holds for model extensions, equations (3.11) and (3.13).

[12] However, no communication from central bank might also send some kind of a signal to financial markets.

3.3.2. EGARCH model

Many authors (for example see Connolly & Kohler 2004, Ehrmann & Fratzscher 2007a, Ehrmann & Sondermann 2012 or Rozkrut *et al.* 2007) use the exponential $GARCH$ ($EGARCH$) model in their research studies on the reaction of financial variables to monetary policy communication. The $EGARCH\,(1,1)$ model is a sufficient model to address the non-normality of the data and asymmetries in returns.

My $EGARCH\,(1,1)$ is modified model proposed by Nelson (1991). Similarly to the $GARCH\,(1,1)$, eq. (3.8) and (3.9), the mean and the variance equations are modified. My model is therefore specified as follows:

$$\begin{aligned} \Delta r_t &= \mu + \upsilon\left(\texttt{direction}_t\right) + \xi_t, && (3.10)\\ \log\left(\sigma_t^2\right) &= \kappa + \alpha\left|\frac{\xi_{t-1}}{\sqrt{\sigma_{t-1}^2}}\right| + \gamma\frac{\xi_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \beta\log\left(\sigma_{t-1}^2\right) \\ &\quad + \varphi_i\sum_{i=1}^{n} CB_{it} + \tau IR_t, && (3.11) \end{aligned}$$

where r_t denotes the log of interest rate, $\xi_t\,|\Psi_{t-1} \sim N\,(0,\sigma_t^2)$, Ψ_{t-1} is the information set at time $t-1$, and the variables capturing the effect of central bank communication, $\texttt{CB}_{it}$. The $\texttt{IR}_t$ is a dummy variable representing the release of the Inflation report.

3.3.3. TGARCH model

Another way how to introduce asymmetric effects is to set the threshold $GARCH$ ($TGARCH$) model. In the context of this thesis, the $TGARCH$ model is specified as follows:

$$\begin{aligned} \Delta r_t &= \mu + \upsilon\left(\texttt{direction}_t\right) + \xi_t, && (3.12)\\ \sigma_t^2 &= \alpha + \beta_1\xi_{t-1}^2 + \beta_2\xi_{t-1}^2 I_{(\xi_{t-1}<0)} + \gamma\sigma_{t-1}^2 \\ &\quad + \delta_i\sum_{i=1}^{n} CB_{it} + \pi IR_t, && (3.13) \end{aligned}$$

where $I_{(.)} = 1$ if $\xi_{t-1} < 0$ and 0 otherwise. In this model, good news, $\xi_{t-1} > 0$, and bad news, $\xi_{t-1} < 0$, have different effects on the conditional variance. The good news has an impact of β_1, while the bad news has an impact of $\beta_1 + \beta_2$. If $\beta_2 > 0$, the bad news increases volatility.

3.4. 3M PRIBOR

First of all, I will try to analyze the effect of the CNB communication on three-month PRIBOR rate by seeking an answer to a question on what effect the CNB's communication has on the volatility of the returns of 3M PRIBOR. The communication is believed to have a significant effect on the volatility because the volatility should be higher during the days when the central bank is talking (Blinder *et al.* 2008, p. 29). For the analysis of the Czech 10-year bond yield, see the next section.

Communication is a signal that contains news. For the transmission of the signal from central bank to its recipients, see fig. 2.1. There are two types of the signals. Regular Bank Board meetings and regular publications (e. g. Inflation report) have a little impact on the volatility of asset returns since its publication date is known to public. On the other hand there are speeches or comments which are flexible in both timing and content (Ehrmann & Fratzscher 2007b).

As it has already been mentioned, I am modeling the occurrence of the communication, not the content nor the importance of a person saying it. The communication is described by the variable $\texttt{minutes}_t$, about a 1000 words description of the Bank Board's meetings. They are released eighth day after the meeting. $\texttt{Comments}_t$ are another stream; they are less official way of expressing opinions of the members of the Bank Board in the period between monetary policy meetings.

One should control for all other possible sources of volatility in order to ensure that the volatility is caused by communication itself and not only by the content of the communication (Blinder *et al.* 2008). My control variable is $\texttt{IR}_t$, dummy variable capturing the release of the most important publication – release of the Inflation Report – that contains not only the past behavior presented on fan charts but also an economic outlook.

For the description of the PRIBOR reference rate, see the beginning of

this chapter. Descriptive statistics for it as well as other variables are presented in tab. 3.1. The time series and the returns plots are depicted on fig. 3.5. The 3M PRIBOR reference rate will be tested in the following subsections using the $GARCH\,(1,1)$, the $EGARCH\,(1,1)$ and the $TGARCH\,(1,1)$ models, described above.

3.4.1. GARCH model

The results are in the tab. A.3. Note that coefficients for the CNB communication (ϕ_1, ϕ_2 and ϕ_3) are multiplied by 10^5. I can conclude that Czech National Bank communication tends to decrease interest rate volatility. This is in line with the findings of Rozkrut *et al.* (2007) or Ehrmann & Sondermann (2012) who studied the communication and its effect in different central banks (see chapter 1).

Almost all the coefficients are significant on at least 10% confidence level, except from β's in specification (2) – (5). Publication of Inflation report, $\texttt{IR}_t$, lowers the volatility in all the studied volatility equations. The effect of Bank Board members' $\texttt{comments}_t$ is not clear, as the sign of coefficient differs across the specifications. $\texttt{Minutes}_t$ have also significantly calming effect on volatility since all its coefficients are negative.

The communication closer to the Bank Board meeting has a more calming effect on the volatility. This is in accordance to Ehrmann & Fratzscher (2007b), who study the timing of Bank of England, European Central Bank and the U.S. Federal Reserve Bank communication. Despite their different definition of timing (they used various dummy variables and interacted them with the model coefficients), they found that the timing is informative for a whole variety of financial assets, including the interest rates or exchange rate.

If we have a look at specification (8), the model is changed by adding the $\texttt{direction}_t$ variable into the mean equation (3.10), following Rozkrut *et al.* (2007). You can see that this does not change the results dramatically. All the coefficients have the same signs as in previous specifications. $\texttt{Minutes}_t$, $\texttt{timing}_t$ and $\texttt{IR}_t$ are decreasing the volatility, but the $\texttt{comments}_t$ are increasing it. The coefficient of $\texttt{direction}_t$ is significant with the value of 0.002614. This represents the tiny increase in the value of PRIBOR interest rate returns.

3.4.2. EGARCH model

The estimated $EGARCH$ model is defined by the mean equation (3.10) and the variance equation (3.11). It is estimated via maximum likelihood using the BHHH algorithm.

The results are in table A.2. The results are different from the previous ones, however the message remains the same – the communication of the CNB decreases the volatility. All the coefficients are significant on 1 % confidence level. The release of the Inflation report, $\texttt{IR}_t$, calms down the volatility as well as $\texttt{minutes}_t$.

On the other hand, the $\texttt{comments}_t$ increase the volatility. The effect of $\texttt{timing}_t$ is unclear. We can say that it decreases the volatility since it has negative value, when accompanied by $\texttt{comments}_t$ and $\texttt{minutes}_t$.

In specification (8), there is also a new variable in the mean equation (3.10), the $\texttt{direction}_t$ variable is added. This coefficient is not significant and the results do not change. All the variables have the same signs as before, they are all significant in the variance equation.

3.4.3. TGARCH model

The $TGARCH$ model estimates the asymmetric effect of the bad news and the good news; the bad news has higher effect on volatility, see the description of the $TGARCH$ mean and variance equations (3.12) and (3.13), respectively.

The results are in the table A.3. The asymmetric effect is captured whenever the coefficient β_2 is significantly bigger than 0. From this table, we see that β_2 is smaller than 0 in all the cases and it is not significant in 5 specifications out of 8. Therefore we can conclude that the $TGARCH$ model does not improve our estimates, and our data do not seem to have a significant asymmetry effect.

3.5. Czech 10Y Bond Yield

Mohanty (2002) states that the Czech government bonds with the 10 year maturity are the most important ones. Therefore, this section analyzes the impact of the CNB communication on the log returns of the Czech 10-year

bond yield. The table 3.1 provides the descriptive statistics. The time series and the returns plots are shown on fig. 3.6. For the analysis of the 3M PRIBOR reference rate see the previous section.

The CNB can influence government bonds in two ways. Firstly, even if the secondary market for bonds is not liquid, the CNB can influence the short-term rate by its communication (we have already proved it, see the tab. A.1, A.2 and A.3 and its description in the section above). The long-rates are then influenced via some transmission mechanism. Second, in case of liquid markets, like the Czech market, the influence is obvious. Moreover, since 2011, there is the MTS (Mercanto Telematico Secondario) platform in the Czech Republic which aims to enhance the liquidity and the transparency on the secondary market for the Czech government bonds.

I will use the $GARCH\,(1,1)$, the $EGARCH\,(1,1)$ and the $TGARCH\,(1,1)$ models. Their description is given above. I have analyzed different combinations of the described CNB communications. Specification (8) changes the mean equations by adding of the variable $\texttt{direction}_t$. The empirical results are printed in tables A.4, A.5 and A.6, respectively. The explanations of the results are provided in the subsections below.

3.5.1. GARCH model

The results are in table A.4. The coefficients representing the CNB communication are multiplied by 10^5. The sign of $\texttt{minutes}_t$ is negative in almost all cases (apart from the specification (4)). This means that the release of $\texttt{minutes}_t$ lowers the volatility. `Comments`, on the other hands, are significantly positive, meaning that the provision of any verbal or written comment increases the volatility.

The CNB manages to lower the volatility, ceteris paribus, by the $\texttt{timing}_t$ of its comments, i. e. a comment closer to the monetary policy meeting has a calming effect. than the decrease given by its timing. The release of the Inflation report also decreases the volatility of returns.

When we have a look at the specification (8), i. e. with the change in the mean equation, we can see that all the variables in the variance equation are significant, but the variable $\texttt{direction}_t$ is not significant. This is not the case in the analysis of the 3M PRIBOR, tab. A.1, where this variable is significantly positive, but very low.

3.5.2. EGARCH model

Table A.5 provides the empirical results. All the coefficients are significant on 99 % confidence level. The results are not the same as the 3M PRIBOR, tab. A.2. The most striking result is the positive coefficient of $\texttt{minutes}_t$.

$\texttt{Minutes}_t$ and $\texttt{comments}_t$ are increasing the volatility. In case of $\texttt{minutes}_t$, this is in contradiction to the already estimated models, where we have seen that $\texttt{minutes}_t$ are significantly decreasing the volatility. Closer comments to a monetary policy meeting have a calming effect as well as the release of Inflation Reports.

The specification (8) with the change in the mean equation does not change our model. Our predicted values of the coefficients do not change; when comparing with the specification (7), i. e. with the same variance equation but with no change in the mean equation, all the coefficients are very similar.

3.5.3. TGARCH model

Once again, we are interested in the sign and the significance of the β_2 coefficient. As it can be seen from the results, tab. A.6, β_2 is significant in all the equations with the positive sign. This means that there is a response to the bad news higher than to the good ones. The *TGARCH* model improves our results.

The results are quite similar to the previous ones. $\texttt{Comments}_t$ have a significantly positive impact on the volatility. $\texttt{IR}_t$ and $\texttt{timing}_t$ have a calming effect on the volatility. This reflects the theoretical thinking about central banks' talks.

The coefficients for $\texttt{minutes}_t$ have different signs. When there is no other variable included, specification (1), and when there is a change in the mean equation, specification (8), the $\texttt{minutes}_t$ have a negative impact. In all other specifications, the coefficient is positive. I tend to the opinion that minutes should have a negative impact. This comes from the fact that there is always another kind of news that accompany the release of minutes.

Conclusion

Over the last two decades, communication has become an important feature of monetary policy. In the previous text, I have summarized the ever-growing literature that gives clear message: communication is an important and powerful part of central bank's toolkit. Why is it so? Central banks' talks have an ability to move financial markets, to enhance the predictability of monetary policy decisions, and it possibly helps to reach macroeconomic objectives of central banks.

As I also discussed, there are a lot of different strategies how, by what means central banks can communicate with professional and broad public and why it communicates. One can therefore ask what constitutes an optimal communication strategy. The answer to this question is not easy and authors agree that there is hardly any optimal one. I have discussed different communication strategies.

This thesis mainly refers to the Czech National Bank. I have described the CNB's primary objective, the price stability, as well as other goals and tasks. I focus on the communication channels the CNB uses to share the main information. Lastly, I discuss its policy instruments.

The core of this thesis is the analysis of volatility of the interest rate caused by the communication. I have created a unique database of dummy variables capturing the release of Inflation reports, the Bank Board meetings, minutes and comments provided by the Bank Board members. I have also shown the communication pattern; the closer the next Bank Board meeting, the higher the communication. To model the volatility of interest rates, 3M PRIBOR rate, and the government bond yield of the Czech 10-year bond yield, I used the $GARCH\,(1,1)$, the $EGARCH\,(1,1)$ and the $TARCH\,(1,1)$ models with the dummy variables, described in the text.

My findings are as follows. I have found that the CNB communication

tends to decrease the volatility of interest rate, i. e. this supports the view that the central bank aims to decrease the noise in the financial markets. The timing of the communication also matters. It is clear from the analysis that the CNB does a great job, since its communication timing is decreasing the volatility. There is not a clear pattern concerning comments. This can be explained by the fact that listeners may not be sure about the content of the comment.

This analysis can be further extended. As mentioned in the text, one can play a little with the data set. There is a possibility to incorporate the division of who provided that comment; if it is a regular member or the governor. It is believed that the governor has higher voice and can therefore influence market expectations. Another option is to code the comments according to whether they are related to monetary policy, economic outlook etc. Last but not least, one can also provide variables capturing the position of the comment. I mean for example the page in the newspapers on which the comment appeared, or assign different values if the comment is in the morning radio news or in the evening ones.

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Appendix A
Regression results

See the following pages for the GARCH analysis results.

Tab. A.1: GARCH: The effects of the CNB communication on PRIBOR

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
μ	-0.00***	-0.00***	-0.00***	-0.00***	-0.00***	-0.00***	-0.00***	-0.00***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$\texttt{direction}_t$								0.00***
								[0.00]
γ	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
α	0.45***	0.82***	0.35***	0.79***	0.62***	0.31***	0.35**	0.37***
	[0.03]	[0.03]	[0.03]	[0.02]	[0.04]	[0.03]	[0.03]	[0.03]
β	0.28***	-0.01	0.07	-0.00	0.05	0.30***	0.24***	0.32***
	[0.03]	[0.01]	[0.07]	[0.02]	[0.04]	[0.04]	[0.06]	[0.04]
$\phi_1\,(\texttt{minutes}_t)$	-15.9***			-8.09***		-14.5***	-15.1***	-13.6***
	[0.00]			[0.00]		[0.00]	[0.00]	[0.00]
$\phi_2\,(\texttt{comments}_t)$		-1.80***		1.9***	3.70***		4.52***	3.31***
		[0.00]		[0.00]	[0.00]		[0.00]	[0.00]
$\phi_3\,(\texttt{timing}_t)$			-0.36***		-0.33***	-0.27***	-0.41***	-0.36***
			[0.00]		[0.00]	[0.00]	[0.00]	[0.00]
$\rho\,(\texttt{IR}_t)$	-6.06***	-10.9***	-14.9**	-9.58***	-13.1***	-13.7***	-16.1***	-15.9***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
AIC	-6.21	-6.47	-6.20	-6.53	-6.38	-6.23	-6.26	-6.28
N	1495	1495	1495	1495	1495	1495	1495	1495

Notes: Standard errors are shown in brackets below the coefficients. AIC is Akaike information criterion. ***, ** and * denote significance at 99 %, 95 % and 90 %, respectively. The value of ϕ_1, ϕ_2, ϕ_3 and ρ are multiplied by 10^5.

Tab. A.2: EGARCH: The effects of the CNB communication on PRIBOR

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
μ	-0.00	-0.00*	-0.00	-0.00*	-0.00	0.00	-0.00	-0.00
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$\texttt{direction}_t$								0.00
								[0.00]
κ	-2.00***	-3.25***	-3.02***	-3.16***	-3.27***	-0.14***	-3.18***	-3.18***
	[0.07]	[0.09]	[0.11]	[0.09]	[0.13]	[0.02]	[0.13]	[0.14]
α	0.49***	0.80***	0.76***	0.78***	0.78***	0.07***	0.74***	0.75***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
γ	-0.26***	-0.42***	-3.40***	-0.39***	-0.40***	-0.02***	-0.35***	-0.34***
	[0.02]	[0.02]	[0.03]	[0.02]	[0.03]	[0.01]	[0.03]	[0.03]
β	0.81***	0.71***	0.73***	0.72***	0.70***	0.98***	0.71***	0.71***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.00]	[0.01]	[0.01]
$\varphi_1\,(\texttt{minutes}_t)$	-0.92***			-0.67***		-1.01***	-0.81***	-0.81***
	[0.12]			[0.14]		[0.06]	[0.14]	[0.15]
$\varphi_2\,(\texttt{comments}_t)$		0.57***		0.55***	0.69***		0.74***	0.73***
		[0.04]		[0.04]	[0.06]		[0.06]	[0.06]
$\varphi_3\,(\texttt{timing}_t)$			0.01***		-0.01***	-0.00***	-0.01***	-0.01***
			[0.00]		[0.00]	[0.00]	[0.00]	[0.00]
$\tau\,(\texttt{IR}_t)$	-0.69***	-1.28***	-1.03**	-0.98***	-1.43***	-0.69***	-1.17***	-1.20***
	[0.20]	[0.21]	[0.19]	[0.23]	[0.21]	[0.10]	[0.25]	[0.25]
AIC	-6.69	-6.71	-6.68	-6.71	-6.71	-6.77	-6.72	-6.72
N	1495	1495	1495	1495	1495	1495	1495	1495

Notes: Standard errors are shown in brackets below the coefficients. AIC is Akaike information criterion. ***, ** and * denote significance at 99 %, 95 % and 90 %, respectively.

Tab. A.3: TARCH: The effects of the CNB communication on PRIBOR

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
μ	-0.00*	-0.00*	-0.00*	-0.00*	-0.00***	-0.00	-0.00	-0.00*
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$\texttt{direction}_t$								0.00**
								[0.00]
α	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
β_1	1.04***	0.85***	0.45***	0.94**	0.55***	0.34***	0.39***	0.48***
	[0.04]	[0.06]	[0.05]	[0.05]	[0.05]	[0.04]	[0.04]	[0.05]
β_2	-0.17*	-0.39***	-0.08	-0.26***	-0.10	-0.00	-0.02	-0.07
	[0.09]	[0.09]	[0.08]	[0.10]	[0.08]	[0.07]	[0.08]	[0.43]
γ	0.00	-0.02***	-0.01***	-0.00	-0.01	0.33***	0.26***	0.24***
	[0.01]	[0.00]	[0.00]	[0.01]	[0.03]	[0.02]	[0.04]	[0.05]
$\delta_1\,(\texttt{minutes}_t)$	-3.71***			-7.91***		-14.8***	-15.4***	-14.7***
	[0.00]			[0.00]		[0.00]	[0.00]	[0.00]
$\delta_2\,(\texttt{comments}_t)$		0.71**		1.95***	3.96***		4.58***	3.68**
		[0.00]		[0.00]	[0.00]		[0.00]	[0.00]
$\delta_3\,(\texttt{timing}_t)$			-0.36***		-0.42***	-0.26***	-0.40***	-0.30***
			[0.00]		[0.00]	[0.00]	[0.00]	[0.00]
$\tau\,(\texttt{IR}_t)$	-4.10***	-13.9***	-14.3**	-9.43***	-15.2***	-12.6***	-14.9***	-14.4***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
AIC	-6.23	-6.37	-6.23	-6.54	-6.25	-6.22	-6.	-6.29
N	1495	1495	1495	1495	1495	1495	1495	1495

Notes: Standard errors are shown in brackets below the coefficients. AIC is Akaike information criterion. ***, ** and * denote significance at 99 %, 95 % and 90 %, respectively. The value of δ_1, δ_2, δ_3 and τ are multiplied by 10^5.

Tab. A.4: GARCH: The effects of the CNB communication on 10Y bond

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
μ	-0.00	0.00	0.00	0.00	-0.00	0.00	0.00	0.00
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$\texttt{direction}_t$								0.00
								[0.00]
γ	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00	0.00***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
α	0.13***	0.08***	0.01***	0.08***	0.08***	0.13***	0.12***	0.13***
	[0.02]	[0.01]	[0.01]	[0.01]	[0.01]	[0.02]	[0.02]	[0.02]
β	0.74***	0.90***	0.90***	0.91***	0.90***	0.75***	0.76***	0.74***
	[0.02]	[0.01]	[0.01]	[0.01]	[0.00]	[0.03]	[0.02]	[0.02]
$\phi_1\,(\texttt{minutes}_t)$	-14.0***			2.48***		-21.3***	-14.8***	-15.3***
	[0.00]			[0.00]		[0.00]	[0.00]	[0.00]
$\phi_2\,(\texttt{comments}_t)$		0.40***		0.54**	1.08***		11.6***	12.2***
		[0.00]		[0.00]	[0.00]		[0.00]	[0.00]
$\phi_3\,(\texttt{timing}_t)$			-0.03***		-0.04***	0.03	-0.21***	-0.22***
			[0.00]		[0.00]	[0.00]	[0.00]	[0.00]
$\rho\,(\texttt{IR}_t)$	-0.16	-1.56***	-14.9	-1.32*	-2.35***	-1.30	-4.94***	-4.61***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
AIC	-5.88	-5.95	-5.95	-5.95	-5.95	-5.74	-5.80	-5.80
N	1495	1495	1495	1495	1495	1495	1495	1495

Notes: Standard errors are shown in brackets below the coefficients. AIC is Akaike information criterion. ***, ** and * denote significance at 99 %, 95 % and 90 %, respectively. The value of ϕ_1, ϕ_2, ϕ_3 and ρ are multiplied by 10^5.

Tab. A.5: EGARCH: The effects of the CNB communication on 10Y bond

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
μ	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$\texttt{direction}_t$								0.00
								[0.00]
κ	-0.24***	-0.43***	-0.34***	-0.31***	-0.47***	-0.25***	-0.38***	-0.39***
	[0.02]	[0.04]	[0.02]	[0.03]	[0.04]	[0.02]	[0.04]	[0.04]
α	0.16***	0.20***	0.18***	0.17***	0.20***	0.16***	0.19***	0.19***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
γ	-0.04***	-0.05***	-0.04***	-0.05***	-0.04***	-0.04***	-0.04***	-0.04***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
β	0.98***	0.97***	0.97***	0.98***	0.96***	0.98***	0.97***	0.97***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.00]
$\varphi_1\,(\texttt{minutes}_t)$	0.45***			0.41***		0.45***	0.32***	0.32***
	[0.08]			[0.08]		[0.08]	[0.09]	[0.00]
$\varphi_2\,(\texttt{comments}_t)$		0.11***		0.08***	0.29***		0.24***	0.25***
		[0.02]		[0.02]	[0.04]		[0.03]	[0.09]
$\varphi_3\,(\texttt{timing}_t)$			-0.00*		-0.01***	-0.00	-0.01***	-0.01***
			[0.00]		[0.00]	[0.00]	[0.00]	[0.00]
$\tau\,(\texttt{IR}_t)$	-0.16***	-0.02***	-0.04**	-0.16**	-0.21***	-0.18**	-0.29***	-0.29***
	[0.06]	[0.07]	[0.8]	[0.07]	[0.07]	[0.07]	[0.07]	[0.07]
AIC	-5.96	-5.96	-5.96	-5.96	-5.97	-5.96	-5.97	-5.97
N	1495	1495	1495	1495	1495	1495	1495	1495

Notes: Standard errors are shown in brackets below the coefficients. AIC is Akaike information criterion. ***, ** and * denote significance at 99 %, 95 % and 90 %, respectively.

Tab. A.6: TARCH: The effects of the CNB communication on 10Y bond

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
μ	0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$\texttt{direction}_t$								0.00
								[0.00]
α	0.00***	0.00***	0.00***	0.00**	0.00***	0.00***	0.00**	0.00***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
β_1	0.1***	0.04***	0.04***	0.04***	0.04***	0.04***	0.04***	0.07***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.05]	[0.00]	[0.00]	[0.01]
β_2	0.07**	0.07***	0.07***	0.06***	0.06***	0.06***	0.06***	0.12***
	[0.03]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.03]
γ	0.74	0.92***	0.91***	0.93***	0.91***	0.92***	0.93***	0.76***
	[0.01]	[0.01]	[0.00]	[0.01]	[0.01]	[0.01]	[0.01]	[0.02]
$\delta_1\,(\texttt{minutes}_t)$	-21.9***			2.82***		1.94***	3.72***	-14.3**
	[0.00]			[0.00]		[0.00]	[0.00]	[0.00]
$\delta_2\,(\texttt{comments}_t)$		0.09		0.34*	0.07**		1.10***	13.3**
		[0.00]		[0.00]	[0.00]		[0.00]	[0.00]
$\delta_3\,(\texttt{timing}_t)$			-0.02***		-0.03***	-0.02***	-0.03***	-0.19***
			[0.00]		[0.00]	[0.00]	[0.00]	[0.00]
$\tau\,(\texttt{IR}_t)$	-0.49	-0.26	-0.38	0.00	-1.08	-0.05	-0.65	-3.17***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
AIC	-5.76	-5.96	-5.96	-5.96	-5.96	-5.96	-5.96	-5.81
N	1495	1495	1495	1495	1495	1495	1495	1495

Notes: Standard errors are shown in brackets below the coefficients. AIC is Akaike information criterion. ***, ** and * denote significance at 99 %, 95 % and 90 %, respectively. The value of δ_1, δ_2, δ_3 and τ are multiplied by 10^5.

Appendix B

Software output

Augmented Dickey-Fuller Unit Root Test for `PRIBOR`

Null Hypothesis: PRIBOR has a unit root			
Exogenous: Constant, Linear Trend			
Lag Length: 2 (Automatic based on SIC, MAXLAG=23			
		t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		-2.014102	0.5926
Test critical values:	1% level	-3.964211	
	5% level	-3.412827	
	10% level	-3.128397	

KPSS Test for `PRIBOR`

Null Hypothesis: PRIBOR is stationary		
Exogenous: Constant, Linear Trend		
Bandwidth: 31 (Newey-West using Bartlett kernel)		
		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.432564
Asymptotic critical values:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

Augmented Dickey-Fuller Unit Root Test for `ld_PRIBOR`

Null Hypothesis: ld_PRIBOR has a unit root			
Exogenous: Constant, Linear Trend			
Lag Length: 4 (Automatic based on SIC, MAXLAG=23			
		t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		-18.25234	0.0000
Test critical values:	1% level	-3.964207	
	5% level	-3.412825	
	10% level	-3.128395	

KPSS Test for `ld_PRIBOR`

Null Hypothesis: ld_PRIBOR is stationary		
Exogenous: Constant, Linear Trend		
Bandwidth: 20 (Newey-West using Bartlett kernel)		
		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.249582
Asymptotic critical values:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

Augmented Dickey-Fuller Unit Root Test for `Yield10Y`

Null Hypothesis: YIELD10Y has a unit root			
Exogenous: Constant, Linear Trend			
Lag Length: 0 (Automatic based on SIC, MAXLAG=23			
		t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		-2.150133	0.5167
Test critical values:	1% level	-3.964192	
	5% level	-3.412819	
	10% level	-3.128392	

KPSS Test for `Yield10Y`

Null Hypothesis: YIELD10Y is stationary		
Exogenous: Constant, Linear Trend		
Bandwidth: 31 (Newey-West using Bartlett kernel)		
		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.576080
Asymptotic critical values:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

Augmented Dickey-Fuller Unit Root Test for `ld_Yield10Y`

Null Hypothesis: ld_YIELD10Y has a unit root			
Exogenous: Constant, Linear Trend			
Lag Length: 0 (Automatic based on SIC, MAXLAG=23			
		t-Statistic	Prob.
Augmented Dickey-Fuller test statistic		-40.23110	0.0000
Test critical values:	1% level	-3.964198	
	5% level	-3.412821	
	10% level	-3.128393	

KPSS Test for `ld_Yield10Y`

Null Hypothesis: ld_YIELD10Y is stationary
Exogenous: Constant, Linear Trend
Bandwidth: 14 (Newey-West using Bartlett kernel)

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.043792
Asymptotic critical values:	1% level	0.216000
	5% level	0.146000
	10% level	0.119000

Appendix C

Proofs of propositions

Proposition 1. *The $AR(p)$ process is stable (stationary) if the roots of the lag polynomial lie outside the unit circle, i. e. if all roots of the equation (3.1) are less than one in modulus.*

Proof. Instead of the proper proof[1], let me present two examples.

1) Consider the $AR(1)$ model:

$$Y_t = \rho Y_{t-1} + \varepsilon_t.$$

It can be written as $(1 - \rho L) Y_t = \varepsilon_t$. By solving the equation:

$$1 - \rho y = 0,$$

one gets $y = \frac{1}{\rho}$. And finally, if $\left|\frac{1}{\rho}\right| > 1$, then $|\rho| < 1$.

2) Consider the $AR(2)$ model:

$$Y_t = 0.8 Y_{t-1} + 0.09 Y_{t-2} + \varepsilon_t.$$

a) Its $AR(1)$ representation is:

$$\begin{bmatrix} y_t \\ y_{t-1} \end{bmatrix} = \begin{bmatrix} 0.8 & 0.09 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} y_{t-1} \\ y_{t-2} \end{bmatrix} + \begin{bmatrix} \varepsilon_t \\ 0 \end{bmatrix}.$$

[1] The proof can be found e. g. here: http://macrofinance.nipfp.org.in/PDF/Lect2ARMA.pdf, slides 17-21. Accessed April 14, 2013.

Its eigenvalues are taken from:

$$\begin{vmatrix} 0.8-\lambda & 0.09 \\ 1 & -\lambda \end{vmatrix} = \lambda^2 - 0.8\lambda - 0.09 = 0.$$

These eigenvalues are smaller than one:

$$\lambda_{1,2} = \frac{0.8 \pm \sqrt{(-0.8)^2 - 4 \cdot 1 \cdot (0.09)}}{2 \cdot 1} = \begin{cases} -0.1 \\ 0.9 \end{cases}.$$

b) Another solution uses lag polynomial representation:

$$\left(1 - 0.8L - 0.09L^2\right) Y_t = \varepsilon_t.$$

Its characteristic polynomial is hence:

$$\left(1 - 0.8z - 0.09z^2\right) = 0,$$

whose solution lie outside the unit circle, -10 and $1.\overline{1}$, respectively. These roots are the inverse to the previous ones. □

Proposition 2. *A $MA(q)$ is stationary for every sequence $\{\theta_n\}_{n=1}^q$.*

Proof. The $MA(q)$ is given by eq. (3.2). We will use the definition of a (weak) stationary, Definition 1:

$$\begin{aligned} \mathbb{E}\{y_t\} &= \mu, \\ \operatorname{var}\{y_t\} &= \left(1 + \sum_{n=1}^{q} \theta_n^2\right) \sigma^2, \\ \operatorname{cov}\{y_t, y_{t-j}\} &= \begin{cases} \sigma^2 \left(\theta_j + \sum_{i=1}^{q-1} \theta_{j+i}\theta_i\right) & \text{if } j = 1 \\ 0 & \text{if } j > 1 \end{cases}. \end{aligned}$$

□

Proposition 3. *The $ARMA(p,q)$ model is stationary provided the roots of the $\Phi(L)$ polynomial lie outside the unit circle.*

Proof. Only the AR part is involved. See the proof of Proposition 1. □

Part II.

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Central Bank Communication and Interest Rates: The Case of the Czech National Bank*

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Abstract
We examine how written and oral central bank communications affect the level and volatility of interest rates. We use detailed daily data on the Czech central bank's communication in 2007–2012. We find that financial markets respond to central bank communication. Short-term interest rates rise if the bank communicates that economic conditions are good. The results suggest that written communication, but not oral communication, decreases the volatility of both short-term and long-term interest rates. The timing of communication has a key role, as comments made closer to the monetary policy meeting have a bigger calming effect on the markets. All in all, our results point to the importance of well-designed communication for reducing noise in the financial markets.

1. Introduction

The transparency about monetary policy communication has increased substantially during the last two decades (Geraats, 2009; Posen, 2003). Many central banks now provide very detailed statements about how they reached their decisions on policy interest rates and frequently communicate their views on the state of economy. What are the implications of this increased transparency, and do financial markets react to central bank communication? Clearly, central bank transparency and open communication do not have to be a goal *per se*, but central banks find them valuable if they help central bankers to achieve their goal of maintaining economic stability.

We gather an extensive dataset on how one of the most transparent central banks,[1] the Czech National Bank (CNB), communicates the economic outlook and its implications for monetary policy to the public. More specifically, we collect data on both written and oral communications. For written communication, we collect data on the release of inflation reports and monetary policy minutes, as they represent the main communication channels used by the central bank. For oral communication, we classify the statements made in the media by Czech central bank board members according to the likely direction of the interest rate change.

Since the Czech central bank explicitly targets inflation, we focus on how (and whether) its communication influences interest rates. Within this monetary policy regime, the central bank sets the (trajectory of the) interest rate in order to achieve

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[1] See Dincer and Eichengreen (2009) for an assessment of monetary policy transparency for 100 central banks around the world.

the inflation target over some time horizon. The financial markets respond to central bank communications if those communications represent news to the markets. Clearly, communication can also exert an effect on other financial variables, such as exchange rates or asset prices, but this has been empirically examined for the Czech case in some other studies (see Égert and Kočenda, 2013, and Fišer and Horváth, 2011).

Importantly, previous research has highlighted the role of the timing of central bank communication (Ehrmann and Fratzscher, 2007). As a consequence, we examine: (i) whether the Czech central bank's communication affects the interest rate (volatility), (ii) whether its communication becomes more potent as the monetary policy meeting approaches, and (iii) whether, in contrast to most of the previous literature, its communication affects not only short-term, but also long-term interest rates.

Our results suggest that financial markets respond to central bank communication. We find that central bank communication affects both the level and the volatility of short-term interest rates. It also affects interest rates at longer maturities to a certain degree. According to our results, although the communication does not affect the level of long-term interest rates, it still has an effect on their volatility. We also find that written communication has a calming effect on financial markets and that the timing of communication is important, so that comments closer to the monetary policy meeting have a stronger effect in terms of curbing interest rate volatility.

The paper is organized as follows. Section 2 provides a brief survey of previous research on Czech central bank communication. Section 3 discusses the data and empirical model that we use. The results are available in Section 4. Concluding remarks are provided in Section 5.

2. Related Literature on Czech Central Bank Communication

This section provides an overview of previous studies focusing on CNB communication. For an authoritative survey of central bank communication, see Blinder et al. (2009).

Rozkrut et al. (2007) evaluate the communication strategies of the Czech National Bank, the National Bank of Hungary, and the National Bank of Poland. They find that communication differs considerably across these banks, and that except for the CNB, policy makers' words do not often match their deeds. Their results show that central banks' communication influences the market expectations of future monetary policy decisions. The consistency of the policy makers' statements (the extent to which their words match their future deeds), communication strategy, and committee structure are found to influence the impact of central banks' communication on the predictability of monetary policy decisions.

Böhm et al. (2012) analyze the coverage of CNB monetary policy in the media during the period of 2002–2007. They study articles in the four most relevant Czech daily newspapers. Their results indicate that surprising policy news is not perceived negatively in the media. Clearly, the media coverage is more extensive when the policy change is not expected. Interestingly, regardless of the direction of the move, the changes in interest rates are appreciated by the media. The media coverage is more negative when inflation rises, but also when inflation falls below zero.

Filáček and Saxa (2012) examine whether the CNB has a coordination effect on private sector forecasts. Their results suggest that there is a coordination effect for interest rate and inflation forecasts, but less so for exchange rate and GDP forecasts.

Bulíř et al. (2007) take a different perspective on assessing central bank communication. They examine whether the communication is internally consistent, i.e., whether inflation targets, inflation forecasts, and the verbal assessments of inflation factors contained in quarterly inflation reports provide an identical message to the public. They examine several central banks around the world, including the Czech central bank, and find that these central banks provided a largely consistent message during the years 2000–2005.

Fišer and Horváth (2010) analyze the effects of CNB communication, macroeconomic news, and the interest rate differential on exchange rate volatility using the GARCH model. They find that communication has a calming effect on the volatility of the exchange rate. Moreover, they discover that the timing of communication matters, as the financial markets respond more to communication before policy meetings than after them.

Horváth et al. (2012) examine whether the voting records of several central bank boards, including the CNB, are informative about future monetary policy. The results suggest that the voting records in all the central banks examined contain information that is new to the financial markets and provide a useful measure of the likely change of interest rates at the next monetary policy meeting.

Égert and Kočenda (2013) investigate the effects of macroeconomic news and central bank communication on the exchange rate in three Central European countries, including the Czech Republic. As regards central bank communication, they find that oral statements had an effect on the exchange rate only during the crisis period.

All in all, the analysis of Czech central bank communication is a burgeoning stream of literature, but to our knowledge the effect of communication on interest rate volatility has not been examined.

3. Data and Empirical Model

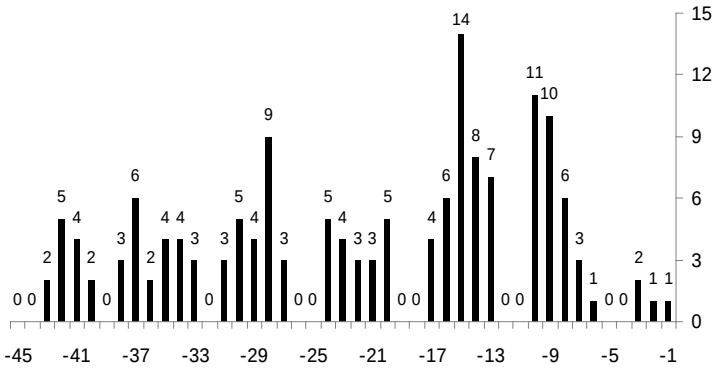
3.1 CNB Communication

The CNB adopted inflation targeting in 1998 and has gradually become one of the most transparent central banks in the world (Dincer and Eichengreen, 2009). The CNB Bank Board meets eight times a year.[2] These meetings are scheduled for the beginning of February, May, August, and November and the end of March, June, September, and December. The monetary policy meeting serves as an opportunity to change the policy rate. The decision is made public at around 1 p.m., followed by a press conference in the afternoon. The CNB releases the voting ratio during the press conference and communicates its interest rate decision, the forecasts, and the risks accompanying the forecast.

The minutes of the monetary policy meeting are made available approximately eight days after the meeting. Since 2008, the minutes have contained the indi-

[2] The Board met on a monthly basis until 2008 and held several extraordinary meetings after the introduction of inflation targeting.

Figure 1 Frequency of the CNB Speeches and Interviews before the Bank Board Meeting, 2007–2012



Notes: The chart represents the number of comments before the day of the Bank Board meeting. Legend to the graph: "-1" for one day before the meeting, "-2" for two days before the meeting, "-3" for three days before the meeting, "-4" and "-5" four and five days before the meeting, respectively, etc.

vidual voting records. The minutes are discussed in greater detail in Horváth et al. (2012). Detailed transcripts of the board meetings as well as the so-called Situation Report on Economic and Monetary Developments and the Monetary Policy Recommendation are published with a six-year lag (available in Czech only). The CNB publishes inflation reports on a quarterly basis (in February, May, August, and November). The inflation report contains a summary of Czech economic developments and, importantly, provides detailed information on the forecast for the macroeconomic environment and associated risks.

In line with what is observed for major central banks (Ehrmann and Fratzscher, 2009), the communication intensity declines prior to the monetary policy meeting and the Czech central bank ceases to communicate with the public at all several days before the monetary policy meeting (see *Figure 1*).

3.2 Data

We collect daily data on CNB communication and interest rates (the Czech 10-year bond yield[3] and the 3M PRIBOR) from the CNB website. Our sample runs from January 2007 to December 2012, which makes 1,495 observations. The frequency of the data is daily.

PRIBOR$_t$ and Yield10Y$_t$ are the bases for calculating our dependent variables. The remaining variables are explanatory. The definitions of all the variables are available below. The descriptive statistics are available in *Table 1*.

DEPENDENT VARIABLES:

PRIBOR$_t$	daily data on three-month PRIBOR (Prague InterBank Offered Rate). It is the interest rate at which banks provide loans to each other on the Czech interbank market;
*Yield*10*Y$_t$*	Czech 10-year government bond yield.

[3] Instead of government bonds, we also tried to use 10-year interest rate swaps (IRS). Unlike IRS, government bond yields are directly influenced by the sovereign credit risk. However, our GARCH-type estimates showed that the results with IRS exhibit non-stationary volatility.

Table 1 Descriptive Statistics

	PRIBOR	Yield10Y	Comments	Minutes	Timing	IR
Mean	2.13	4.04	0.11	0.04	3.98	0.02
Maximum	4.52	5.42	1.00	1.00	45.00	1.00
Minimum	0.50	1.84	0.00	0.00	0.00	0.00
Std. deviation	1.16	0.77	0.31	0.18	10.25	0.13
Skewness	0.62	-0.74	2.56	5.08	2.51	7.70
Kurtosis	1.90	3.29	7.53	26.81	7.94	60.35
Observations	1496	1496	1496	1496	1496	1496

EXPLANATORY VARIABLES:

IR_t dummy variable describing the release of the inflation report:

$$IR_t = \begin{cases} 1 & \text{on all days the inflation report is released,} \\ 0 & \text{otherwise.} \end{cases}$$

$minutes_t$ dummy variable describing the minutes:

$$minutes_t = \begin{cases} 1 & \text{on all days the minutes are released,} \\ 0 & \text{otherwise.} \end{cases}$$

$comments_t$ dummy variable showing whether or not there was a comment on that day. A comment is defined as an oral or written statement made by a member of the Bank Board concerning interest rates, the economic outlook, inflation, or the exchange rate. These data come from the CNB website ("Media service—Interviews, articles" and "Media service—speeches, conferences, seminars–Speeches"):

$$comments_t = \begin{cases} 1 & \text{on all days a comment is made,} \\ 0 & \text{otherwise.} \end{cases}$$

$direction_t$ dummy variable capturing the direction[4] of the comment:

$$direction_t = \begin{cases} +1 & \text{positive comment,} \\ -1 & \text{negative comment,} \\ 0 & \text{otherwise.} \end{cases}$$

$timing_t$ describes how the influence of a Bank Board comment gets stronger as the date of the monetary policy meeting approaches. A comment that occurs on the day of the meeting has a value of 45, a comment from the previous day has a value of 44, a comment made two days before the meeting has a value of 43, and so on.[5] In consequence, comments closer to the monetary policy meeting get a greater weight.

[4] "Positive comment" represents the improved economic outlook or an inclination toward tightening monetary policy, and "negative comment" represents the weaker economic outlook or an inclination toward easing monetary policy. We are aware that the coding of this variable is, to a certain extent, subjective and we therefore exclude this variable from some regression specifications to evaluate the stability of our results.

[5] The value of 45 is set because the Bank Board's meetings are held eight times a year. There are 360 days in a year, so 360 ÷ 8 = 45.

3.3 Econometric Model

We use the threshold generalized autoregressive conditional heteroskedasticity (*TGARCH*) model (Zakoian, 1994) to evaluate the effect of central bank communication on interest rate volatility. The general model is specified as follows:

$$\Delta r_t = \mu + \upsilon\left(direction_t\right) + \xi_t \tag{1}$$

$$\sigma_t^2 = \gamma + \alpha\xi_{t-1}^2 + \beta_1\sigma_{t-1}^2 + \beta_2\xi_{t-1}^2 I_{(\xi_{t-1}<0)} + \sum_{i=1}^{n}\delta_i CB_{it} \tag{2}$$

where r_t denotes the log of the interest rate. The error term, ξ_t, in the mean equation (1) is $\xi_t = \sigma_t e_t$, where σ_t is the volatility of Δr_t and ξ_t is an iid variable. In equation (2), $I(\cdot) = 1$ if $\xi_{t-1} < 0$ and 0 otherwise. In this model, good news, $\xi_{t-1} > 0$, and bad news, $\xi_{t-1} < 0$, have different effects on the conditional variance. The conditional variance equation (2) additionally includes a constant γ, the *ARCH* term ξ_{t-1}^2, the GARCH term σ_{t-1}^2, and variables capturing the effect of central bank communication, CB_{it}. The model is estimated via maximum likelihood using the BHHH algorithm for optimization, and is estimated for all business days in the sample.

Our goal is to examine whether the coefficients δ_i capturing central bank communication are significant. It is important to note that a *priori* the coefficients δ_i can be negative, positive, or insignificant. Positive (negative) coefficients imply that the central bank increases (reduces) the interest rate volatility. Note that in the case of tick-by-tick data the coefficients are unlikely to be negative, as news will change the price of financial assets and therefore increase its volatility by definition. In the case of daily data, this does not have to be so and the estimated coefficient can be negative (see also Fišer and Horvath, 2010). Insignificant coefficients δ_i indicate that central bank communication does not represent news for the financial markets.

As an alternative to the TGARCH model, we also employ the exponential generalized autoregressive conditional heteroskedasticity (*EGARCH*) model (Nelson, 1991). The motivation is to include a different GARCH-type model which allows for asymmetries in financial market dynamics to examine the stability of our results. The EGARCH model is specified as follows:

$$\Delta r_t = \mu + \upsilon\left(direction_t\right) + \xi_t \tag{3}$$

$$\log\left(\sigma_t^2\right) = \kappa + \alpha\left|\frac{\xi_{t-1}}{\sqrt{\sigma_{t-1}^2}}\right| + \gamma\frac{\xi_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \beta\log\left(\sigma_{t-1}^2\right) + \sum_{i=1}^{n}\varphi_i CB_{it} \tag{4}$$

4. Results

This section contains the results of the econometric estimation evaluating whether central bank communication affects short-term and long-term interest rates. Using the TGARCH model as the baseline, we examine whether central bank communication influences the level and volatility of interest rates.

Table 2 TGARCH: The Effects of the CNB Communication on PRIBOR

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
μ	-36.9*	-68.4*	-119.9*	-54.3*	-125.7***	-140.7	-123.2	-83.4*
	[22.0]	[39.8]	[66.0]	[33.1]	[49.0]	[65.1]	[55.1]	[53.3]
v (direction$_t$)								284.9**
								[125.6]
α	5.37***	14.3***	20.8***	9.44***	18.6***	14.2***	15.2***	14.4***
	[0.11]	[0.21]	[0.06]	[0.17]	[0.34]	[0.18]	[0.69]	[0.80]
$ß_1$	1.04***	0.85***	0.45***	0.94**	0.55***	0.34***	0.39***	0.48***
	[0.04]	[0.06]	[0.05]	[0.05]	[0.05]	[0.04]	[0.04]	[0.05]
$ß_2$	-0.17*	-0.39***	-0.08	-0.26***	-0.10	-0.00	-0.02	-0.07
	[0.09]	[0.09]	[0.08]	[0.10]	[0.08]	[0.07]	[0.08]	[0.43]
γ	0.00	-0.02***	-0.01***	-0.00	-0.01	0.33***	0.26***	0.24***
	[0.01]	[0.00]	[0.00]	[0.01]	[0.03]	[0.02]	[0.04]	[0.05]
δ_1 (*minutes*$_t$)	-3.71***			-7.91***		-14.8***	-15.4***	-14.7***
	[0.40]			[0.40]		[1.16]	[1.01]	[0.66]
δ_2 (*comments*$_t$)		0.71**		1.95***	3.96***		4.58***	3.68**
		[0.30]		[0.50]	[0.01]		[1.32]	[1.75]
δ_3 (*timing*$_t$)			-0.36***		-0.42***	-0.26***	-0.40***	-0.30***
			[0.04]		[0.00]	[0.05]	[0.00]	[0.06]
δ_4 (*IR*$_t$)	-4.10***	-13.9***	-14.3**	-9.43***	-15.2***	-12.6***	-14.9***	-14.4***
	[0.41]	[0.01]	[0.04]	[0.17]	[0.03]	[3.35]	[3.19]	[3.04]
AIC	-6.23	-6.37	-6.23	-6.54	-6.25	-6.22	-6.00	-6.29
N	1495	1495	1495	1495	1495	1495	1495	1495

Notes: Standard errors are shown in brackets below the coefficients. *AIC* is Akaike information criterion. ***, ** and * denote significance at 99%, 95% and 90%, respectively. The values of μ, v, α, δ_1, δ_2, δ_3 and δ_4 are multiplied by 10^5, their standard errors are also multiplied by 10^5.

Table 3 TGARCH: The Effects of the CNB Communication on 10Y Bond

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
μ	13.1	-7.76	-7.86	-5.81	-11.3	-6.26	-8.55	-3.26
	[55.7]	[32.4]	[31.4]	[31.5]	[33.1]	[30.9]	[31.9]	[50.1]
v (direction$_t$)								96.7
								[290.8]
α	6.11***	0.33***	0.47***	0.10**	0.47***	0.30***	0.15**	4.11***
	[55.7]	[0.03]	[0.05]	[0.05]	[0.05]	[0.06]	[0.06]	[0.25]
$ß_1$	0.1***	0.04***	0.04***	0.04***	0.04***	0.04***	0.04***	0.07***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.05]	[0.00]	[0.00]	[0.01]
$ß_2$	0.07**	0.07***	0.07***	0.06***	0.06***	0.06***	0.06***	0.12***
	[0.03]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.03]
γ	0.74	0.92***	0.91***	0.93***	0.91***	0.92***	0.93***	0.76***
	[0.01]	[0.01]	[0.00]	[0.01]	[0.01]	[0.01]	[0.01]	[0.02]
δ_1 (*minutes*$_t$)	-21.9***			2.82***		1.94***	3.72***	-14.3**
	[1.69]			[0.67]		[0.72]	[0.80]	[1.19]
δ_2 (*comments*$_t$)		0.09		0.34*	0.07**		1.10***	13.3**
		[0.22]		[0.22]	[0.33]		[0.27]	[2.06]
δ_3 (*timing*$_t$)			-0.02***		-0.03***	-0.02***	-0.03***	-0.19***
			[0.00]		[0.00]	[0.00]	[0.00]	[0.03]
δ_4 (*IR*$_t$)	-0.49	-0.26	-0.38	0.00	-1.08	-0.05	-0.65	-3.17***
	[3.12]	[0.85]	[0.85]	[0.88]	[0.85]	[0.88]	[0.91]	[1.91]
AIC	-5.76	-5.96	-5.96	-5.96	-5.96	-5.96	-5.96	-5.81
N	1495	1495	1495	1495	1495	1495	1495	1495

Notes: Standard errors are shown in brackets below the coefficients. *AIC* is Akaike information criterion. ***, ** and * denote significance at 99%, 95% and 90%, respectively. The values of μ, v, α, δ_1, δ_2, δ_3 and δ_4 are multiplied by 10^5, their standard errors are also multiplied by 10^5.

Our regression results are provided in *Table 2* and *Table 3*. *Table 2* contains the regression results with the short-term interest rate as the dependent variable. We provide eight different specifications in order to assess the robustness of the results. The results suggest that the direction of comments has an effect on the level of short-term interest rates. Comments expressing that economic conditions are good are likely to be associated with an increase in interest rates.

We also find that central bank communication matters for the volatility of short-term interest rates. Both the monetary policy minutes and the inflation report exert a negative effect, i.e., they have a calming effect on the financial markets. This is in line with some previous studies on the effects of central bank communication, such as Jansen and de Haan (2005) and Fišer and Horváth (2010). Interestingly, we do not find this calming effect for oral communication.

Finally, the timing of central bank communication is important, according to our results. The financial markets react more strongly to statements made closer to the day of the monetary policy meeting. In addition, we find that the asymmetric term in the TGARCH model is negative and often significant. This result suggests that bad news has a disproportionately greater effect on volatility than good news, which is a widely observed phenomenon in the financial markets.

Our results with the long-term interest rate as the dependent variable are provided in *Table 3*. They suggest that central bank communication to a certain extent affects interest rates even at longer maturities. The level of short-term interest rates is not affected, but the volatility is. This is an interesting result, because central banks typically communicate about the near-term economic outlook (note that the typical monetary policy horizon of central banks is 1–2 years), but rarely about the more distant future. Otherwise, the results largely confirm our findings in *Table 2*.

We subject our regression results to further robustness checks. First, we use a different asymmetric GARCH model and estimate the EGARCH model instead of TGARCH models. In addition, we restrict β_2 from Eq. (2) to be zero and we therefore estimate simple GARCH models, too. The estimation of the GARCH models is a further check of the stability of our results. The results largely confirm our baseline findings showing that financial markets respond to central bank communication. The results are available upon request.

5. Concluding Remarks

We analyze the importance of central bank communication for the level and volatility of short-term and long-term interest rates in the Czech Republic using the GARCH, TGARCH, and EGARCH modelling frameworks. Using daily data in 2007–2012, we find that financial markets respond to central bank communication.

More specifically, we find that more positive statements about economic conditions are followed by an increase in short-term interest rates. Central bank communication matters for interest rate volatility, too. Written communication, as captured by the monetary policy minutes and inflation reports, exerts a calming effect on the financial markets. However, we fail to find this calming effect for oral communication.

Importantly, our findings show that the timing of central bank communication plays an important role. Comments made closer to the monetary policy meeting have

a stronger effect on interest rate volatility. Our results also indicate that central bank communication matters to a certain extent for interest rates at longer maturities, too. To summarize, we find that Czech central bank communication affects financial market expectations, in line with what we observe for many developed central banks (see de Haan, 2008).

Our analysis could be extended in several ways. The communication of individual board members could be studied in order to evaluate whether communication by some members, such as the governor, has a stronger effect on interest rates. The monetary policy meetings are held eight times a year, but a new macroeconomic forecast is released at only four of them. The variable capturing the timing of central bank communication could differentiate between these two types of meetings. In addition, multivariate GARCH models could be employed to study the effects of central bank communication jointly on more financial assets.

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