Univerzita Karlova v Praze
Fakulta sociálních věd
Institut ekonomických studií

BAKALÁŘSKÁ PRÁCE

The impact of the Czech National Bank's communication on exchange rate: A GARCH evidence

Praha 2008 **Radovan Fišer**

Univerzita Karlova v Praze
Fakulta sociálních věd
Institut ekonomických studií

BAKALÁŘSKÁ PRÁCE

The impact of the Czech National Bank's communication on exchange rate: A GARCH evidence

Autor: Radovan Fišer

Vedoucí práce: Roman Horváth, M.A., Ph.D.

Akademický rok: 2007/2008

Prohlášení

Prohlašuji, že jsem bakalářskou práci vypracoval samostatně a použil pouze uvedené zdroje.

V Praze dne _____ _____

podpis

Poděkování

Rád bych poděkoval zejména vedoucímu své práce Romanu Horváthovi, M.A., PhD., který mi věnoval nejen zajímavé téma, ale také dostatek svého času k potřebným konzultacím. Filipu Pertoldovi děkuji za cenný komentář k ekonometrické analýze.

Bibliografický záznam

Fišer, Radovan. The impact of the Czech National Bank's communication on exchange rate: A GARCH evidence. Praha: Univerzita Karlova, Fakulta sociálních věd, Institut ekonomických studií, 2008, 78 s. Vedoucí bakalářské práce: Roman Horváth, M.A., Ph.D.

Abstrakt

Tato práce podává přehled literatury na téma komunikace centrálních bank a empiricky analyzuje vliv komunikace České národní banky a vliv publikování aktuálních hodnot makroekonomických veličin na volatilitu kurzu CZK/EUR. Analýza je provedena pomocí GARCH modelu, který je v práci podrobně představen. Originalita této práce leží v tom, že jde o první pokus o analýzu vlivu komunikace ČNB na volatilitu kurzu. Výsledkem práce je zjištění, že komunikace ČNB, stejně jako publikování hodnot makroekonomickcýh veličin, volatilitu snižuje.

Název práce:	Vliv komunikace České národní banky na směnný kurz: důkaz GARCH modelem
Autor:	Radovan Fišer
E-mail autora:	rfiser@gmail.com
Vedoucí práce:	Roman Horváth, M.A., Ph.D.
E-mail vedoucího práce:	roman.horvath@gmail.com
Akademický rok:	2007/2008
Klasifikace JEL:	C01, E52, F31
Klíčová slova:	GARCH, komunikace centrálních bank, volatilita, směnný kurz

Abstract

This study surveys the recent literature on the topic of central banks communication and empirically analyses the impact of both the Czech National Bank's communication and the macroeconomic news releases on the volatility of the CZK/EUR exchange rate. It does so using the GARCH model which is presented in detail. The originality of this study lies in the fact that it is the first attempt to study the effect of the CNB's communication on the volatility of the exchange rate. The main finding is that the Czech National Bank's communication, as well as the releases of the macroeconomic news decrease volatility.

Title:	The impact of the Czech National Bank's communication on exchange rate: A GARCH evidence
Author:	Radovan Fišer
Author's e-mail:	rfiser@gmail.com
Supervisor:	Roman Horváth, M.A., Ph.D.
Supervisor's e-mail:	roman.horvath@gmail.com
Academic year:	2007/2008
JEL Classification:	C01, E52, F31
Keywords:	GARCH, central bank communication, volatility, exchange rate

Contents

List of Figures

List of Tables

Introducion

Knights of the Stable Price Level. Such a paraphrase does not point only to the objective of low inflation, the primary target which central banks pursuit. It points mainly the *round table* which has always been a symbol of communication. And the communication is today considered as one of the main tools of the central bankers. But has it always been? Certainly not. It is only in the last two decades that we see the rise of openness in the communication of central banks. Communication accompanies their traditional policy tool, the short-term interest rate. The question may arise, what is the way that causes the short-term interest rate influence the long-term values like the real output. The answer, according to many, as documented in this study, lies in the expectation of the market participants.

There are people who call central banking of modern day an art of managing expectations. Obviously, there are no expectations without communication.

In this study on the particular effects of the communication of the Czech National Bank, I describe the recent trends in the theory of central bank communication. In the empirical part, I concentrate on the analysis of the CNB's communication influence on the CZK/EUR exchange rate. The analysis is realized by the GARCH model, which is able to analyse both mean and variance of the price of an asset. Particularly, I take into account the acts of releasing minutes and of publishing comments from the Bank Board's members. Put more directly, the question to be answered is whether the CNB's communication adds to market speculations and thus to the fluctuation of the return on the exchange rate, or rather calms it down.

The secondary aim of this study is the analysis of the impact of the releases of macroeconomic news on the volatility of the same exchange rate. It emerged as an explanation for a result in the primary part.

The level of surprisingness of the results is mixed. The Czech National Bank's communication has been found with calming effect on the volatility, which is in line with the finding of a similar study for the Magyar Nemzeti Bank (Gábriel & Pintér, 2006). Quite

surprising is the conclusion for the macro news releases which were all found with negative[1] effects on volatility, while usually similar studies report mixed or positive effects.

[1]To clarify, any reference to negative or positive effects is meant in terms of an decrease or an increase.

Chapter 1

From basic time series to the ARCH class of models

In this chapter I lay the basic information that we need to understand the GARCH model. Thus, I start with the theory of time series and go across the ARIMA model, from which there is a logical step towards the GARCH model, at least according to the Nobel prize winner Robert Engle who suggested the autoregressive conditional heteroskedastic model, the core of the GARCH model. This chapter heavily draws from Pindyck & Rubinfeld (1991).

1.1 Basic time series analysis

One can define time series modeling as a method of extrapolating data. There are two classes od extrapolating methods. *Deterministic* modeling is based on the past behaviour of the particular time series. There are many types of this simple extrapolation, e.g., linear, exponential, quadratic, logistic, (logaritmic) autoregressive. *Stochastic* modeling tries to describe the structure of a random (stochastic) process that generates the series. It aassumes that the particular set $y_1, y_2, \ldots, y_T$ has been drawn from a probability distribution. From now on we will deal only with the stochastic processes.

An example of these is a random walk process y_t. It is described by

$$y_t = y_{t-1} + \varepsilon_t \tag{1.1}$$

where $E(\varepsilon_t) = 0$ and $E(\varepsilon_t \varepsilon_s) = 0$ for $t \neq s$. Now suppose we wanted to make a

forecast.

$$\begin{aligned}\hat{y}_{T+1} &= E(y_{T+1}|y_T,\ldots,y_1) = E(y_T) + E(\varepsilon_{T+1}) = y_T,\\ \hat{y}_{T+2} &= E(y_{T+2}|y_{T+1},\ldots,y_1) = E(y_{T+1}+\varepsilon_{T+2}) = E(y_T+\varepsilon_{t+1}+\varepsilon_{T+2}) = y_T.\end{aligned} \tag{1.2}$$

The forecast is the same for all future periods. However, the variance of the error term behaves differently. For a one and a two period forecast the error term e_t is given by

$$\begin{aligned}e_1 &= y_{T+1} - \hat{y}_{T+1} = y_T + \varepsilon_{t+1} - y_T = \varepsilon_{t+1}\\ e_2 &= y_{T+2} - \hat{y}_{T+2} = y_T + \varepsilon_{t+1} + \varepsilon_{t+2} - y_T = \varepsilon_{t+1} + \varepsilon_{t+2}\end{aligned} \tag{1.3}$$

and the variance of e_1 and e_2 is

$$\begin{aligned}&E[\varepsilon_{t+1}^2] = \sigma_\varepsilon^2\\ &E[(\varepsilon_{t+1}+\varepsilon_{t+2})^2] = E(\varepsilon_{t+1}^2) + E(\varepsilon_{t+2}^2) + E(\varepsilon_{t+1}\varepsilon_{t+2}) = 2\sigma_\varepsilon^2\end{aligned} \tag{1.4}$$

We can see that the value of the error term increases with the number of periods we forecast. For the l-period forecast, the error variance is $l\sigma_\varepsilon^2$. The stability of the first and the second moment of a time series, i.e., its mean and variance, is an important issue in modeling time series, as we will see later.

1.1.1 The concept of stationarity

In the beginning of this chapter it was said that stochastic processes assume a (joint) probabilistic distribution that is defined for example by its mean and variance. Stationarity requires these to be fixed in time.

Definition 1.1 (Stationary Time Series): Let the joint distribution and conditional distribution of a process be invariant with respect to time. Then we call the process stationary. ▶

If a time series process is nonstationary, it is often difficult to analyse it by a simple model. By contrast, if the stochastic process is fixed in time, then it can be modeled by an equation with fixed coefficients that can be estimated from past data. It follows from (1.1) that for a stationary series $E(y_t) = E(y_{t+m})$, $Var(y_t) = Var(y_{t+m})$ and $Cov(y_t, y_{t+k}) = Cov(y_t, y_{t+k+m})$ for any t, k and m. These are the preconditions of weak (wide sense) stationarity which is usually called just *stationarity*. If not only the first and second moments do not vary in time but all of the moments do, we speak of strict stationarity.

The autocorrealtion function (ACF) describes the level of correlation (interdependency) between neighboring data points in a series.

Definition 1.2 (Autocorrelation with lag k):

$$\rho_k = \frac{Cov(y_t, y_{t+k})}{\sigma_{y_t}\sigma_{y_{t+k}}} \tag{1.5}$$

▶

A nonstationary time series can be transformed into a stationary one. Fortunately, majority of time series that arise in economics and business belong to this class of time series (Pindyck & Rubinfeld, 1991). We call such a series homogenous.

Definition 1.3 (Homogenous series): Let a nonstationary time series be such that if it is differentiated one or more times, the resulting time series will be stationary. Then we call it a homogenous time series. The number of times it has to be differentiated to become stationary is called order of homogenity (Pindyck & Rubinfeld, 1991) or equivalently the degree of integration (Nobel Commitee 2003). ▶

An example of a first-order homogenous process is the random walk process defined in Eq. (1.1). After differentiating, we have

$$w_t = \Delta y_t = y_t - y_{t-1} = \varepsilon_t, \tag{1.6}$$

where w_t is a stationary process since ε_t is assumed to be independent of time.

The value of the autocorrelation function of a stationary series falls as the number of lags k becomes large. Usually, this does not hold for nonstationary series.[1] There are statistical tests on the significance of the autocorrelation coefficients ρ_k that have the null hypothesis that the coefficients are zero. They are called portmanteau tests; most often we use the improvement of the Q statistics by Box and Pierce known as the Box-Ljung test that uses the statistics defined as

$$Q = T(T+2)\sum_{k=1}^{m}\frac{\rho_k^2}{T-k}\,, \tag{1.7}$$

where T is the number of observations and m is the number of autocorrelations terms we include in the statistic[2]. The null hypothesis is that none of the autocorrelation coeficients is different from zero. The Q is distributed as $\chi^2_{(m-p-q)}$.

[1] Pindyck & Rubinfeld (1991) provide the proof of this statement in their textbook.

[2] Pindyck & Rubinfeld (1991) mention 15 or 20 is sufficient for low-order models

Pindyck & Rubinfeld (1991) mention several studies that show that many economic series seem to follow a random walk process. A regression of a random walk process against another leads to spurious results[3], i.e., suggesting a statistically significant relationship between variables where an economic relationship may not exist at all. David Dickey and Wayne Fuller introduced[4] tests designed to recognise a random walk process defined in Eq. (1.1). If the hypothesis of unit root, i.e., $|\rho| = 1$, is confirmed, we say that there us a unit root present in the process. The solution to the presence of the unit-root process in, for example, the dependent variable, is differencing, which yields stationary series.

1.2 ARIMA

The integrated autoregressive-moving average model provides a general framework for modeling homogenous nonstationary time series.

- **Moving average models**. In the moving average process of order q each observation y_t is generated by a weighted average of random disturbances going back q periods. We denote this process as MA(q) and write its equation as

$$y_t = \mu_t + \varepsilon_t - \theta_1\varepsilon_{t-1} - \theta_2\varepsilon_{t-2} - \ldots - \theta_q\varepsilon_{t-q}. \tag{1.8}$$

  The ACF ρ_k for the MA(q) process has q nonzero values and is 0 for $k > q$.

- **Autoregressive models**. In the autoregressive process of order p the current observation y_t is generated by a weighted average of past observations going back p periods, together with a random disturbance in the current period. We denote this process as AR(p) and write its equation as

$$y_t = \phi_1 y_{t-1} + \phi_2 y_{t-2} + \ldots + +\phi_p y_{t-p} + \delta + \varepsilon_t, \tag{1.9}$$

  where δ is a constant term relating to the mean of the process. The ACF for AR processes of order greater than one are typically geometrically declining, oscillating, sinusoidal functions.

[3]Described firstly in Granger, C. W. J. and Newbold, P. (1974). "Spurious regressions in econometrics". Journal of Econometrics 2: 111—120.

[4]Dickey, D.A. and W.A. Fuller (1979), "Distribution of the Estimators for Autoregressive Time Series with a Unit Root," Journal of the American Statistical Association, 74, p. 427–431.

- **ARMA models**.

  A process might have characteristics of both MA and AR processes. Thus a logical extension of MA and AR is the mixed autoregressive-moving average process of order (p,q). We denote this process as ARMA(p,q).

$$y_t = \phi_1 y_{t-1} + \phi_2 y_{t-2} + \ldots + + \phi_p y_{t-p} + \delta + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \ldots - \theta_q \varepsilon_{t-q}. \quad (1.10)$$

- **ARIMA models**. If $w_t = \Delta^d y_t$ and w_t is an ARMA(p,q) process, then we say that y_t is an integrated autoregressive-moving average process of order (p,d,q) or simply ARIMA(p,d,q).

After a time-series model has been estimated one should check whether the specification is correct (so called diagnostic checking). First, the ACF of the original times-series and of the simulated time series should not be markedly different. Second, by assumption, the random error terms on the actual process are normally distributed and independent. Thus in a correctly specified model, residuals $\hat{e}_t$ should resemble a white noise process which can be checked by the Box-Ljung test.

1.3 ARCH class of models

The name *general autoregressive conditional heteroskedasticity* might induce us a feeling of doubt, but in reality, the class of econometric models called ARCH and GARCH belongs to the basic knowledge of everyone interested in watching financial time series throw the eyes of an econometrician.

In this section I will introduce the ARCH class of models and then I will present some practical examples of using the GARCH model in finance.

1.3.1 Engle's ARCH

During his visit to the London School of Economics in 1979 Robert Engle was interested in measuring the response of economic agents to uncertainty using time series data.[5]

[5]Engle was looking for a model that could assess the validity of Milton Friedman's conjecture from 1977 that the unpredictability of inflation was a primary cause of business cycles (Engle, 2004).

Today, it is not the uncertainty of inflation that would be the daily bread of Engle's contribution but the world of finance. The contribution enabled people to model the second moments of random variables, i.e., the variance, in a very sophisticated way than has been awarded a Nobel prize. As Engle says, the constant variance does not allow the uncertainty to be identified, so he tried to measure and model the variance. Contrary to the common practise of conventional econometric models of his day, he proposed a class of models where the variance of the error term depends upon the past. We call this conditional variance (Engle, 1982). It implies heteroskedasticity, the variance varying in time. It is important to distinguish between several forms of heteroskedasticity.

- The variance of the error term may vary directly with one or more independent variables. For example in the equation

$$y_t = \beta_0 + \beta_1 x_{1t} + \beta_2 x_{2t} + \varepsilon_t$$

  the variance of ε_t may be proportional to x_{2t}^2. In that case we could use a weighted lease squares procedure to combat heteroskedasticity and reach homoskedasticity.

- The error term variance may not vary with the independent variable but with the past value(s) of it self. This is the conditional variance which the autoregressive conditional heteroskedasticity model is designed to deal with.

In 1978, Granger and and Andersen[6] introduced the bilinear model which allows the variance to depend on the past realizations of the series. Engle (1982) names the simple case $y_t = \varepsilon_t y_{t-1}$, ε_t being a white noise process, where the conditional variance is $\sigma^2 y_{t-1}^2$. However, this model has some undesireable properties (Engle, 1982, p. 998) and does not suffice the needs. Nevertheless, Granger's test for bilinearity, which I do not discuss here, turned out to be the optimal or Lagrange Multipler test for ARCH (and GARCH–see below) effects in residuals of a fitted model (Engle, 2004, p. 328); the test will be described later.

In 1982 Engle (1982) introduces an example of what he calls an autoregressive conditional heteroskedasticity (ARCH) model[7] which consists of a mean equation (y_t) and a

[6]Clive W. J. Granger, A. Andersen, "Introduction to Bilinear Time Series Models", Vandenhoeck & Ruprect, Gottingen, 1978.

[7]In 2003, Engle became the Nobel prize winner "for methods of analyzing economic time series with time-varying volatility". He received half of the prize. The second half belongs to Clive Granger, who received it for "methods of analyzing economic time series with common trends (cointegration)". Source: `http://nobelprize.org/nobel_prizes/economics/laureates/2003/`.

variance equation (h_t):

$$\begin{aligned} y_t &= \varepsilon_t \sqrt{h_t} \\ h_t &= \alpha_0 + \alpha_1 y_{t-1}^2, \end{aligned} \tag{1.11}$$

where ε terms are independent, standard normal variables, and h stands for variance.[8] More generally, the ARCH regression model for variance h_t could depend on a moving average of q past error terms $h_t = h(\varepsilon_t, \varepsilon_{t-1}, \ldots, \varepsilon_{t-q}, \alpha)$. Then, the ARCH($q$) process would be given by

$$\begin{aligned} \varepsilon &\sim N(0, h_t) \\ h_t &= \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 = \alpha_0 + \alpha(L)\varepsilon_t^2, \end{aligned} \tag{1.12}$$

where $\alpha_0 > 0$, $\alpha_i \geq 0$ to ensure positive variance, L denotes the lag operator. To clarify, the mean equation includes a constant and the disturbance ε, which is shown in Eq. (1.12). Generally, the mean may include any specification, for example an ARIMA model. If $\sum_{i=1}^{q} \alpha_i < 1$, the process is weakly stationary with constant unconditional variance

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

ARCH model forecasts the error variance at time t on the basis of information known at time $t-1$. Engle et al. (2008, p. 4) notes that as the forecasting is conditionally deterministic, it does not leave any uncertainty on the expectation of the squared error at time t knowing past errors; the squared error that really occurs in time t can, however, deviate widely from the forecast value.

Engle cites McNees[9] who suggests that the inherent uncertainty or randomness associated with different forecast periods seems to vary widely over time and that large and small errors tend to cluster together[10]. Engle notes that these are exactly the properties that the ARCH model is suited to cope with. It allows the variance to change over time and be predicted by past errors.

[8] This is the standard notation for financial series.

[9] McNees, S. K. (1979), "The forecasting record of the 1970s". New England Economic Review, September/October, 33–53.

[10] The clustering of errors is known as volatility clustering, i.e., the state when large (small) proce changes are followed by other larg (small) price changes, but of unpredictable sign (Bollerslev et al., 1992). Volatility itself means either the squared root of the variance or just variance (Engle, 2004).

In some cases, Gauss-Markov assumptions for linear regression are satisfied and ordinary least squares is the best linear unbiased estimator for an ARCH model. However, it does not achieve the Cramer-Rao bound. The maximum-likelihood estimator, which is nonlinear, is more efficient than OLS. Engle (1982) proceeds with the proof and all technical details. He notes that the OLS is the appropriate procedure for estimating ARCH if the disturbances are not conditionally heteroskedastic.

As a test of the presence of the conditional heteroskedasticity Engle proposes the Lagrange Multiplier test. Before I describe the ARCH-LM test in detail, I will mention the BDS test that serves the same purpose ad the ARCH-LM test. Unlike the ARCH-LM test, it is not a test for volatility clustering but rather for general conditional heteroskedasticity, or general non-linear dependance. The null hypothesis is that the random variable is independent and identically distributed. It is important because there are some clearly heteroskedastic processes which do not exhibit volatility clustering since the empirical serial correlations of squared errors approach zero in large samples (Bollerslev et al., 1992).

The ARCH-LM test is done as follows (Engle, 1982, p. 1000).

1. Run the OLS regression and save the residuals,

2. regress the squared residuals on a constant and p lagged values of ε_p^2 and test TR^2 as a χ_p^2. The null hypothesis is that the coefficients of the explanating variables, i.e., the p lagged values of ε_p^2, are zero.

In practise, we try several values of p and examine whether the null hypothesis is rejected or not. We then include p lagged squared disturbances in the ARCH regression model, as does Engle in his study of the variance of the UK inflation (Engle, 1982, p. 1002). We can check the choice by a standard model selection criteria like Akaike (AIC) and the Schwartz information criterion.

1.3.2 Bollerslev's GARCH

In his paper Bollerslev (1986) notes both the success of ARCH modeling but also mentions the rather arbitrary linear-declining lag structure,[11] which should be chosen to avoid

[11] In order to reduce the number of parameters and ensure a monotonic declining effect of more distant shocks, an ad hoc linearly declining lag structure was often imposed in ARCH models, i.e., $\alpha_i = \alpha \frac{q+1-i}{q(q+1)}$ like in many Engle's applications (Bollerslev, 1986, p. 8).

problems with negative variance parameter estimates. Engle (1982, p. 1002) himself has shown such a structure in his paper where he used Eq. (1.13) as a model for the variance of the UK inflation.

$$h_t = \alpha_0 + \alpha_1(0.4\varepsilon_{t-1}^2 + 0.3\varepsilon_{t-2}^2 + 0.2\varepsilon_{t-3}^2 + 0.1\varepsilon_{t-4}^2). \tag{1.13}$$

Bollerslev, an outstanding Engle's student, introduces a general ARCH model called GARCH (General Autoregressive Conditional Heteroskedastic) especially in the light of the problems with the lag structure of ARCH. He aims to allow both for a longer memory (by its definition, see below) and a more flexible lag structure while reaching a more parsimonious model.[12] Even in its simplest forms, GARCH has proven surprisingly successful in predicting volatility (Engle, 2001). The key insight of GARCH is that it recognises that the Eq. (1.12) is simply a distributed lag model for h_t. Thus it is possible to replace many of the past values of ε_t by a past value of h_t (Pindyck & Rubinfeld, 1991). The GARCH(p,q) process is specified by

$$\begin{aligned} &\varepsilon \sim N(0, h_t) \\ &h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i h_{t-i} = \alpha_0 + \alpha(L)\varepsilon_t^2 + \beta(L)h_t. \end{aligned} \tag{1.14}$$

where

$$\begin{aligned} &p \geq 0, q > 0 \\ &\alpha_0 > 0, \alpha_i \geq 0, i = 1, \ldots, q, \\ &\beta_i \geq 0, i = 1, \ldots, p. \end{aligned} \tag{1.15}$$

and L is a back-shift operator. For $p = 0$ the process reduces to ARCH(q) process and for $p = q = 0$ ε_t is a white noise process.

The variance of the GARCH(1,1) model

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1} \tag{1.16}$$

is $\sqrt{\alpha_0/(1-\alpha_1-\beta_1)}$. This formula works only if $\alpha_1 + \beta_1 < 1$, which also assures (weak) stationarity. On the other hand, if this sum is close to one, we say that there is

[12] Bollerslev et al. (1992) compare studies on modeling high-frequency US dollar exchange rate data and say that the simple GARCH(1,1) does better in describing the data than ARCH(12). They say that as ARMA(p,q) model often leads to a more parsimonious specification than AR(p) model, so does GARCH(p,q) compared to ARCH(q) model.

high persistence of shocks in volatility (Franke et al., 1995)[13] of the process. The model really makes sense only if the weights are strictly positive (Engle et al., 2008, p. 4).

GARCH(1,1) uses three components which it puts into a weighted average:

1. the long-run average variance (the constant),
2. this period's news about variance (the ARCH term, ε_{t-1}^2) and
3. the forecast of variance to this period (the GARCH term, h_{t-1}).

Based on this separation, (Engle, 2001, p. 160) gives an example of a trader who knows that the long-run average daily standard deviation of the Standard and Poor's 500 index is 1 %. Yesterday, the trader made a forecast for todays S&P's standard deviation 2 %, which in fact is today 3 %. The trader recognises that today is more volatile than usually, for example because of the arrival of good news concerning the price of oil, and that tomorrow it might be too. On the contrary, the long-run variance lowers his forecast. The trader might do a simple average, the forecast would then be $\sqrt{(1+4+9/3} = 2.16$. However, notes Engle, rather than weighting these values equally, for daily data it has been found that weights (0.02, 0.9, 0.08) are much more accurate, decreasing the forecast to 2.08. What the GARCH model does is that it models the variance of residuals in time t on the basis of $t-1$ information. By repeating this process we can construct long-horizon forecasts. For the GARCH(1,1), the two-step forecast is a little closer to the long-run average variance than is the one-step fore cast, and, ultimately, the distant-horizon forecast is the same for all time periods as long as the condition of stationarity holds. This is the the unconditional variance. Thus, we can say that GARCH models are mean reverting and conditionally heteroskedastic but have a constant unconditional variance (Engle et al., 2008, p. 5).

Continuing with Eq. (1.16), Pindyck & Rubinfeld (1991) mention that as long as long as $\beta_1 < 1$ we can rewrite it as

$$h_t = \frac{\alpha_0}{1-\beta_1} + \alpha_1 \sum_{j=1}^{\infty} \beta_1^{j-1} \varepsilon_{t-j}^2. \tag{1.17}$$

In other words, the variance today depends on all past volatilities, but with geometrically declining weights.

[13]Taken from the online version of their textbook, available at `http://www.quantlet.de/mdstat/scripts/sfe/html/sfenode67.html`.

Estimation of the GARCH model is done by maximum likelihood. The idea is that we try to find such parameters for the model that maximize the matching between real values and the fitted values. The only difference from Engle's derivation of ARCH estimation is the inclusion of the recursive part based on h_t. To start up the recursion, we need pre-sample estimates of h_t and ε_t^2, $t \leq 0$. Bollerslev uses the sample analogue $T^{-1} \sum_{t=1}^{T} \varepsilon_t^2$.

Testing of GARCH presence is done the same way as testing of ARCH presence.

As for ARCH, the fitted values of ARCH modeling, $\hat{h}_t$, are the one-step-ahead forecasts of variances. How are they obtained, practically? Imagine we have a time series of returns on an asset r_t and an initial set of parameters α_0, α_1 and β_1 (result of a guess, intuition or experince) for GARCH(1,1) model. Now we can start up the GARCH updating formula. To estimate h_2, we

1. set a reasonable estimate of the long-term variance to α_0,
2. from r_1 we take the squared residual (the residual comes from the estimated mean equation) and use it both as
   (a) the variance forecast, h_1, and
   (b) the last news about variance.

Then we can calculate the estimate of h_2. It serves then as input to the calculation of the estimate of h_3, together with ϵ_2^2. The method of maximization of the likelihood function is a systematic way of adjusting the parameters α_0, α_1 and β_1 so asto give the best fit, i.e., to make the forecast as close to the variance of the next return as possible (Engle, 2001, p. 160).

Diagnostic checking of a fitted GARCH model can be done as follows (Engle, 2002).

- The best model minimizes AIC and Schwarz criterion.
- Assuming we model returns r_t, then standardized returns $r_t/\sqrt{h_t}$ should no longer show significant volatility clustering, which one can test by the Box-Ljung statistics on squared returns.

The goal of the volatility analysis must ultimately be to explain the causes of volatility Engle (2001, p. 166). GARCH model is not a close set of variables. It is a flexible and amodular system. We can include in it external regressors relevant to the volatility we analyse. GARCH has many extensions, i.e., models that are based on it. For example,

exponential GARCH (EGARCH)[14] measures volatility by a multiplicative function of lagged error terms, captures the asymmetry in volatility induced by big positive and negative asset returns , and puts no restriction on the parameters of GARCH and ARCH terms (Tsay, 2002, p. 80). Threshold ARCH and GARCH (TARCH)[15] allow for different effect of error terms on volatility by setting disjoint intervals, for example for negative and positive error terms a threshold is set to zero. Thus it can be used for the analysis of particularly stock returns where 'bad news' increase volatility more than 'good news'. By including conditional standard deviation as another regressor into the mean equation, GARCH-M (in mean) allows for the analysis of for example risk on price. There are many other extensions.[16]

1.3.3 Financial practise

The basic tool of applied econometricians is OLS but increasingly, they are asked to forecast and analyze the size of errors of models. These issues concern volatility and standard tools in this field have become ARCH/GARCH models (Engle, 2001, p. 157). Contrary to weighted least squares, heteroskedasticity robust coefficients or other ways of correcting for heteroskedasticity,[17] ARCH models[18] treat heteroskedasticity as something to be modeled. The particular use of the ARCH family of models is in financial applications where the dependent variable is the return on an asset (portfolio) and the variance of the return, or its standard deviation, represents the risk level (Engle, 2001, p. 158).

ARCH effects have generally been found to be highly significant in equity markets (stocks and its indices, future markets) and in exchange rates; ARCH has often been used for modeling interest rates. Let's name some empirical regularities of these assets

[14]Introduced in Nelson, Daniel B, 1991. "Conditional Heteroskedasticity in Asset Returns: A New Approach," Econometrica, Econometric Society, vol. 59(2), pages 347-70, March.

[15]Introduced in Zakoian, J.M., 1994. "Threshold heteroskedastic models". J. Econ. Dyn. Control 18, 931–944, and Glosten, L.R., Jaganathan, R., Runkle, D., 1993. "On the relation between the expected value and the volatility of the normal excess return on stock". J. Finance 48, 1779–1801.

[16]For a survey and a technical view on the models, see Bollerslev and Engle and Nelson, 1994. "ARCH Models", Chapter 49 of the "Handbook of Econometrics". Available at `http://faculty.chicagogsb.edu/jeffrey.russell/teaching/timeseries/handouts/GARCH.pdf`. A more intuitive survey is in a well readable Engle et al. (2008).

[17]In the presence of heteroskedasticity, the regression coefficients for an ordinary least squares regression are still unbiased, but the standard errors and confidence intervals will be too narrow, giving false image of precision (Engle, 2001).

[18] By "ARCH models" I mean the generalization of ARCH (GARCH) and its extensions.

returns volatility that ARCH models should capture; based on Bollerslev et al. (1992).

- **Thick tails**, or heavy tails or leptokurtic,[19] illustrated in Fig. 1.1. Compared to normally distributed variable, a variable with a leptokurtic distribution has a higher probability to be both closer to the mean and to have an extreme value.

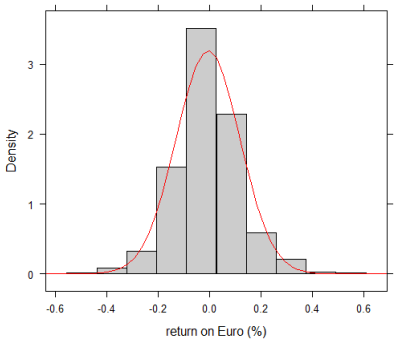

Figure 1.1: Histogram of returns on the CZK/EUR exchange rate from Jan 2006 to Feb 2007 with an imposed line representing a normal distribution with mean and standard deviation same as the euro series.

- **Volatility clustering of returns** means that there are (quite long) periods of high and low returns. It can ben understood as news clustering (Engle et al., 2008, p. 8).[20] Bollerslev (1986) notes that it may show up as significant autocorrelations of squared returns. It is illustrated in Fig. 1.2 which plots returns on Standard and Poors 500 Index in the 1990's. The returns are certainly not distributed identically.

- **Leverage effects**. Standard GARCH models assume that positive and negative error terms have a symmetric effect on the volatility. In practice, however and particularly in stock returns, 'bad news' increase volatility more than 'good news'. Therefore, standard GARCH model has been extended to reflect this assymetry, most notably by the the threshold GARCH (Franke et al., 1995).

- During **non-tradign periods** information accumulate and after opening of the market it influences prices volatility: if we assume a constant information accumulation rate, than the volatility from Friday close to Monday Close should be three

[19] Positive kurtosis.

[20] Engle himself has instroduced a tool that measures the impact of news on volatility, the impct news curve. See Engle, Robert F. & Ng, Victor K., 1993. "Measuring and Testing the Impact of News on Volatility," Journal of Finance, American Finance Association, vol. 48(5), pages 1749-78, December.

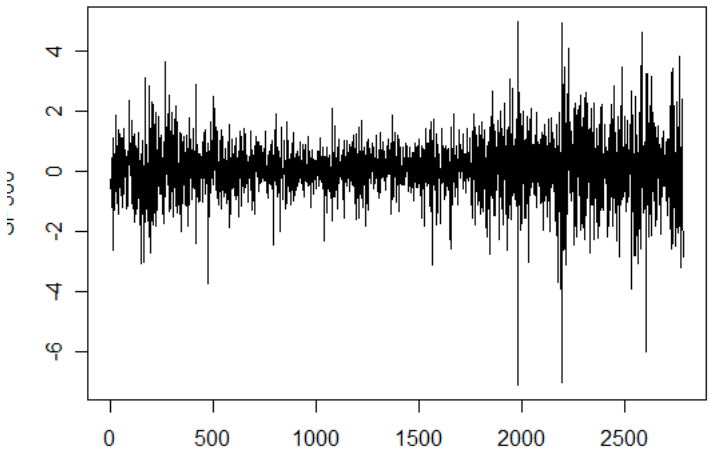

Figure 1.2: Returns of the Standard and Poors 500 Index in the 1990's.

times higher than from Monday close to Tuesday close. However, this is not the fact in reality. After weekends, volatility is only slightly higher.

- Forecastable events may increase volatility. For example, companies earnings announcements or the announcements of the decision making bodies of central banks.

- **Co-movements in volatilities** have been recognised not only within a market, but also across different markets. For econometricians this is positive because they may hope that a few common factors may suffice to explain much of temporal variation in the conditional variations of assets returns. An extension of the GARCH model for the study of the relations between the volatilities and co-volatilities of several markets is the multivariate GARCH (MGARCH).[21]

Until the introduction of ARCH, the primary descriptive tool for variance was the rolling standard deviation which assumes equal weights for all the recent observations it uses. However, the assumption of equal weights for the included observations and zero weights for those not included might seem unattractive. It surely did to Robert Engle whose ARCH model estimates the weights by MLE and allows for the inclusion of as many terms as needed.

The success of the ARCH family of models is attributable mainly to the applications in finance. They are well suited for modeling volatility of returns, whose time series are

[21]For details, see Sébastien Laurent & Luc Bauwens & Jeroen V. K. Rombouts, 2006. "Multivariate GARCH models: a survey," Journal of Applied Econometrics, John Wiley & Sons, Ltd., vol. 21(1), pages 79-109.

almost unpredictable, have large number of extreme values (so called *fat tails* in the plot of the density function of the returns series) and show both stable and very volatile periods. Engle (2004) notes that GARCH(1,1) is the workhorse of financial applications and that it is able to describe volatility dynamics of almost any financial returns series.

If I should recommend the reader an ideal source of information on GARCH, I would definitely recommend Engle et al. (2008).

1.3.3.1 Example: Modeling volatility

Following Engle's example, let's try to estimate volatility of a time series (Engle, 2004). We will use the CZK/EUR exchange rate measured daily from January 4, 2005, to February 14, 2007[22]. The series is plotted in Fig. 1.3 and I will refer to it as the euro series.

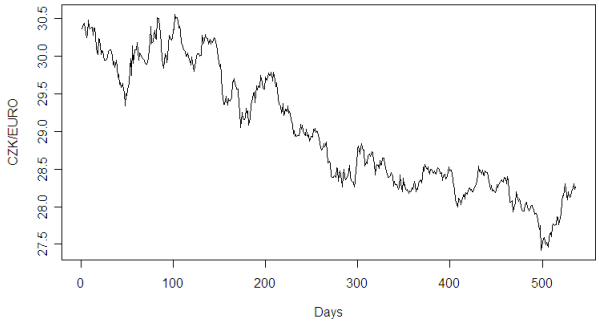

Figure 1.3: CZK/EUR exchange rate measured daily from January 4, 2005, to February 14, 2007.

The returns from the euro series are plotted in Fig. 1.4. It was constructed by taking the first difference of the logarithm of the euro series.

The Nobel Commitee's report (2003) illustrates volatility by plotting a 20-day moving average of the squared returns. For the euro series, it is demonstrared in Fig. 1.5.

Let's try to do what is called estimating historical volatility. It is based on the rolling standard deviation of returns. For various rolling windows, it is plotted in Fig. 1.6. The problem is that we do not know which rolling window we should choose.

The GARCH model supposedly provides a solution to this dilemma. We can apply it to the euro series.

[22]It is the series I will use in the empirical part of this study. The observations were obtained via Reuters.

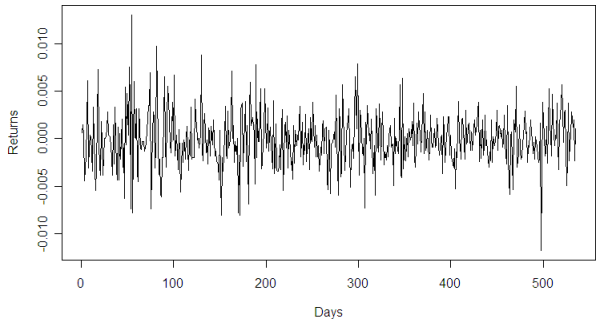

Figure 1.4: CZK/EUR exchange rate returns.

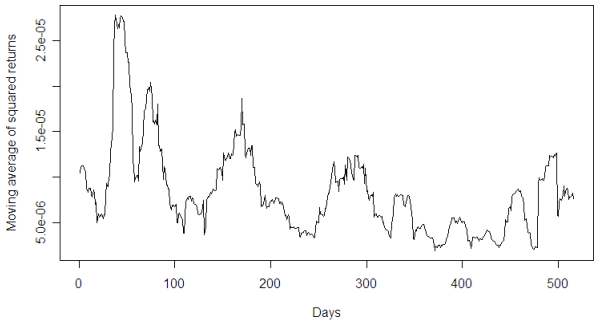

Figure 1.5: 20-day moving average of the squared returns on CZK/EUR exchange rate.

Let's take up now to what was described in Section 1.2 and follow the procedure of estimating the GARCH model described in (Horváth, 2007).[23] Generally, we should follow this way:

1. Fit 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. Test for the GARCH effects presence in residuals from the ARIMA model using the ARCH-LM test.

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

We can now try to model the volatility of the euro series.

[23]For statistic and econometric computing I use R, the free software which is available for download at `http://www.r-project.org/`. However, for the empirical analysis of the Czech National Bank's communication, I have to switch to the commercial software Eviews since up to May 2008, there is no way in R to how to estimate the GARCH model with external regressors in the variance equation.

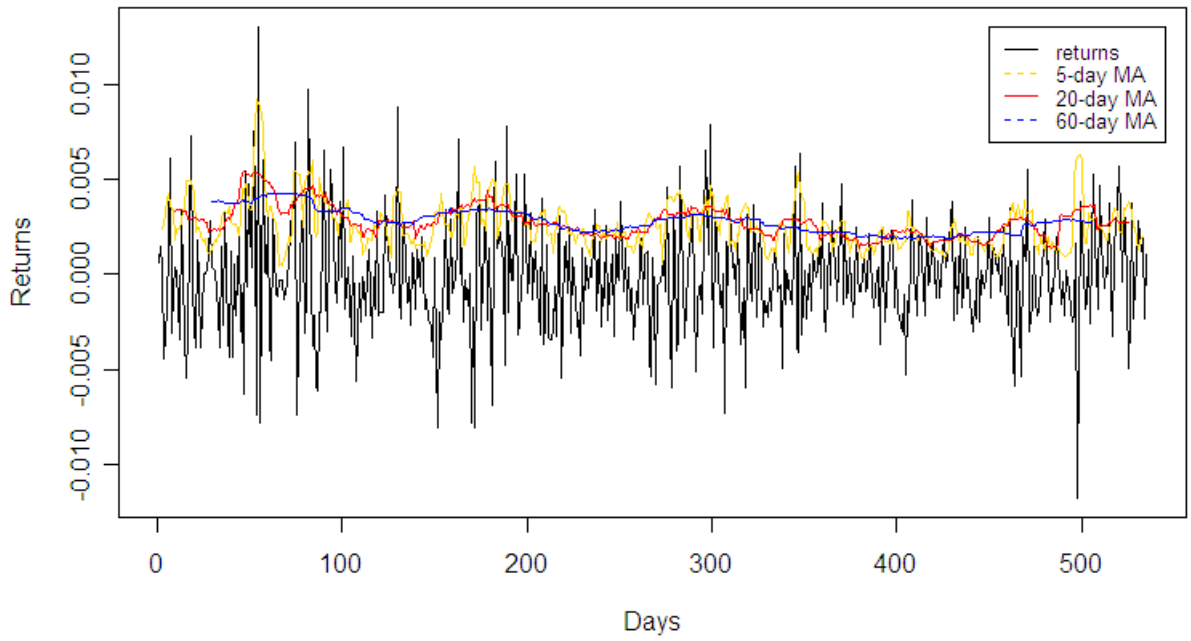

Figure 1.6: Rolling standard deviation of returns of the euro series.

1. To make the euro series stationary we differentiate it. The visual inspection of the autocorrelation and partial autocorrelation functions of the series leads us to ARIMA(0,1,1). P-value of the Box-Ljung's Q statistic is 0.9, which confirms the correctness of the chosen ARIMA model.

2. The ARCH-LM test for the GARCH effects in residuals presence gives p-value 0.001, rejecting the hypothesis that there ARE no GARCH effects.

3. Estimating GARCH model on residuals from ARIMA(0,1,1) yields parameters 0.03 for the long-term (unconditional) variance, 0.04 for the last news measured as the square of the yesterday residual and 0.93 for the last forecast. In Fig. 1.7 we see the residuals series from ARIMA(0,0,1) plotted against 2 conditional standard deviation predictions of the differentiated euro series from the GARCH estimation.

1.3.3.2 Example: Volatility of returns on the CZK/EUR exchange rate

Let's create a time series of returns on the CZK/EUR exchange rate measured in percents[24]. Box-Ljung tests gives the p-value only 0.020 which raises suspicion of a non-

[24]The prices to returns conversion is done by subtracting logarithms of the euro exchange rate, for example $ret_{100} = \log\left(\frac{CZKEUR_{100}}{CZKEUR_{99}}\right) = \log(CZKEUR_{100}) - \log(CZKEUR_{99})$.

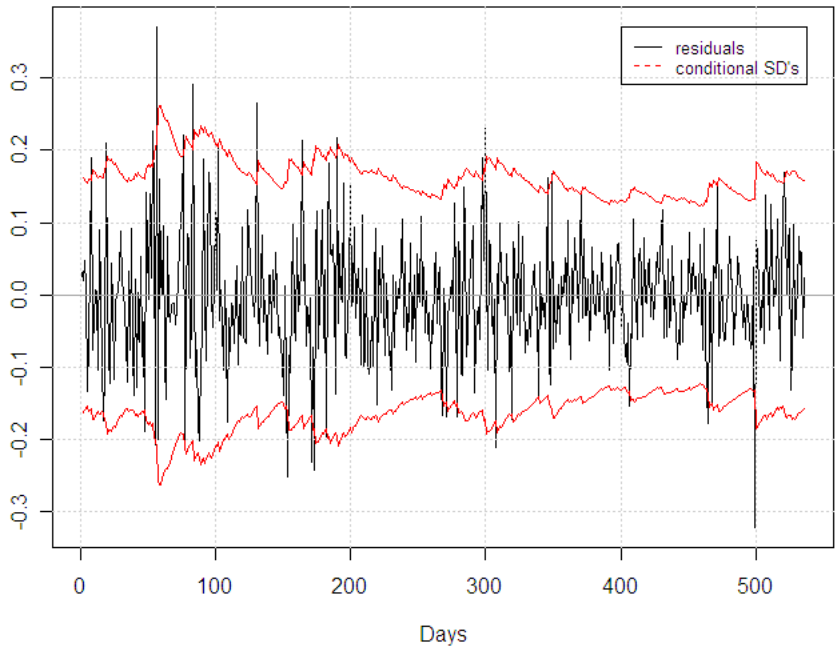

Figure 1.7: Residuals from ARIMA(0,1,1) on the CZK/EUR exchange rate and the GARCH estimate of its volatility.

stationary process. To ensure that the series is stationary, let's difference it[25]. The p-value is now less than $2 \cdot 10^{-16}$. The p-value from the ARCH-LM test on the presence of GARCH effects in the differenced returns series is also less than $2 \cdot 10^{-16}$. The estimated GARCH(1,1) process is plotted in Fig. 1.8.

1.3.3.3 Example: Value at Risk

Financial services institutions and banks estimate risk of their portfolios by various measures, but the typical one is called Value at Risk (VaR). The VaR is a way of measuuring probability of losses that could occur to a portfolio. *The 99% one day VaR* is a value of money that, with the declared probability of 99 %, will be higher than any possible loss on the next day. For example, if the 99% one day VaR in a company is €50,000, than the particular risk management office asserts that only in one day out of hundred losses will be higher than €50,000 (Engle, 2004, p. 341).

The 99 % VaR of a portfolio can be estimated using GARCH. One estimates the best model from historical data and then calculates the standard deviation for the following day. Then it is needed to make an assumption about the probability distribution of

[25] $ret_{100} - ret_{99} = \log\left(\frac{CZKEUR_{100}}{CZKEUR_{99}}\right) - \log\left(\frac{CZKEUR_{99}}{CZKEUR_{98}}\right) = \log\left(\frac{CZKEUR_{100}CZKEUR_{98}}{CZKEUR_{99}^2}\right)$

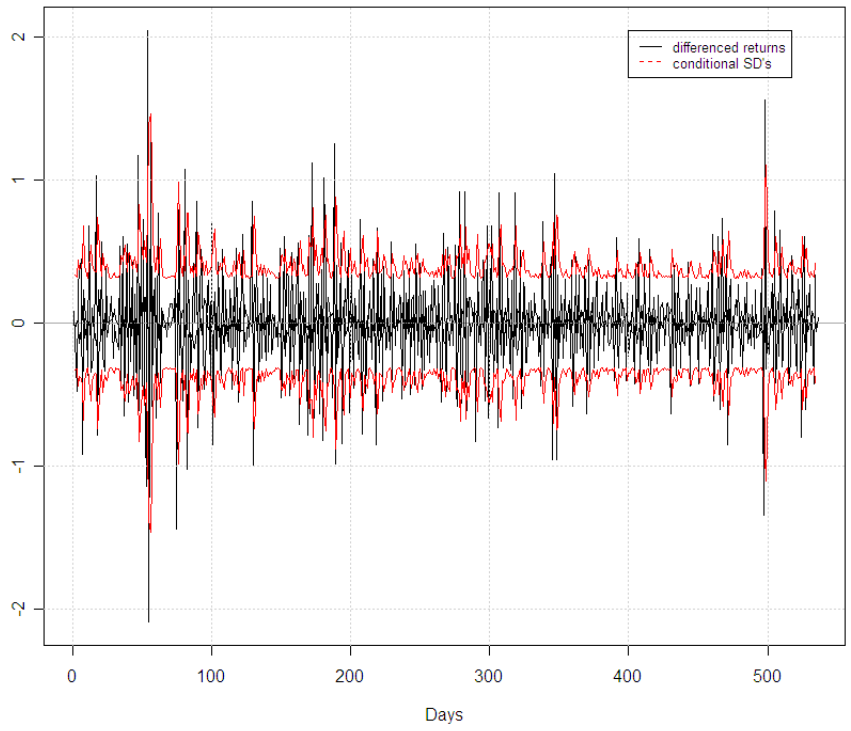

Figure 1.8: Differenced euro returns series and the predicted conditional standard deviations.

returns of the portfolio to determine the value of the first percentile of the distribution of returns. The higher is the standard deviation, the higher the loss may be. For example, is the distribution is assumed to be normal, then the 1 % point is –2.33 standard deviations from zero. The value at risk (a percent of the given portfolio) is the product of the standard deviation and the 1 % point (Engle, 2004, p. 342).

Chapter 2

Central banks communication: A survey

In this chapter I introduce the topic of central banks communication by surveying recent literature. I will mention several phenomena of the communication and present several empirically proved answers to the question whether central banks communication has influence on financial markets.

2.1 Introduction

The communication of central banks has already been in the center of academicians interest for several years. The reason of the attractiveness of the topic is the fact that altough central banks monetary policy has a short-term effect on economic activity, a long tradition of low inflation environment can positively influence economic growth. Central banks have been given a mix of economic and monetary policy targets. For example, the Federal Reserve System should seek to promote the goals of maximum employment, stable prices, and moderate long-term interest rates.[1] The primary objective of the European Central Bank (ECB) is to maintain price stability and, without prejudice to the objective of price stability, the general economic policies in the European Union.[2] The primary objective of the Czech National Bank (CNB) is also the maintaining the price stability

[1]Source: Federal reserve Act, Section 2A—Monetary Policy Objectives. Available at `http://www.federalreserve.gov/generalinfo/fract/sect02a.htm`.

[2]Source: Treaty Establishing the European Community, Article 105 (1). Available at `http://www.eel.nl/documents/ectreaty/ecomon.html`.

and, without prejudice to the primary objective, the support of the general economic policies of the Czech Government.

Typically, central banks have at their disposal only short-term interest rates which they charge on borrowings and pay for deposits. However, since their objective usually concerns such long term issues as stable prices, an inflation target or long-term growth, central banks must have another channel of influence that would enable them to reach their objectives. The practical stance of a central banker concerning the problem of short term tool and long term objective is clear: "Control of the federal funds rate[3] is (therefore) useful only to the extent that it can be used as a lever to influence more important asset prices and yields like stock prices, government and corporate bond yields and mortgage rates, which in turn allow the Fed to affect the overall course of the economy." (Bernanke, 2004). Woodford (2005, p. 402) speaks in the same manner, asserting that it is the expected future path of short-term interest rates over coming months and even years that should matter for the determination of the price of assets like longer-term interest rates, equity prices, and exchange rates.[4] It is clear that the market expectations of the future path of monetary policy are crucial for the policy's effectiveness (Amato et al., 2003, p. 2).

The counterpart of the short-term interest rates is the communication of the central banks, whose objective according to Smaghi (2007) is efficiency and accountability; the former in sense of achieving the objectives, the latter in sense of credibility. In the sense of Marcel Fratzscher's definition of central bank transparent communication, by removing assymetric information between market and monetary policy makers, communicating the expected development of central bank's policy may anchor long term policy expectations of markets, thus influencing investment and spending decisions in the economy and long-term interest rates reaction (Reeves & Sawicki, 2007).[5] According to Ehrmann & Fratzscher (2007), communication can partly substitute policy action[6] and is generally

[3]The federal funds rate is the only interest rate that the Federal Reserve System directly controls. It is the rate of an overnight facility.

[4]There is a paper by Roman Matousek which examines the effect of changes in the two-week repo rate on short and long–maturity market interest rates: Roman Matousek, 2001. "Transparency and Credibility of Monetary Policy in Transition Countries: The Case of the Czech Republic," Zagreb International Review of Economics and Business, Faculty of Economics and Business, University of Zagreb, vol. 4(2), pages 91-104, November.

[5]Citing Ehrmann, M., Fratzscher, M., 2005. "Central Bank Communication: Different Strategies, Same Effectiveness?" European Central Bank Working Paper 05–488 Frankfurt.

[6]Such a channel of central bank's influence is called *open-mouth operations*

considered to be a powerful tool to move financial markets. It is logical then that central banks introduce strategical communication policies.

Ehrmann & Fratzscher (2007, p. 7) offers a general look on the options of the communication setup. Generally, it occurs throw a commitee (press conferences, official publications, minutes) and throw individuals, whose comments are more flexible and occur in between regular meetings of commitees. The second distinction is the amount of information and the level of diversity of views in banks decision making bodies that is going to be made public. The former encompasses information on monetary policy strategy, i.e., the future path of interest rates, and economic outlook made by the banks teams of analysts and researchers. The latter is the choice of dispersion level in the spectrum of opinions that go public; members thus might represent their own opinion and show the full spectrum of views in the commmitee, or they might respect a consensual style of communication. There are also banks where decisions are taken by individuals, for example the Reserve Bank of New Zealand. Ehrmann & Fratzscher (2005) analyze predictability of decisions of central banks bodies and the reaction of financial markets to them, in relation to the banks communication and decision-making strategy. They have found that the result is the same for the Federal Reserve, which pursues an individualistic communication strategy and a collegial decision-making, and the ECB, which is collegial both in its communication and in its decision-making.

2.2 The step towards transparency

The conduct of monetary policy has substantially changed since the early 1990s. It has gone from secrecy towards openness about monetary decisions, objectives and strategy, and economic outlook, as Woodford (2005) describes the past of central bankers communication: “Central banking was shrouded in mystery.”

However, it is not only the will of central banks, accelerated by the academia, who have filled up the banks communication channels. The demand for information has been steadily increasing, based on the fact that markets allocate resources more efficiently with more information, and that there are more financial instruments to be priced both in type and volume. The flow of information has been further stirrud up by the rapid technological progress of information technology, mainly of the Internet, that made the question of providing information, whether on the level of business to business or business

to customer, a low-cost issue. On the other hand, it has contributed to a higher level of information noise (disorder).

Another source of the strengthening of the information flow from central banks, or transparency, has been the issue of concentration of power in a single, independent institution. "Greater support for independent central banks with goals set by the political process was one of the results of the lessons of the great inflation of the 1970s. But an arm's-length distance from immediate political pressures requires accountability and reporting to elected representatives," notes Kohn (2005), a member of the Board of Governors of the Federal Reserve System.

Mentioning independency, a question may arise whether it is connected to communication. Independency concerns the influence of outsiders, including politicians, on monetary policy, which is, in majority of countries, deemed to be under the supervision of a central bank that pursues its objectives that are subject, among others, mainly to the expectations of market participants, as was argued earlier. In case of independent central banks, it follows from law that the Government, or politicians in general, should not try to make the central bank leave its focus solely on their primary target. Since the power of Government is obviously high, it should be aware of stirring up markets expectations by commenting interest rates, if it wants to respect the idea of independent central banks, as it is laid down, in case of he Czech Republic, in the Act on the CNB. "In most countries, the political authorities never communicate in public on issues related to monetary policy, even less on interest rates," notes Smaghi (2007) and puts forward reasons why it should be correct that way.[7] First, a cacophony of statements on the design of monetary policy coming from different institutional actors adds unnecessary 'noise' to the information flow leading possibly to the detriment of monetary policy's overall effectiveness. Second, as almost all statements form outside of the central banks call for monetary loosening, central banks may, for reputational reasons, feel need to follow an unnecessarily firm stance.

It is interesting to note his opinion on the correct 'solution' of an oil or food price shock form the central bank's point of view. "Communication is key. It has to raise awareness of the inflationary problem but without causing alarm because the shock can remain

[7]His own experience is that in the Eurosystem (Eurozone), politicians often comment on ECB's Executive Board strategy and (future) steps. For example, read "Faulty Sarkonomics", September 27, 2007, in The Economist available at `http://www.economist.com/opinion/displaystory.cfm?story_id=9867011`. He notes that it is the institutional environment, in which politicians attack ECB's independence, that forces ECB not to publish Minutes from its Executive Board's meetings; ECB claims that the Executive board takes decisions by unanimity (Blinder et al., 2008).

temporary and be re-absorbed if agents behave properly. If the central bank's message fails to convince agents not to engage in second-round effects, the temporary inflationary pressures may become permanent. The central bank has then no other choice than to tighten monetary policy to counteract these pressures," says Smaghi (2007).

The ideal situation concerning public performance of central banks according to King (2000) is that overyone knows, what it wants to do and will do: "Transparency should lead to policy being predictable. Hence a successful central bank should be boring; rather like a referee whose success is judged by how little his or her decisions intrude into the game itself." Rozkrut et al. (2007, p. 194) speak in a more particular manner: provided transparency and no assymetric information between markets and policy makers, central banks decisions should be in line with market expectations. The benefit of transparency is supposed to be that with it, it is less costly to accomplish given objectives.

The main objective in majority of countries is a stable price level. Chortareas et al. (2001) shows that greater transparency of central banks is associated with lower inflation. Ehrmann & Fratzscher (2007, p. 124) cite a general conclusion of Blinder (1998)[8] that transparency can enhance the effectiveness of central banks policy.

However, transparency concerns not only the topics (macroeconomic data, and analytical power of extraordinarily quality, and monetary policy strategy) but also the limited absorbing capacity of the receivers of the communication (Gábriel & Pintér, 2006, p. 5). According to Kohn (2005) it is not clear how markets incorporate information and whether more is necessarily better; there are open questions about herding behavior, information cascades, multiple equilibria, and the amount of investment in financial research and consequent superior information. Kohn mentions two reasons why the pace of increasing transparency should be constrained. First, it is the possibility of central bank communication being misunderstood since it is generally aggravated by the complexity of the monetary policy and by the institutional setting of the particular banks. Secondly, transparency may harmfully interact with monetary policy decisions. Simply said, a statement, an outlook or opinion released into public may perspectively bind up hands of central banks decisionmakers by interfering with the otherwise most effective way of achieving the policy objectives. A release of information tunes market expectations and a succeeding contrary policy move may roil markets and actually impinge on welfare. The effects of such inconsistency have been measured by Rozkrut et al. (2007, p. 185).

One way of reducing inconsistency in communication is to have a decisionmaking

[8]Blinder, A., 1998, "Central Banking in Theory and Practice", MIT Press Cambridge MA.

commitee in which decisions are taken in consensual manner and the members do not conduct as sovereign individuals. An example of such a commitee is the Executive Board of the ECB, contrary to the Board of the Federal Reserve System. Smaghi (2007), a member of the ECB's Executive Board in 2008, explains princeples that, according to him, should apply in order to not to allow markets be disrupted by *noise*, standing against *information*. Central bankers should be aware that their communication moves the markets; they should communicate only in a case of misalignment between market prices and expected central bank action; such a communication should be coordinated and occur through a single channel, coming from the institution's top decision-making body. It might happen that markets are accidentally moved; then a communication mistake was probably made and a corrective step should be made.

The most classic article opposing the optimistic views concerning the central banks communication was written by Amato et al. (2003). The authors argue (page 19) that there is a possibility that public information may suppress the private information of individual agents, disrupting the communicative channel of economic fundamentals. Blinder et al. (2008, p. 14) refuse the arguments that emphasize the negative side of central bank communication, except of issues on which a central bank receives noisy signals itself.

Jarmuzek et al. (2004) evaluated transparency of monetary policy of the central banks of the Czech Republic, Poland and Hungary, and compared it to that of ECB. They have used an institutional transparency index by Eijffinger and Geraats based on a survey. It touches question on the amount and kind of information published, on procedural and policy transparency. The behavioural transparency evaluation is based on the Haldane-Read model which analyses shifts in forward yield rates following announcements about official interest rates (changes). By the institutional definition, CNB is the most transparent bank, even outperforming the ECB. By the behavioural index, the winner is the National Bank of Poland. The National Bank of Hungary scores last, mainly because of the duality of its primary objective which was actual in 2004 and misguided market players, as will be documented later. CNB has been adviced by the authors to expand the range of economic data available for public.

Finally, which central banks are pioneers in transparency? "The Reserve Bank of New Zealand and the Bank of England were early and enthusiastic converts to greater transparency, and the central banks of Norway and Sweden may now be in the vanguard," (Blinder et al., 2008).

2.3 Empirical studies

The research in central bank communication studies the relation of the communication and economy. To take a distant while detailed perspective, I will present the model by Blinder et al. (2008) which is the backbone of their important surveying paper.

Blinder et al. (2008, p. 3) claim that "the view that monetary policy is, at least in part, about managing expectations is by now standard fare both in academia and in central banking circles". Comparing this with the situation in 1980s, the authors call the progress a revolution in thinking.

Blinder et al. (2008, p. 4) present two ways of managing expectations, 'creating news' and 'reducing noise'. Studies of the prior focus on how, e.g., the central bank's pronouncements influence expectations and therefore move asset prices, while studies of reducing noise focus, e.g., on how central bank talk increases the predictability of central bank actions, which should in turn reduce volatility in financial markets. "In both cases, the central banks presumed objective is to raise the signal-to-noise ratio," say the authors.

Blinder et al. (2008, p. 6) give a theory of how is the overnight rate embedded in the longterm decision-making. According to the theory of the term structure, the n-th day interest rate should be

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

where r_t is the current overnight rate, r^c_{t+1} is todays expectation for the overnight rate tomorrow (and so on for $t+2, \ldots$), α_n is a term premium, which might be stochastic, therefore the $\varepsilon_{1,t}$.

Then the authors develop a macroeconomic framework illustrating the influence of the central banks communication, marked by the vector s_t; r from equation 2.1 is the short term rate and R is the long term rate.

1. The aggregate demand y_t is given by r, R, expected inflation π^e_t and other factors:

$$y_t = D(r_t - \pi^e_t, R_t - \pi^e_t, \ldots) + \varepsilon_{2,t}. \tag{2.2}$$

2. The aggregate supply has the form of the New Keynesian Phillips curve:

$$\pi_t = \beta E(\pi_{t+1}) + (y_t - y^*_t) + \varepsilon_{3,t}, \tag{2.3}$$

where π_t is inflation and y_t y^*_t are actual and potential output, respectively.

3. The last equation is a central bank reaction function, e.g., the Taylor rule:[9]

$$r_t = G(y_t - y_t^*, \pi_t, \pi_t^*, \ldots) + \varepsilon_{4,t}, \tag{2.4}$$

where π_t^* denotes the central bank's inflation target.

Blinder et al. (2008, p. 8) define the conditions under which there is no space for the central bank's communication: the economic environment is stationary, i.e., Eq. (2.2), Eq. (2.3), and 2.4 do not change over time, the central bank is credibly commited to its policy rule defined by equation 2.4, and the expectations are rational. On the other hand, conditions, under which central communication can matter, are: non-stationarity of economy or of the policy rule, and either non-rational expectations or informational assymetry between public and the central bank. To make the model more realistic, authors embed the assumption of rational expectations into the model in a form of an explicit specification of the expected interest rates:

$$r_{t+j}^e = H_j(y_t, R_t, \ldots, s_t) + \varepsilon_{5,t}. \tag{2.5}$$

The effect of any central bank action takes at least three faces:

- the effect of the overnight rate on the aggregate demand in Eq. (2.2),
- the effect of cental bank's signals s_t on expected future short rates r_{t+j}^* in Eq. (2.5)
- the effect of the overnight rate changes, defined in Eq. (2.5), on the expected future short rates, defined in Eq. (2.1), and the following effect on long rates and therefore onto demand (equation 2.2), influenced by s_t.

If the first type of a central banks actions has small effect, and the authors think that it is the case, then the core of monetary policy lies in communiucation. That is why monetary policy is often called "(art of) managing expectations" (Blinder et al., 2008, p. 12). The authors then proceed in their survey in a way based on the model. They ask how does s_t looks like in reality, how do its parts influence interest rates, stock prices

[9]The Taylor rule defines the monetary policy rule for central banks. The interest rate is defined by $i_t = \pi_t + r_t^* + a_\pi(\pi_t - \pi_t^*) + a_y(y_t - \bar{y}_t)$, where r_t^* is the assumed equilibrium real interest rate, π_t^* is the inflation target, and $\bar{y}_t$ is the potential output. The original article is in Taylor, John B., 1993. "Discretion versus policy rules in practice," Carnegie-Rochester Conference Series on Public Policy, Elsevier, vol. 39, pages 195-214, December.

and exchange rates and by surveying literature they try to find out whether it is true, as the model suggests, that skillful communication can raise the signal-to-noise ratio, reduce financial market volatility and lead to better monetary policy outcomes.

Up to now there have been posed many hypothesis in the empirical studies. The typical example of a hypothesis is the question whether and how various types of communication (the vector s_t from previous paragraphs; differing for example by content, communication channel, timing) influence prices of financial assets. Another topic are indices classifying particular banks qualities like consistency of talk and acts, predictability of decisions. A comprehensive survey of empirical literature can be found in Gábriel & Pintér (2006, p. 35) (contains especially particular empirical results) and in the already mentioned survey by Blinder et al. (2008) that takes a rather theoretical stance but still very effective.

A respected duo of economists, Marcel Fratzscher and Michael Ehrmann, have published several studies of central bank communication; in (Ehrmann & Fratzscher, 2007) they realized the analysis of the market influence of the comments of the members of decision-making bodies of the Federal Reserve, the Bank of England and the European Central Bank in the period from 1997 to 2004. By comments, they understand any written or oral expression of opinion published in between pre-scheduled events like press conferences of the banks boards. As a source of data, they used Reuters News, a source often used by the financial world, thus building a real-time database with the perspective of receiers of the banks communication. Following an influential study by Kohn & Sack (2003) they separated statements referring to the monetary policy inclination from those covering the economic outlook, and assigned them values to make the econometric analysis possible:

$$C_t^{EC} = \begin{cases} +1 \\ 0 \\ -1 \end{cases}, C^{MP} = \begin{cases} +1 \\ 0 \\ -1 \end{cases},$$

where, for economic outlook, 1 is stronger outlook and -1 weaker, and for monetary policy inclination, 1 is tightening and -1 easing. To make the econometric analysis as real as possible, the authors included a large number of controlling variables in their EGARCH model. First, they examined whether there is a systematic pattern in timimg of communication. They have found that on the days immediately prior to the meetings of the banks boards, intensity of communication declines, and that the intensity of communication is generally higher before than after the meetings. Further, they examined whether more communication occurs prior to meetings at which interest rates are

changed. A very significant positive result has been found in case of the Federal Reserve while ECB's communication has been found virtually equally intense. The authors of the study suggest that the reason lies in several factors: ECB communicates with the highest frequency and usually consistently and uniformly across its Governing Council. As a consequence, there is no noeed of intensifying communication. Secondly, they focused on the question whether various assets prices (bonds of maturities ranging from 3 month to 20 years, equity prices, exchange rates and inflation expectations derived from inflation-indexed bonds) change thanks to the central bank communication. They have shown that mainly short-term bonds prices are significantly responsive. In various combinations of situations, communication moves prices maximally by 3 basis points. Finally, they examined responsiveness of prices to communication differenced by content, i.e., by the stance against, or in line with last interest rate change. Markets take into aaccount the fact, that some central banks profess collegiate communication strategy while others respect individual opinions. Thus, it has been shown that "ECB's communication that is leaning against the policy stance can change interest rates by up to 7 basis points for the intermediate maturities," contrary to the FED's communication that does not move prices of bonds over 6-month maturity at all. We can say that markets differ betwen the "communication of central banks" and the "communication of its members", the latter being less trustworthy or worth action.

To sum up, Ehrmann & Fratzscher (2007) have shown that markets respond strongly to inter-meeting communication of central banks and most strongly prior to interest rate changes. An interesting result is that the "UK markets are much less responsive to communication overall", confirming the opinion of King (2000), the Bank of England's Governor, that "central bank communication should not create news itself".

Contrary to the results of Ehrmann & Fratzscher (2007) for the most developed and big countries, Gábriel & Pintér (2006) have found that the relation between communication and parallel changes in short term interest rates in Hungary is weak. They explain it by the character of the Hungarian economy, which is small and open, and periods of inconsistency among the communication of members of the Monetary Council, the governing body of Magyar Nemzeti Bank (MNB). Gábriel and Pintér created 12 dummy variables along the dimensions of channel (verbal/written), target (exchange rate, monetary policy, economic outlook) and content (positive, negative) of the MNB's communication and used them in the GARCH(1,1) specification in Eq. (2.6) and Eq. (2.7) to estimate the effect of

communication on volatility of various assets prices.

$$y_t = c + \sum \alpha_i \cdot communication\_dummy_{it} + \sum \beta_i \cdot control\_\text{var}iable_{it} + \varepsilon_t, \qquad (2.6)$$

$$\sigma_t^2 = \omega + \lambda \cdot \varepsilon_{t-1}^2 + \eta \cdot \sigma_{t-1}^2 + \sum \alpha_i \cdot communication\_dummy_{it} + \sum \beta_i \cdot control\_\text{var}iable_{it} + u_t. \qquad (2.7)$$

The explanated variable in Eq. (2.6) is the return on an asset and it is explained by a constant, a set of 12 central bank communication dummies and a set of control dummies which consist of surprise components[10] of macro news (the consumer price index, the growth rate of the gross domestic product, the current account balance, the foreign trade balance and the general government deficit) and of MNB's interest rate decisions.

The variance equation in Eq. (2.7) includes standard GARCH specification, i.e., ε_{t-1}^2 as unexplained variance, σ_{t-1}^2 as the forecast from last period and the memory of all past variances, and communication and control variables from 2.6 but only with those coefficients that appeared to be significant in the mean equation, where they were left in both cases. Gábriel & Pintér (2006, p. 18) emphasize that the model suffers from several possible pitfals, for example a necessary underspecification, as it misses foreign macroeconomic news and other central banks decisions or communication. However, they decided to disregard this fact. The R^2 in such a type of regression typically falls in between 3 nad 6 &, which "is low, but very similar to values reported by other studies".

The results are surprising mainly for the interest rate communication, which does not influence short term interest rates, similar to the exchange rate communication which does not influence the exchange rate. However, short-term interest rates rise after exchange rate strenghting communication. We might suspect that market participants do not consider the MNB to be a heavy-weight player that would stand its words. The authors mention that in case of the CNB and the NBP, the influence is significant, but only statistically, since the size of the effect is below one basis point. As to the the effect of central bank communication on volatility analysed in equation 2.7, authors have found the same as earlier studies: "Central bank communication either has no effect on the volatility of asset prices or it reduces uncertainty" (page 27). More specifically, release of macroeconomic news usually adds to volatility while certain central bank statements reduce it.

[10]The surprise component is defined as the difference between the actual value and the average expectated value in the Reuter's survey among market leaders.

Authors explain the influence of the exchange rate communication by the fact that during the sample period, the MNB based its interest rates changes largely on its goals concerning a stable exchange rate (p. 28). Since the volatility of exchange rate was high, it sometimes required large changes in official interest rate. The step towards this ambiguity in what is, or what market participants percieve as, the primary goal was made in 2001 when the MNB adopted inflation targeting and added it as a nominal target to the already existing 1 % exchange rate band of forint with the central parity pegged to Euro; the band was widened to 15 % in that year.

Later, on February 26, 2008, the Monetary Council of the MNB abolished the band in favor of the floating exchange rate regime. The unannounced step resulted from the 7 year long experience of the coexistence of the two nominal targets: "Restricting exchange rate fluctuations in an inflation targeting system does not contribute to anchoring long-term inflation expectations," said the MNB's governor András Simor in a press conference[11] following the decision, bearing up to the opinion of many economists, according to a KBC's report:[12] "The conflicting dual inflation and exchange rate targets have been mentioned by many observers as a possible source of instability." Simor further emphesized that the long-term sustaining of price stability is the most important objective. By saying that keeping an exchange rate band under inflation targeting harms the long-term expectations, Simor has confirmed the conclusion of Gábriel & Pintér (2006).

Rozkrut et al. (2007) have analysed the communication of Czech, Polish and Hungarian central banks in period 2001-2004. The methodology on data, as well as results concerning the NMB, are similar to Gábriel & Pintér (2006). They have discovered that the influence of communication of these central banks on asset prices is important, which has so far been proved only for central banks in the most developed countries.

They begin by introducing *average ratios* constructed by setting the ratio of tightening to easing statements against the ratio of actual interest rate increases to interest rates decreases, and analogically for the exchange rate. The result is that the CNB and its governer in particular provide the best guidance for markets.

Consistency ratio of interest rate communication is a sum of points given (respectively subtracted) if for example a tightening statement is (respectively not) followed by the

[11]Source: "Monetary Council drops forint band, keeps rate on hold" in The Budapest Sun, February 27, 2008, available at `http://www.budapestsun.com/cikk.php?id=27942`.

[12]KBC Market Research Desk. "Hungary moves to free-floating FX to fight inflation". February 27, 2008. Available at `http://www.fxstreet.com/fundamental/analysis-reports/kbc-flash/2008-02-27.html`.

increase of the interest rate. The communication of CNB has been found the most consistend while the two others banks failed to provide a more clear guidance, see Fig. 2.1; the authors provide some explanation. The MNB, a small open country in the world of massive capital flows, pursued the dual target of low inflation and an exchange rate band, which creates antagonistic pressure of higher interest rate on the upper border of the exchange rate band (the argument is the same as in the case of Gábriel & Pintér (2006)). As to NBP, authors suggest several explanations, for example the initiation period for new Board members, pressure by the NBP on Polish government to improve fiscal balance and others.

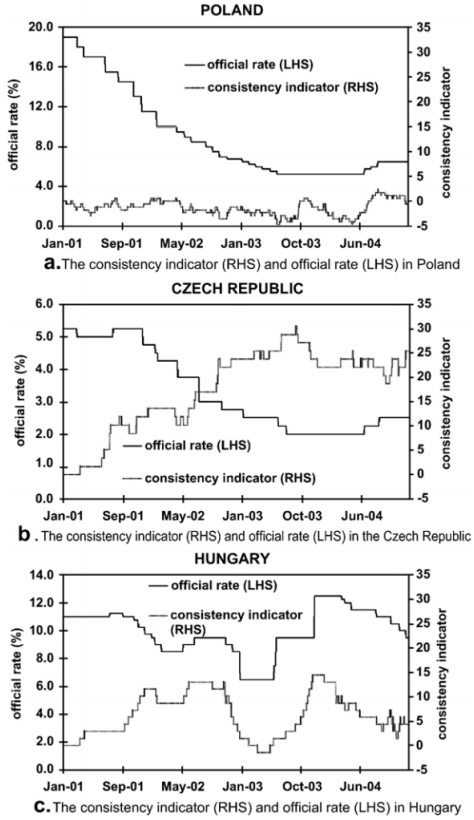

Figure 2.1: Consistency indicator for central banks of Poland, Czechia and Hungary. Source: M. Rozkrut et al., European Journal of Political Economy 23 (2007) 176–206.

In the measure of the *effectiveness* of communication, similarly to the results of Gábriel & Pintér (2006), the Hungarian central bank outstands for its inability to influence by monetary policy talk any yield curve ranging from 3 month maturity to 5 years maturity, contrarily to CNB and NBP. If anything, the yields move in the direction that is contraintuitive to the communication intentions. Continuing in the argument of the dual

target of the MNB, Rozkrut et al. suppose that market believed in the superiority of the exchange rate target, since it has been the exchange rate commmunication that has moved with yields curves.

Monetary surprise component (MSC), is the unexpected component of monetary policy decisions, approximated by the change in 1 month money market rate on the day of a central bank's board meeting, zero otherwise. By MSC, we can measure the level of assymetry of information between banks and market.

Rozkrut et al. cite Ehrmann & Fratzscher (2005) who measured MSC for the ECB, the Federal Reserve and the Bank of England; they have found out that the value of the $|MSC|$ was 3.6, 5.6 and 6.0 respectively. Results by Rozkrut et al. might indicate that CNB belongs to the first league of central banks in terms of its policy predictability ($|MSC| = 5.9$ basis points). The other two banks reached two (NBP) or three times (MNB) higher values. Rozkrut et al. present higher local market volatility as a possible non-communication factor that makes it harder for MNB and NBP to reach lower $|MSC|$. To be precise, they tried to explain the $|MSC|$ by econometric means:[13]

$$\frac{|MSC_t|}{volatility_t} = \beta_0 + \beta_1 stock\_ratio + \beta_2 \left|consensus\_ratio\right| + \sum_{j=1}^{m} \beta_j^{mac} mac_{j,t} + \varepsilon_t, \quad (2.8)$$

where *volatility* is measured on the basis of daily changes in one-month money market rate, *stock ratio* is a number of statements on monetary policy while the *consensus ratio* is a measure of their unity concerning likely move of interest rates. According to the results of regression of 2.8, the more statements in public, the more is the CNB predictable, and the more unified statements it provides, the less is the CNB predictable. The effects in Hungary are opposite. In Czechia, the regression suggests, markets prefere the detailed knowledge of single opinions of decision-makers of as many as possible Bank Board members. Rozkrut et al. mention that this fact reflects the individualistic character of the Bank Board and that in this case, additional information is more valuable than outside consensus. However, under this situation, markets ability to predict CNB's actions is worse if the CNB's inter-meeting communication is more unified in opinion, which is simply strange; it might originate in possible communication errors. However, this fact might be tackled in the empirical part of this study. In Hungary, markets want to know mainly the governor's opinion and the more consistent it is, the better.[14]

[13]The results are the same both for standardized $|MSC|$ and for $|MSC|$ as the explained variable.

[14]Contrary to CNB and NBP, communication of MNB is dominated by the governor.

Chapter 3

Czech National Bank's Communication

The key objective of this chapter is the analysis of the influence of the Czech National Bank's communication on the volatility of the return on the exchange rate between Czech crown (CZK) vis-á-vis euro (EUR).[1] The secondary objective, that originated as an attempt of explaining the results of the primary objective analysis, is the analysis of the impact of macroeconomic news announcements on the volatility. Prior to the econometric analysis I describe the means of CNB's communication and its development.

3.1 A general view on the Czech National Bank

I briefly describe the institutional position of the CNB, its objectives and ways of achieving them and the way it communicates with public.

3.1.1 Institutional background

This section is based mainly on the information in the Act No. 6/1993 Coll. of 17 December 1992, on the Czech National Bank,[2] and on the information published on CNB's

[1] To avoid any misunderstanding, I declare that by any reference to the exchange rate between CZK and EUR, I mean the amount of CZK for 1 EUR.

[2] Available online at `http://www.cnb.cz/m2export/sites/www.cnb.cz/en/legislation/acts/download/act_on_cnb.pdf`.

website[3] including citations in quotation marks.

The CNB is the central bank of the Czech Republic and its financial market supervisor; its primary objective is the maintaining of price stability and the secondary is, if not out of accord with the primary objective, the support of the government's economic policies. To fulfil the primary objective, CNB has been given the right to set the monetary policy (MP) of the Czech Republic. The governing body of the eCNB is the Bank Board. It governs MP, its strategy and instruments. It consists of seven members, a Governor, two Vice-Governors and four other members of the Bank Board; all of them are appointed and relieved from office by the President of the Czech Republic.

From the point of view of the CNB, the independence is a necessary shield against politicians preference of short-term economic growth, that threatens the objective of stable prices. The CNB has suffered a period of uncertainty in the period 2000-2002 when an amendment was made to the CNB Act, curbing its independence. However, in 2002 the law was restored to the pre-2000 state.[4] The independence can be desribed from a few points of view. *Personal* independence concerns appointment and dismissal of members of the Bank Board. It is managed exclusively by the President of the Czech Republic. The CNB act names reasons for which a members of the Bank Board might be suspended from office; the reasons are specified in terms of personal integrity, education, absence of commercial activities; the law is more specific on the Governer, who might be relieved from office if he has been guilty of serious misconduct. *Institutional* independence is based on the fact that the Bank Board is forbidden to seek for of accept instruction from the Executive branch of the Czech Republic or any other institutional body. *Functional* independence consists in the CNB's autonomy in conducting of the MP, i.e., formulating inflation target and setting the instruments required to achieve it. The relation of the CNB and the Government is based on the "duty to inform each other on matters concerning the principles and measures of monetary and fiscal policy". *Financial* independence of the CNB is assured by the fact that the implemenation of the CNB's budget is not subject to an external inspection and is approved only by the Bank Board, including salaries of its members; CNB only has to let its annual accounts be audited by an external auditor, publish an annual financial report, and, every ten days, publish balance sheets on its financial position. The external pressure on CNB's sources is protected by the prohibition of CNB to finance any public sector body.

[3] `http://www.cnb.cz/`

[4] For details, visit `http://www.cnb.cz/en/faq/faq_mp/cb_indenpendence.html`.

3.1.2 CNB's communication

A secret independent institution with monopoly power over the short-term interest rates is certainly not what market participants would welcome. To reach a high level of accountability, an independent bank must also be transparent, which is to be fulfilled mainly by communicating several type of information:

- monetary policy strategy and its target,
- decisions on monetary policy,
- economic analysis, the background of the monetary policy decisions.

Since 2008, the Bank Board of CNB meets eight times a year, while in the time before it used to meet every month. The meetings are planned at the beginnings of February (the 2nd month in year), May (5), Autumn (8) and November (11), and at the ends of March (3), June (6), September (9) and December (12). For four months, there are no meetings, i.e., in January (1), April (4), July (7) and October (10). The Bank Board decides by voting on possible increase or decrease of interest rates. The result of the vote is immediately made public in a print release and later in the day explained and commented in a press conference. The ratio of votes in the vote of the Bank Board is also made public. Usually one hour after the conference, an audio record of the conference is posted online on the CNB's website. A detailed description of Bank Board's discussion, so called minutes, is made public after eight days; minutes were published 12 days after the conference until 2005; since January 2008, they includes namely voting record. A complete transcript of the regular Bank Board meetings and the background materials for the Bank Board's members (the Situation Report on Economic and Monetary Developments, the Opinion of one of advisors to the Bank Board and Monetary policy recommendation; in Czech only) are published six years later.

There are many documents the CNB publishes. One of the most important is the quarterly (February, May, Autumn, November) Inflation Report focused on monetary and economic developments. Among others belong the macroeconomic forecast and the inflation target for the next year.

Except of the official ways of the CNB's communication, there are less formal channels; the comments of Bank Board members in media in the inter-meeting periods,[5] which

[5]In a step towards clarity in its communication, Bank Board has decided to publish namely voting results from its meetings in Minutes. One of the reasons is to make clear whether the Bank Board's members comments reflect a personal or rather an official stance.

"provide the flexibility to communicate changes in the committee's views to the public instantaneously" and allow the Bank Board to "respond to new information by adjusting the intensity or the timing of this particular type of communication" (Ehrmann & Fratzscher, 2007).

3.1.3 Policy instruments

Since 1998 maintaining price stability has meant reaching an inflation target for CNB. The policy of inflation targeting has been introduced after a forced abandonment of the Czech crown peg to a besket of currencies caused by currency crisis in the beginning of the second half of the 1990s.[6] According to the CNB,[7] "the purpose of the switch to this monetary policy regime was to provide the still transforming economy with a new nominal anchor." Until April 2001, inflation target was represented by net inflation. Since then, CNB switched to growth in consumer price index and to expressing the target trajectory in a continuous band. From January 2002 (inflation at 3-5 %) the target was set to 2-4 % in December 2005. From January 2006, the target of 3 % with a tolerance band of ±1% has been set and in March 2007 (see Fig. 3.1), a target of 2 % with the same band was announced to be valid for January 2010 and later, thus getting closer to the European Central Bank's target "below, but close to, 2 % ".[8] The overview of CNB's inflation targets can be seen in Fig. 3.3.

In Fig. 3.1 we can see that at by the end of 2007, inflation climbed over the 3% rate and continued in its rapid increase. CNB's February 2008 forecast expects that the inflation will not get back to the target band sooner than in second half of 2009, see Fig. 3.2.

The tools that CNB uses to steer interest rates in order to maintain stable price level are as follows.

- Open market operations

[6]Except of inflation and exchange rate targeting, there are two other basic types of MP regimes: a regime with an implicit nominal anchor and money targeting. Source: `http://www.cnb.cz/en/monetary_policy/inflation_targeting.html`.

[7]Source: CNB, "The setting of the inflation target for 2001", available online at `http://tinyurl.com/4g22rt`.

[8]For details, check CNB's site `http://www.cnb.cz/en/monetary_policy/inflation_targeting.html` and ECB's site `http://www.ecb.int/mopo/html/index.en.html`.

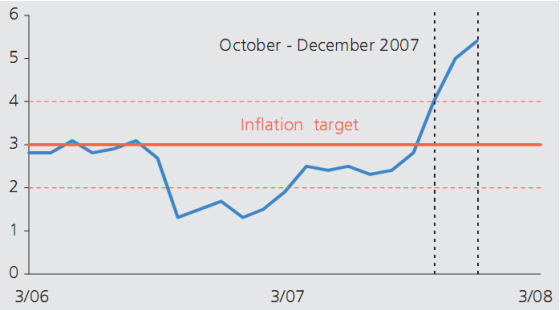

Figure 3.1: Fulfilment of the inflation target of CNB in the period from March 2006 to March 2008. Source: Inflation Report I/2008, CNB.

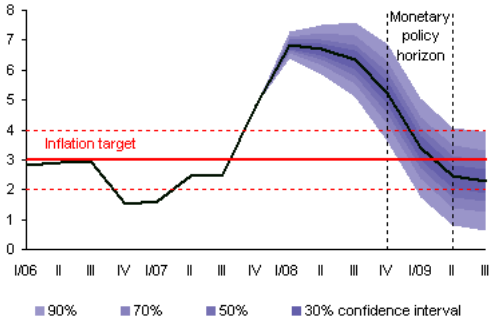

Figure 3.2: CNB's forecast for inflation at the monetary policy horizon, published in February 2008. Source: CNB's website, Monetary Policy - Forecast.

  - The main policy instrument is the **repo operation**, i.e., a sale and a repurchase agreement backed by collateral. The usual duration of this operation is two weeks in the Czech Republic, therefore the two-week repo rate (2W repo rate) is considered to be the most important of interest rates set by the CNB. The organization of repo operations is realized by limited-size tenders, in which contenders (banks) may compete for the tender by declaring lower required rate than is the repo rate.
  - Ad hoc instruments (foreign exchange and securities operations) are used to smooth the effects of unexpected liquidity fluctuations on interest rates.

- Automatic facilities serve for providing and depositing liquidity overnight.
  - The **deposit facility** is used by banks for overnight deposits at CNB for the discount rate, which is generally a minimum rate for short-term interest rates on the money market.

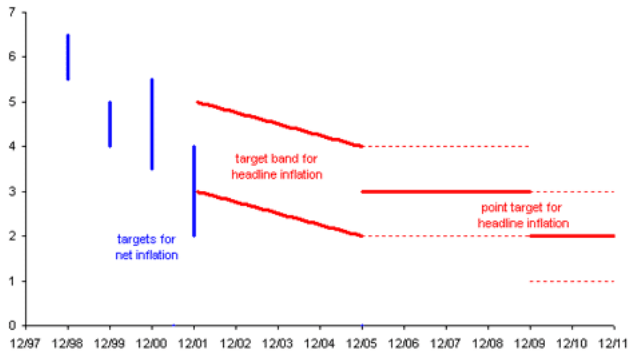

Figure 3.3: The CNB's inflation targets. Source: CNB's website, Monetary Policy - Inflation Targeting.

  - The **marginal lending facility** provides banks with overnight liquidity from the CNB in form of repo operations. The credit is charged by Lombard rate, which represents the ceiling for short-term interest rates on money market.

- **Minimum reserves** is a specified part of bank's liquid funds that has to be put on the CNB's account.

3.2 Analysis of the CNB communication's role in the volatility of exchange rate

This section is the core of this study. It aims at econometric analysis of the impact of comments of the members of the CNB's Bank Board occuring between its monetary policy (MP) meetings on the volatility of the return on the exchange rate CZK/EUR. It does so by estimating the GARCH model over a dataset with daily data on the exchange rate and a set of control variables. The area of interest is the variance equation which is the mirror for volatility for the exchange rate return. Kohn & Sack (2003, p. 6) used the same methodology and names the basic idea of this analysis, i.e., "if policy statements have an effect on the financial variables, then their volatility should be higher on the days of policy statements than it otherwise would be".

Kohn & Sack (2003, p. 8) did not use GARCH for the estimation of volatility, instead, as a measure of it he used the sole variance of η_t in OLS estimated equation $\Delta y_t = \beta_0 + \beta_1 \Delta f f_t^u + \sum_{i=2}^{n} \beta_i \cdot mac_i^u + \eta_t$, where y_t is a value of a financial variable, $f f_t^u$ is the

unexpected component of policy decisions and mac_i^u is the macroeconomic data surprise. Not did GARCH used Galati & Ho (2003, p. 9) for the analysis for the relation of macroeconomic announcements and euro/dollar exchange rate. One fo the drawbacks of using the ordinary least squares is that it does not utilitize the core feature of GARCH which is the estimation of volatility based on past values of it. This feature reflects the standard quality of financial time series, the volatility clustering.

The section is organized as follows. First I briefly summarize the results of other studies. Then I present my dataset and the variables I use in the subsequent regression of a GARCH model. Last but not least I take a closer look on the volatility from the perspective of the macroecnomomic figures announcements, since, as the control variable, they produced unordinary results. Finally I present the results of my regressions and compare them on the estimate of the model and compare the results with other studies.

3.2.1 Literature overview

Methodologically, the closest study to this one is that by Gábriel & Pintér (2006). They tried to explain the return on the exchange rate and its volatility by a structured set of variables describing the MNB's communication which was created along the dimensions of type of communication (verbal or written), content (exchange rate, monetary policy, economic outlook) and direction (positive, negative). Then they estimated the GARCH(1,1) model; the mean equation was left with all variables, whether significant or not, and the variance equation was left with only the significant variables. The result for the variance equation is that every kind of communication which is significant decreases volatility on the exchange rate market. Since the insignificant variables do not matter, we can say that the MNB's communication either calms exchange rate market down or it has no influence. The significant variables are all kinds of economic outlook communication (defined as such a communication that "calls the attention to the increase or decline in risks in the longer term economic developments") and the communication of possible raise in the main MP interest rate. The control variables constructed as surprise components were found not significant. For other assets, namely the short term and long term yields, the control variables significantly increase volatility.

Jansen & De Haan (2005, p. 6) mention the seminal paper by Andersen and Bollerslev (1998)[9] that specifies the various effects on the volatility of exchange rates: calendar ef-

[9]Torben G. Andersen & Tim Bollerslev, 1998. "Deutsche Mark-Dollar Volatility: Intraday Activity Patterns, Macroeconomic Announcements, and Longer Run Dependencies," Journal of Finance, Ameri-

fects (intraday, weekly, holiday, time-change), macroeconomic announcements effects and 'interdaily volatility dependencies'. Andersen and Bollerslev conclude that in explaining overall volatility, the announcements effect is secondary to the other two effects; however, the authors say that the effect of the announcements is large.

Jansen & De Haan (2005) analyse the influence of the ECB's communication on the euro-dollar exchange rate. Concerning calendar effects, they found lower volatility on Mondays and Fridays. Concerning communication effects, they considered, among others, statements

- from ECB's officials (a group including the executive Board) and found an unsignificant decrease of volatility on the day when the statement was published, and a significant increase one day after the statement was made;
- solely from the Executive Board's members, which insignificantly increased volatility.

To sum these results up, Hungarian central bank's talk decreases volatility of the exchange rate (Gábriel & Pintér, 2006), while the talk of the European Central Bank has no significant influence, except of the positive effect in a one day lag.

Then there are many studies that analyse the relation of central banks communication and various yield curves. They differentiate the communication's content and reach mixed results. Some type of talk increases volatility of some yields while the other decreases. However, for the case of the Czech National Bank, Rozkrut et al. (2007, p. 191) found that statements of the Bank Board, as well as minutes from the MP meetings increase volatility of prices of all examined interest bearing assets.

3.2.2 The data set

In the following paragraphs I use variables `eur` (exchange rate CZK/EUR), `int_dif` (interest rate differential between 3M Euribor and Pribor rates), `timing` (comments weighted according to distance from Bank Board's MP meetings) and dummy varibles `macro_news` and `macro_news2` which have value 1 if an official macroeconomic figure is released (see details below), `events` (`macro_news` and a selection of important political, natural and economic events), `comments` (Bank Board's members comments occurrance), `minutes` (releases of minutes from the Bank Board's MP meetings), `cbc` (a release of minutes or a

can Finance Association, vol. 53(1), pages 219-265, 02.

commment in media), `pre_mn` and `pre_mn2` (a macroeconomic figure announcement is due in a week, respectively in the second week from now), `PPI` (the PPI news was released; producers price index) , `CPI` (the CPI news was released), `GDP` (quarterly GDP), `FT` (foreign trade balance), `PB` (balance of payments). The detailed description of the variables follows.

- `eur` I obtained 535 observations of the exchange rate CZK/EUR from January 4, 2005, to February 14, 2007. The time series is plotted in Fig. 1.3 and the return on it, plotted in Fig. 1.4, was constructed by taking first difference of the logarithm of it. The exchange rate in the examined period has been steadily appreciating after a three-month period of fluctuation at the beginning of 2005. By the end oo 2006, it depreciated. From Fig. 1.8 it is clear that volatility was relatively highest in the beginning of 2005 (the period of fluctuation), followed by a relatively calm period of the stable appreciation and finally followed by a period of depreciation with high volatility. The aim of this study is to offer a structured view on the volatility from the point of view of the CNB's communication represented by minutes and comments.

- `macro_news` Macroeconomic news reflect the macroeconomic condition of the economy and thus have influence on market participants expectations and subsequently on their behaviour that is reflected in volatility. To model the volatility as precisely as possible, it is necessary to pick up the moments of surprise on the market. To a certain degree of success, it can be done by using a dummy explanatory variable that has value 1 on the day when an important macroeconomic news is released. To be precise, the variable, as well as the variable `comments`, has value one not necessarily on the day of the release (althougn in practise most probably yes), but on the day when the release appears in the Reuters news stream which I use as a source of data in my data set. Controlling just for the day of the release (there is the possibility for controlling the effects on the subsequent day, for example) seems to be enough, since "after three hours most of the effect from the announcement has disappeared" as conclude for the case of DEM/USD exchange rate[10] (Almeida et al., 1997). On the other hand, Evans & Lyons (2005) findings provide "strong evidence that currency markets are not responding to news instantaneously", and that "news-induced changes in trading behaviour remain significant for days". Jansen

[10]DEM stands for the predecessor of Euro in Germany, the Deutsche Mark.

& De Haan (2005) comments this issue undirectly, talking about the use of high-frequency exchange rate observations: "If the effects of talking up the currency can only be observed using higher frequency data, ECB statements cannot be considered a very powerful instrument to influence developments in the foreign exchange market." However, one should take into account the degree of market-maturity. Podpiera (2000) found found in his analysis that "the Czech market lacks basic efficiency properties. It reacts to the expected part of the news announcement, and the adjustment is stretched over a period of several days." However, these findings are from year 2008 and the situation may be different today.

In my case, I control for the release of the PPI, CPI, quarterly GDP, balance of foreign trade,[11] balance of payments,[12] and for the days when the CNB's main policy interest rate was changed. As a source of these macroeconomic figures announcements I used Reuters. However, it should be noted that the release of macroeconomic announcements might be described with higher precision and effectivity by using a component of 'macroeconomic surprise' which is based on the difference between market expectations and the reality; Jansen & De Haan (2005) describe this 'news approach' to modeling exchange rates by the Eq. (3.1):

$$R_t = \alpha + \beta_1(X_t^n - X_t^e) + \beta_2 Z_t + \varepsilon_t, \tag{3.1}$$

where R_t is the exchange rate return, β_1 is the parameter of news on the exchange rate market and news is defined as the difference between new realizations of macroeconomic variables (X_t^n) and the expectations of them (X_t^e), and Z_t is the matrix of control variables. The equation reflects the efficient market hypothesis according to which markets should move only in reaction to the unexpected news.

All of the aggregated announcements are also available in separate variables (`ppi`, `cpi`, `gdp`, `ft`, `pb`, `board_acted`). Variable `macro_news2` is the same as `macro_news` except of that it does not consider changes in CNB's main policy rate. In Fig. 3.4 we see the distribution of comments (61 instances) and macroeconomics news releases (104) in time. The prior is distributed irregularly with long periods of silence in the last quarter of 2005, in the breaks of July and August of 2005 and November and December 2007. The latter is characterized by periodicity.

[11] Managed by the Czech Statistical Office, available at `http://tinyurl.com/5ey38h`.
[12] Managed by the CNB, available at `http://tinyurl.com/66m8pd`.

- `pre_mn` This variable checks for the period of seven days from today in which a macroeconomic figure announcement is due.
- `pre_mn2` The sense of this variable is the same as for `pre_mn` except of the period, which is from 7 to 14 days from today.
- `post_mn` This variable has value 1 if a macroeconomic figure announcement was released in past three days from today.
- `board_session` This variable has value 1 for days in which the Bank Board met.

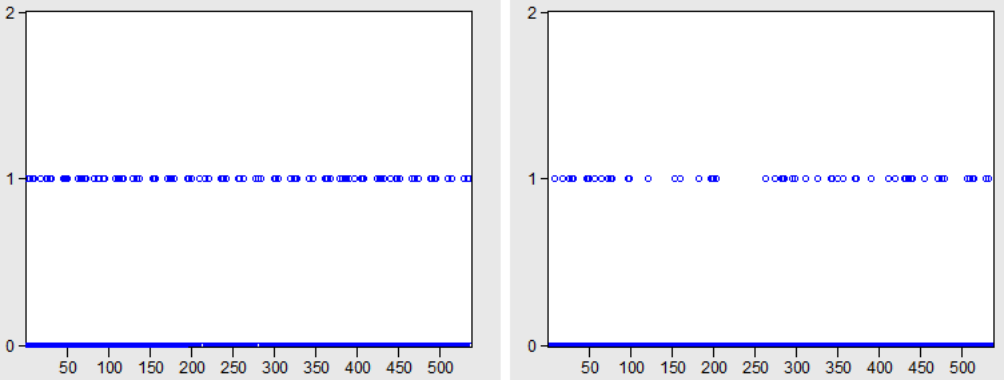

Figure 3.4: The distribution of comments (right) and macroeconomics news releases (left) in time.

- `board_session` This variable has value 1 for days in which the Bank Board met.
- `board_acted` This variable has value 1 for days in which the Bank Board changed CNB's main policy rate.
- `comments` The key (dummy) variable of this analysis shows whether there was a comment on a day or not. As a comment I take every written or oral expression of a member of the Bank Board towards the interest rates, economic outlook or the exchange rate. As a source of data I used the database of Reuters which is often used by financial institutions. Contrary to Gábriel & Pintér (2006) I do not distinguish among content, type or the "direction" of the comments. Thus I cannot decompose the effects CNB's communication into particular parts. Instead I take a general look on the relation between Bank Board's MP meetings and the volatility of the return on the exchange rate CZK/EUR. The advantage of my approach is that I do not have to code the comments which can be ambiguous, to a certain degree. In Fig. 3.5 we can see the histogram of comments distinguished by its distance

from Bank Board's sessions; the closer, the higher the number (from 1 to 30). See Fig. A.1 for a comparison of the frequency of comments between the MP meetings across several central banks and the CNB; the time-occurence of the comments of Bank Board's members is similar to that of Federal Reserve's FOMC and Bank of England's MPC, i.e., gradually less and less dense as the meeting becomes closer, contrarily to the stable flow of comments of the members of the ECB's Governing Council.

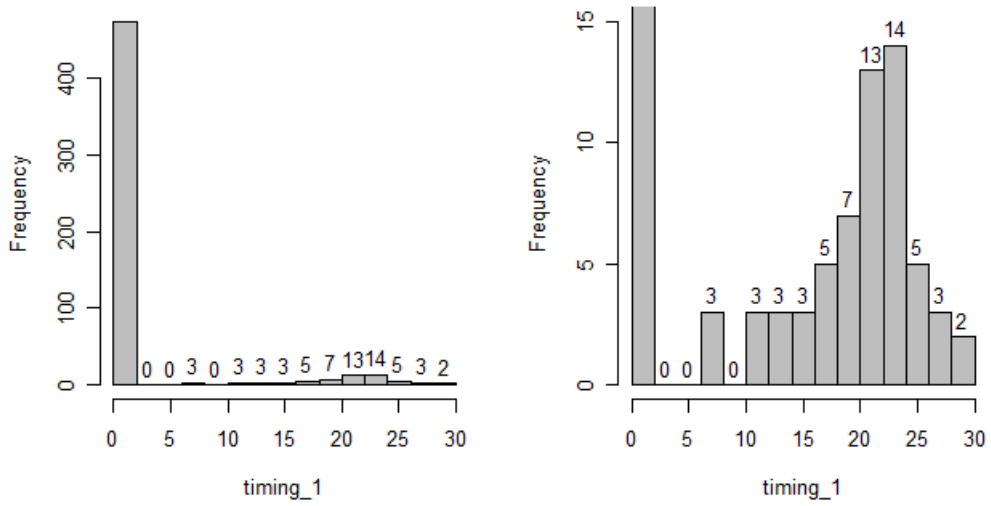

Figure 3.5: The histogram of `timing` shows that in the period 2005-2007, comments of Bank Board members most often occured a week before its meeting. (The zero is the most often value; it marks days without any comments. The right panel is the zoomed version of the left panel.

- `timing` Comments that occur closer to the Bank Board meeting might have sounder influence than the more distant comments. This variable has values from 30 to zero. A comments that occurs on the day of Bank Board's meeting has 30, the comment from previous day has 29 and so on.

- `minutes` Minutes are a brief but insightful records of the meetings of the Bank Board released eight days after the MP meeting describing the arguments that were heard before voting on the possible measures the Board may take.

- `cbc` This variable has value 1 if variable `comments` or `minutes` has value 1.

- `int_dif` The difference between three-month Pribor and Euribor rate represents the difference between main policy rates in Eurozone and the Czech Republic.

- `events` This variable marks by value 1 these events: `macro_news` and a selection of important political, business and natural events like terrorists attacks, referendum in France on the Eupoean Union's constitution, hurricanes in the United States, revaluation of the Chinese Yuan and so on.

3.2.3 Assumptions

First, I will consider the time series whose volatility is to be modeled. Then I will check whether all assumptions of proper use of the modeling methods hold; if they do not, I will try to find an alternate solution. Then I will try to estimate the mean equation and the variance equation. The latter is the part I am primarily interested in. By including external regressors in the equation, we can measure their significance and the direction and the magnitude of their influence on volatility.

There are several reasons why the already mentioned empirical studies of central bank communication do not model the level of exchange rate but instead its change (i.e., return) or the logarithmic change. First, market is generally interested in the volatility of return, and secondly and more importantly, level of exchange rate rarely is a stationary time series (for our case see Fig. 1.3, while the yield of the exchange rate usually is (for our case see Fig. 1.4 where the logarithmic return is plotted). Finally, in finance, logarithmic return is more often used because it has some desirable properties over the ordinary return.

A nonstationary time series has a trend. Regressing a trending variable against another, for example against time, leads a regression we call spurious. It suggests a strong statistical relationship where, in reality, a no economic relationship may exist. There are at least three types of statistical tests that recognise nonstationarity. The first are informal procedures, i.e., visual identification of a mean and variance that are fixed in time. The second type, which has already been mentioned in Section 1.1.1, 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 Box-Ljung's Q statistics is tested against the null hypothesis that the autocorrelation coefficients are zero. Such a state would confirm the series to be stationary. Usually, this test is being used for testing of the presence for autocorrelation in residuals of a fitted model. The third type of tests are unit-root tests 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. If it were not, then, based on the discussion of random walk in Section 1.1, the time series would be non-stationary.

Since the time series of the CZK/EUR exchngee rate is clearly non-stationary, I create the logarithmic return series $d\log(eur) = \log\left(\frac{ER_t}{ER_{t-1}}\right), t = 2, \ldots, 534$ which I will refer to as the returns series. To check whether the series is stationary we may examine Fig. 1.4 which suggests stationarity. To confirm this hypothesis, let's check the correlogram in Fig. 3.6 which plots the autocorrelation function. It suggests that there is no significant autocorrelation in the returns series. The Box-Ljung's Q statistic, for some lags, rejects the null hypothesis of zero autocorrelation coefficients on the significance level of 5 %. The final decision is made by the Augmented Dickey-Fuller (ADF) which strongly rejects the hypothesis of unit root. The returns series is thus stationary.

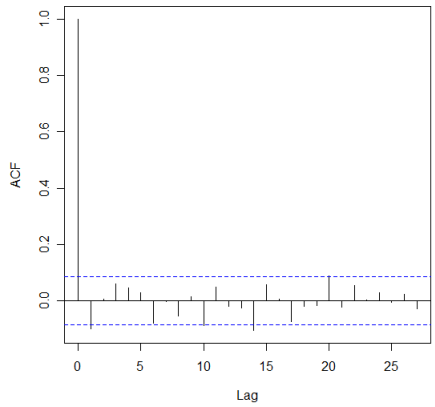

Figure 3.6: Autocorrelation function of the returns series.

3.2.4 Modeling volatility and the central bank communication

The aim of this section is to answer questions on what effect does the CNB's communication have on the volatility of the return on CZK/EUR exchange rate. Blinder et al. (2008, p. 29) define the basic idea of this type of analysis in the way that "if communication affects the returns on financial assets, the volatility of these returns should be higher on days of central bank communications, ceteris paribus, because the signals contain news." This is exactly what Gábriel & Pintér (2006) examined in their mean and variance model. However, their conslusion is reverse, mainly for the exchange rate and the short-term yield. On the other hand, the results of Rozkrut et al. (2007) are generally in accordance with the pattern Blinder et al. (2008, p. 29) suggested.

The analysis uses for the regressions only the fact that an instance of communication occured, leaving the content analysis for further examination. The communication is

described by the variable `minutes`; minutes are about a 1000 words descriptions of the Bank Board's meetings, released eight days after the meeting by the Bank Board. The unofficial, or less official, stream of communication is represented by the variable `comments` which catches all expressions of opinion of the members of the Bank Board in the period between monetry policy meetings.

Blinder et al. (2008) list problems of the volatility analysis. To catch the effects of communication, one should ideally control for all other possible sources of volatility; the volatility may then be caused by communication itself and not only by the content of the communication.

In the two following regressions I use two control variables. The interest rate differential reflects the difference between main policy rates in Czechia and the Eurozone. `Macro_news` is a dummy variable that marks the announcement of various macroeconomic figures. To increase the controlling power, I checked the results listed below by using the variable `events` instead of `macro_news`; the prior includes a selection of important world events. The results remained as they were. As the regression tool, I use GARCH(1,1), described in equation 1.16, as it suits the needs best. The mean equation consists of only a constant since no ARMA behaviour was recognised. Each regression has been checked for the presence of ARCH effects in residuals, with the result of not rejecting the null hypothesis of no further ARCH processes. The correlograms of squared residuals after GARCH estimation were also checked with no problematic results.

3.2.4.1 Volatility and minutes

The first regression asks what is the influence of the release of the document that describes the discussion of the Bank Board of the CNB prior to its decision on the main policy rate of the CNB. The result is summarized in Table 3.1. In the variance equation

```
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1) + C(5)*INT_DIF +
+ C(6)*MACRO_NEWS + C(7)*MINUTES
```

all explanatory variables are very significant, except of the ARCH term. Interest rate differential, intuitively, adds to volatility. Since minutes are a record of the Bank Board's discussion, it might also be considered to be intuitive that their publication adds to volatility. Market participants cannot be sure what to take of the message minutes bring. On the other hand, the releases of macroeconomic announcements lower volatility. Their calming effect stems from the power to effectively confront market expectations

with reality, i.e., limiting uncertainty that causes the exchange rate swings. Markets are probably nervous in the time when the macroeconomic figures are coming. We might even imagine that the main exchange rate movers regard the Czech economy as emerging and thus unstable and thus in need of exact figures; however, this is just a help in the understanding of the interpretation.

Table 3.1: Explaining volatility by the releases of minutes.

Variable	Coefficient	Std. Error	p-value
Mean Equation			
C	-0.000124	0.000118	0.2964
Variance Equation			
C	5.13E-07 ***	1.72E-07	0.0029
RESID(-1)^2	0.009607	0.009834	0.3286
GARCH(-1)	0.950667 ***	0.016814	0.0000
INT_DIF	3.77E-07 ***	1.04E-07	0.0003
MACRO_NEWS	-1.38E-06 ***	4.19E-07	0.0010
MINUTES	5.51E-06 ***	1.24E-06	0.0000

Asterisks ***, **, * indicate significance at the 99%, 95% and 90% levels, respectively.

3.2.4.2 Volatility and minutes and comments

Modeling volatility by minutes and comments leads to, at least on the first sight, surprising results. Adding comments to the explanatory variables next to minutes forces minutes to change the direction of their relases effect. Now, macroeconomic news announcements, comments occurence and the minutes releases all cool volatility down. The reason may lie behind the fact that minutes have insufficient level of explanatory power, which, on the other hand, comments supply. The conclusion for minutes at the end fo the day is that their influence is not robust. The negative effect for comments and minutes suggests that they help market participants understand the behaviour and expected path of the policy action of the CNB's Bank Board.

Rozkrut et al. (2007) has examined market yields and found that on the Czech market, CNB's communication and its minutes increase volatility of interest bearing assets. Jansen & De Haan (2005) found that statements from the ECB add to volatility, but only one day after they were made public, otherwise not. On the other hand, the results of Gábriel & Pintér (2006) are quite on line with the results of this regression because the comments

from the members of the MNB's Monetary Council have calming effect on the volatility of the exchange rate between forint and euro.

The significance of the regression increases when we replace comments by weighted comments that reflect, as confirmed by its significance, the timing effect. Market participants probably step up their curiosity of the Bank Board's decision and thus might be more responsive to comments that occur closer to the meetings. The result of the regression of variance equation is in Table 3.2.

Table 3.2: Explaining volatility by the releases of minutes and comments.

Mean Equation			
Variable	Coefficient	Std. Error	Prob.
C	-0.000119	0.000210	0.5718
Variance Equation			
C	6.76E-06 **	2.62E-06	0.0100
RESID(-1)^2	0.149996 *	0.088074	0.0886
GARCH(-1)	0.599990 ***	0.153141	0.0001
INT_DIF	1.78E-06	1.22E-06	0.1443
MACRO_NEWS	-3.53E-06 *	1.87E-06	0.0600
MINUTES	-5.45E-06 ***	1.51E-06	0.0003
TIMING	-1.58E-07 **	6.52E-08	0.0153

Asterisks ***, **, * indicate significance at the 99%, 95% and 90% levels, respectively.

The most straighforward way of demonstrating the GARCH's abilities in modeling time-varying volatility is the predicted conditional standard deviation series, plotted over the original series, thus identifying the periods of high and low volatility. In Fig. 3.7 I compare three different series of conditional standard deviations with the returns series. One is from the model that models volatility by minutes, the second is from the model with minutes and weighted comments and the third is from a regression without external regressors. The second series forecasts the volatility of the original series more accurately then the first one which is generally slightly better than the ordinary series but fails to capture two spikes in the returns series. The second series suggests that the volatility of returns was especially high at the beginning of the year 2005 and at the end of 2006. In Fig. A.2 there is another comparison of the models, particularly of the variance series they generated. The left top one is from the second regression and it shows that the volatility has been steadily declining and that the depreciation of the Czech Crown at the end of 2007 was a big blow to volatility.

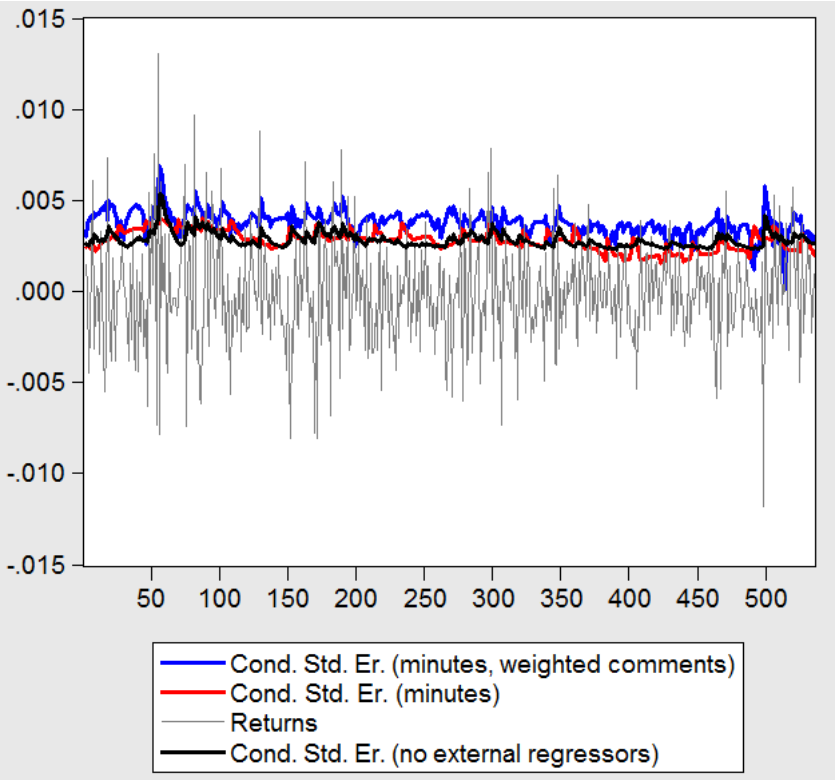

Figure 3.7: Returns series and the estimated conditional standard deviations compared to a GARCH model without external regressors.

To sum up the findings up, I have discovered that the releases of minutes from the CNB's Bank Board's meetings significantly add volatility to the exchange rate market for CZK/EUR. However, when accompanied with the comments of the members of the Bank Board that occur between MP meetings, minutes and comments both cool market volatility down by shedding light on the uncertainty about the behaviour and future policy path of the Bank Board, which is consistent with the general conclusion of Gábriel & Pintér (2006, p. 27) for the case of Hungary that "the central bank communication either has no effect on the volatility of asset prices or reduces uncertainty." The control variable containing releases of macroeconomic news has been found with a significantly negative effect on volatility. I will talk about this particular result in next section.

3.2.5 A closer look on the macro news

On the first sight, it is surprising that news about for example growth in producers and consumers prices should decrease volatility in markets including the exchange rate market,

because it is *news*. On the second look, it might seem natural because market participants estimate the growth in prices so as to avoid risk in medium and long term contracts. Exact figures from the (Czech) Statistical office pour certainty into their decision-making processes, making end to the pre-release speculative expectation-driven market operations (speculations).

In the preceding section I found that macroeconomic news releases overally decrease volatility. The term *news* might be misleading since I did not use the macroeconomic surprise component (for details, see Eq. (3.1)). The result is surprising because one would typically assume news to support the business, i.e, amount of transactions. In the exchange rate market volatility is the higher the bigger are the swings of the level of the exchange rate which depend on the difference in demand and supply. The decrease in volatility of the return, $ret_2 = \frac{ExRate_2}{ExRate_1} - 1$, is in fact a slowdown in appreciation or depreciation, which occurs if demand and supply, for example, for the Czech crown, get closer to each other.

It is difficult to identify the particular powers behind the decrease of volatility. Generally, it can be said that the figures straighten out the market expectations, confront them with reality, thus getting them closer to each other.

3.2.5.1 Survey of literature on macro-news effects

The empirical studies on the effects of macroeconomic announcements have been older than their counterparts that analyse central bank communication. Some of them analyse solely the effects of releasing the news, others control the nature of the news, others examine the effects on a single market while others across markets. Kim et al. (2004) has found that "markets do not respond in any meaningful way to the act of releasing information by the government". For DEM/USD, releases of PPI and balance of trade were significant negatively, resp. positively, while for the JPY/USD, only nominal retail prices were significant, positively. Kim et al. have also studied the volatility under the flow of macroeconomic news releases differed according to being below or over market expectation. In that case, in the variance equation, only positive PPI remained negatively significant on DEM/USD market, on JPY/USD none remained significant. However, in the mean equation positive balance of trade news became negatively significant and the negative news vice versa. Kim et al. (2004, p. 226) see the reason in the implication that increased spending (induced by the surplus on the current account) will purge imports which cause the currency to lose value. However, the authors probably do not consider

the fact that exports push the value of the currency on the opposite direction. To sum the results up, Kim et al. (2004) have found that only the releases of PPI have consistently negative effect on volatility and that the balance of trade releases affect the mean of the return.

Kopecký (2004) examined the exchange rate CZK/USD using high frequency data in relation to macroeconomic announcements emanating from both the United States and the Czech Republic. To analyse volatility, he calculated standard deviations of the returns on the exchange rate, leaving the method unspecified, with a link to Ederington & Lee (1996) who used the implied standard deviation, which is standard deviation (volatility) that yields the current market price in a particular pricing model. Kopecký used the series of standard deviations to visually depict the volatility of the return on the exchange rate for days both with and without any announcement(s). He found "a large spike between the time 8:00 and 8:10. This corresponds to the time when the announcements are released. During this time, the volatility is 7 times its average value over the graphed time interval where it remains practically flat" (page 17).

Laakkonen (2004) examined the impact of the US and European macroeconomic news on the USD/EUR exchange rate volatility using the Flexible Fourier Form method instead for the usual ARCH class of models, which "does not seem to work at all when modeling the intraday returns; this is due to the systematic periodical structure of volatility during the course of a day that ARCH models fail to consider." The most relevant conslusion of this study is that "macro news in general do increase the volatility" (page 36). The author also checked the volatility potential of so called *no-news*, i.e., those news for whom $X_t^n - X_t^e = 0$ in Eq. (3.1). The estimated parameter for the no-news is significantly positive and is higher than the parameters for all news and for the surprising news.

Eddelbuttel & McCurdy (1998) have examined the effect of general news on the volatility of the exchange rate DEM/USD measured in a high-frequency (5 minutes intervals)[13] and concluded that the frequency of news and the interest rate differential significantly increase volatility of the exchange rate return.

Gábriel & Pintér (2006) found no significant effect "of the surprise content of interest rate decisions and of the disclosure of macroeconomic data" on the volatility of the return on the exchange rate. For yield curves, Rozkrut et al. (2007, p. 191) found mixed results for the Czech Republic; PPI release increases volatility of short-term yields, while the release of retail sales and GDP figures decrease; for 1Y and older maturities, the releases

[13]They used the data set 'HFDF93' collected by Olsen & Associates, available at `http://mihd.net/kzq046m`, thus making it possible for reader to "check the results".

generally decrease volatility.

To sum up the conclusions from the examined literature, there is no general conslusion. Some studies did not found any significant impact, some found mixed effects and some concluded that macro news increase volatility.

3.2.5.2 Analysis of the macro news releases effect

Now I will try to disassemble the effects of the variable `macro_news` on the volatility of the yield on CZK/EUR exchange rate. It consists of the releases of the PPI, CPI, balance of payments, current account balance (all monthly), quarterly GDP estimates and the Bank Board's acts (a no-act is not considered to be an act here). In the regression I will use only the releases of macroeconomic figures. I encountered one problematic issue. The presence of both the balance of payments release (`pb`) and the foreign trade balance cause other variables become insignificant. Therefore I excluded the variable on the foreign trade balance since it is included in the other variable. Contrary to preceding method of analysis, I included the variable `pb` into the mean equation since for a small open country it is highly relevant.

The result of the regression of the model which describes volatility and the mean of the CZK/EUR exchange rate market return by means of the macroeconomic news releases is depicted in Table 3.3.

Table 3.3: Explaining volatility by the releases of macroeconomic announcements.

Mean Equation			
Variable	Coefficient	Std. Error	Prob.
C	-0.000170	0.000202	0.4000
PB	0.001048 ***	0.000304	0.0006
Variance Equation			
C	6.17E-06 ***	1.86E-06	0.0009
RESID(-1)^2	0.149826 ***	0.052777	0.0045
GARCH(-1)	0.599492 ***	0.133927	0.0000
PPI	-7.05E-06 *	3.62E-06	0.0513
CPI	-8.19E-06 **	3.53E-06	0.0203
GDP	-7.31E-06 **	2.87E-06	0.0107
PB	-7.17E-06 **	3.45E-06	0.0378

Asterisks ***, **, * indicate significance at the 99%, 95% and 90% levels, respectively.

I have found that the macroeconomic news releases in the examined period have been decreasing volatility of the exchangee rate return. All of them have been found with negative sign and significant. The release of PPI has been often found significant in similar studies; in Kim et al. (2004, p. 225) it has the same sign. The balance of payments release in the mean equation has positive sign; since in the period of years 2005-2007, foreign trade balance was in surplus,[14] we could apply the Kim's explanation of the foreign exchange market's behaviour–that the arrival of good news implies depreciation since higher subsequent spending in abroad will put downward pressure on the value of the currency.

To sum up the analysis of particular macroeconomic figures announcements effects, it was found that the the releases of information on the actual figures on PPI, CPI, GDP and balance of payments have significant negative effect on the volatility of the return on the CZK/EUR exchange rate. The mean of the return significantly increases on the day when a there is a release of the balance of payments figures. These results are unique in empirical literature which reports contrary or semi-contrary results; up to my knowledge, none of them found that all examined macro news releases decrease volatility.

It should be mentioned that from the economic point of view, the effect of considered variables on volatility is negligible and smaller than in the relevant studies, for example in the case of central bank communication (Gábriel & Pintér, 2006; Rozkrut et al., 2007), and in the case of the analysis of the macroeconomic news announcements (Kim et al., 2004; Eddelbuttel & McCurdy, 1998).

[14]Source: CNB's website, see `http://www.cnb.cz/cs/statistika/platebni_bilance_stat/`.

Conclusion

I attempted at working up a study on the communication of the Czech National Bank. I surveyd the literature that copes with the communication of central banks in different ways. In accordance with recent trends, I analysed econometrically the influence of the Czech National Bank's communication on the volatility of the return on the CZK/EUR exchange rate, using the GARCH model which I presented first. Overreaching the original outline of this study, I tried to analyse in detail the effect of macroeconomic announcements relases on the volatility.

First, I found that the effect of the releases of minutes, which are the interpreted record of the monetary policy meetings of the decision making body of the Czech National Bank, the Bank Board, is not robust. Alone, they increase the volatility. On the other hand, together with the comments of the CNB's Bank Board members, they calm the volatility down, as well as the comments alone. This finding is in line with the conclusion of Gábriel & Pintér (2006, p. 31). Second, I found that the fact of releasing a macroeconomic figure also lowers volatility of the exchange rate return. Results of similar studies are mixed but none of them reports negative effect on volatility for all examined figures releases.

The negative effect on volatility of both the CNB's communication and the macroeconomic news releases might be explained by the fact that they pour information into the markets which, successfully, narrows expectations and helps in clearing of the forces of supply and demand for the foreign currencies.

The study I realized could have been made more precise by confronting the macroeconomic announcements with the expectations of market participants, whose forecasts are regularly published by news agencies.

As a suggestion for future research in this topic, I would name the influence of the statements by politicians that have various interests, reflecting interests of various interests groups, in face of the appreciating Czech currency. The development is expected to be peculiar given the approaching acception of the euro. Secondly, choosing from the list of open topics in Blinder et al. (2008, p. 58), I like the question of central bank commu-

nication and the general public (instead of financial markets). In the Czech Republic, for example, more and more people are interested in the strength of the crown and express their views in public, while the level of interest rates has always been a topic of common conversation, not only among mortgages holders.

References

Almeida, A., Payne, R., & Goodhart, C. (1997). The Effects of Macroeconomic News on High Frequency Exchange Rate Behaviour. FMG Discussion Papers dp258, Financial Markets Group.

Amato, J., Morris, S., & Shin, H. S. (2003). Communication and Monetary Policy. Levine's Bibliography 506439000000000330, UCLA Department of Economics.

Bernanke, B. S. (2004). Remarks by Governor Ben S. Bernanke At the Meetings of the American Economic Association, San Diego. Technical report, The Federal Reserve Board.

Blinder, A. S., Ehrmann, M., Fratzscher, M., Haan, J. D., & Jansen, D.-J. (2008). Central Bank Communication and Monetary Policy: A Survey of Theory and Evidence. Technical report, NBER Working Paper No. 13932.

Bollerslev, T. (1986). Generalized Autoregressive Conditional Heteroskedasticity. *Journal of Econometrics*, *31*, 307–327.

Bollerslev, T., Chou, R., & Kroner, K. (1992). ARCH Modeling in Finance: A Review of the Theory and Empirical Evidence. *Journal of Econometrics*, *52*, 5–59.

Chortareas, G., Stasavage, D., & Sterne, G. (2001). Does it pay to be transparent? International evidence from central bank forecasts. Bank of England working papers 143, Bank of England.

Eddelbuttel, D. & McCurdy, T. H. (1998). The Impact of News on Foreign Exchange Rates: Evidence from High Frequency Data. Technical report.

Ederington, L. H. & Lee, J. H. (1996). The Creation and Resolution of Market Uncertainty: The Impact of Information Releases on Implied Volatility. *The Journal of Financial and Quantitative Analysis*, *31*, 513–539.

Ehrmann, M. & Fratzscher, M. (2005). Communication and decision-making by central bank committees - different strategies, same effectiveness? Working Paper Series 488, European Central Bank.

Ehrmann, M. & Fratzscher, M. (2007). The timing of central bank communication. *European Journal of Political Economy*, *23*(1), 124–145.

Engle, R., Focardi, S., & Fabozzi, F. (2008). *Handbook Series in Finance*, chapter ARCH/GARCH Models in Applied Financial Econometris. John Wiley and Sons.

Engle, R. F. (1982). Autoregressive Conditional Heteroskedasticity with Estimates of the Varianceof U.K. Inflation. *Econometrica*, *50*, 987–1008.

Engle, R. F. (2001). GARCH 101: The Use of ARCH/GARCH Models in Applied Econometrics. *Journal of Economic Perspectives*, *15*, 157–168.

Engle, R. F. (2002). Lecture notes on Volatility models. From hisvisit at the School of Finance and Business Economics, Edith Cowan University, Australia.

Engle, R. F. (2004). Risk and Volatility: Econometric Models and Financial Practice. *American Economic Review*, *94*, 405–420.

Evans, M. D. & Lyons, R. K. (2005). Do currency markets absorb news quickly? *Journal of International Money and Finance*, *24*(2), 197–217.

Franke, J., Härdle, W., & Hafner, C. (1995). *Introduction to Statistics of Financial Markets* (1 ed.). MD*Tech - Method and Data Technologies.

Galati, G. & Ho, C. (2003). Macroeconomic News and the Euro/Dollar Exchange Rate. *Economic Notes*, *32*(3), 371–398.

Gábriel, P. & Pintér, K. (2006). The effect of the MNB's communication on financial markets. MNB Working Papers 2006/9, Magyar Nemzeti Bank (The Central Bank of Hungary).

Horváth, R. (2007). Lecture notes on Applied econometrics course. Institute of Economic Studies, Charles University.

Jansen, D.-J. & De Haan, J. (2005). Talking heads: the effects of ECB statements on the euro-dollar exchange rate. *Journal of International Money and Finance*, *24*(2), 343–361.

Jarmuzek, M., Orlowski, L. T., & Radziwill, A. (2004). Monetary Policy Transparency in Inflation Targeting Countries: the Czech Republic, Hungary and Poland. Technical report, Center for Social and Economic Research.

Kim, S.-J., McKenzie, M. D., & Faff, R. W. (2004). Macroeconomic news announcements and the role of expectations: evidence for US bond, stock and foreign exchange markets. *Journal of Multinational Financial Management*, *14*(3), 217–232.

King, M. (2000). Address to the American Economic Association and the American Finance Association. Technical report, Bank of England. Available online at `http://www.bankofengland.co.uk/publications/speeches/2000/speech67.htm`.

Kohn, D. L. (2005). Remarks by Governor on the topic Central Bank Communication. Technical report, Annual Meeting of the American Economic Association, Philadelphia. Available at `http://www.federalreserve.gov/boarddocs/speeches/2005/20050109/default.htm`.

Kohn, D. L. & Sack, B. P. (2003). Central bank talk: does it matter and why? Finance and Economics Discussion Series 2003-55, Board of Governors of the Federal Reserve System (U.S.).

Kopecký, M. (2004). Impact of macroeconomic releases on high frequency exchange rate behaviour: the case of the Czech crown/USD spot exchange rate. Discussion Paper No. 2004 - 115, January 2004, CERGE-EI.

Laakkonen, H. (2004). The impact of macroeconomic news on exchange rate volatility. Research Discussion Papers 24/2004, Bank of Finland.

Pindyck, R. S. & Rubinfeld, D. L. (1991). *Econometric models and economic forecasts* (4 ed.). McGraw-Hill.

Podpiera, R. (2000). Efficiency of Financial Markets in Transition: The Case of Macroeconomic Releases. CERGE-EI Working Papers wp156, The Center for Economic Research and Graduate Education - Economic Institute, Prague.

Reeves, R. & Sawicki, M. (2007). Do financial markets react to Bank of England communication? *European Journal of Political Economy*, *23*, 207–227.

Rozkrut, M., Rybiński, K., Sztaba, L., & Szwaja, R. (2007). Quest for central bank communication: Does it pay to be "talkative"? *European Journal of Political Economy*, *23*, 176–206.

Smaghi, L. B. (2007). The value of central bank communication. Technical report, European Central Bank. Available at `http://www.ecb.eu/press/key/date/2007/html/sp071120_2.en.html`.

Tsay, R. S. (2002). *Analysis of financial time series*. Wiley.

Woodford, M. (2005). Central bank communication and policy effectiveness. *Proceedings*, (Aug), 399–474.

Appendix A

Figures and tables

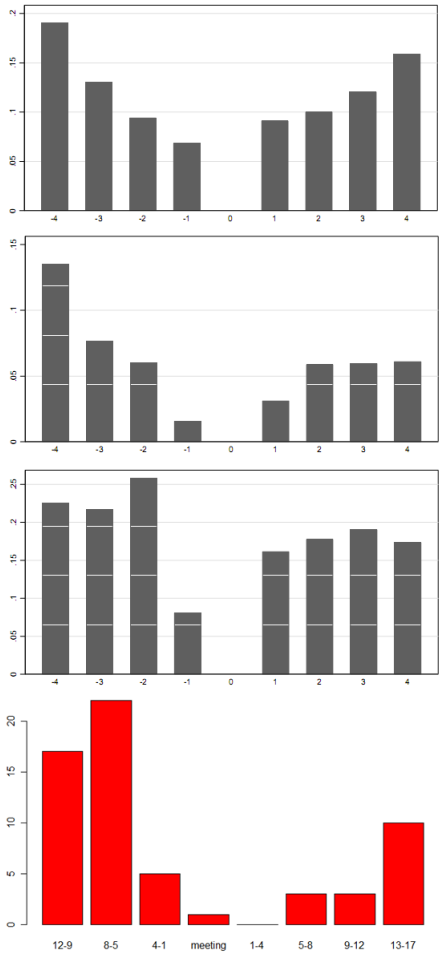

Figure A.1: The comparison of the frequency of communication around monetary policy meetings of (from top) the Federal Reserve's FOMC, the Bank of England's MPC, the ECB's Governing Council and the the CNB's Bank Board. The bars show number of meetings before and after the meetings, counted in groups of four days, i. e. 1-4, 5-8 and so on. Source of the upper three graphs: Ehrmann and Fratzscher (2005).

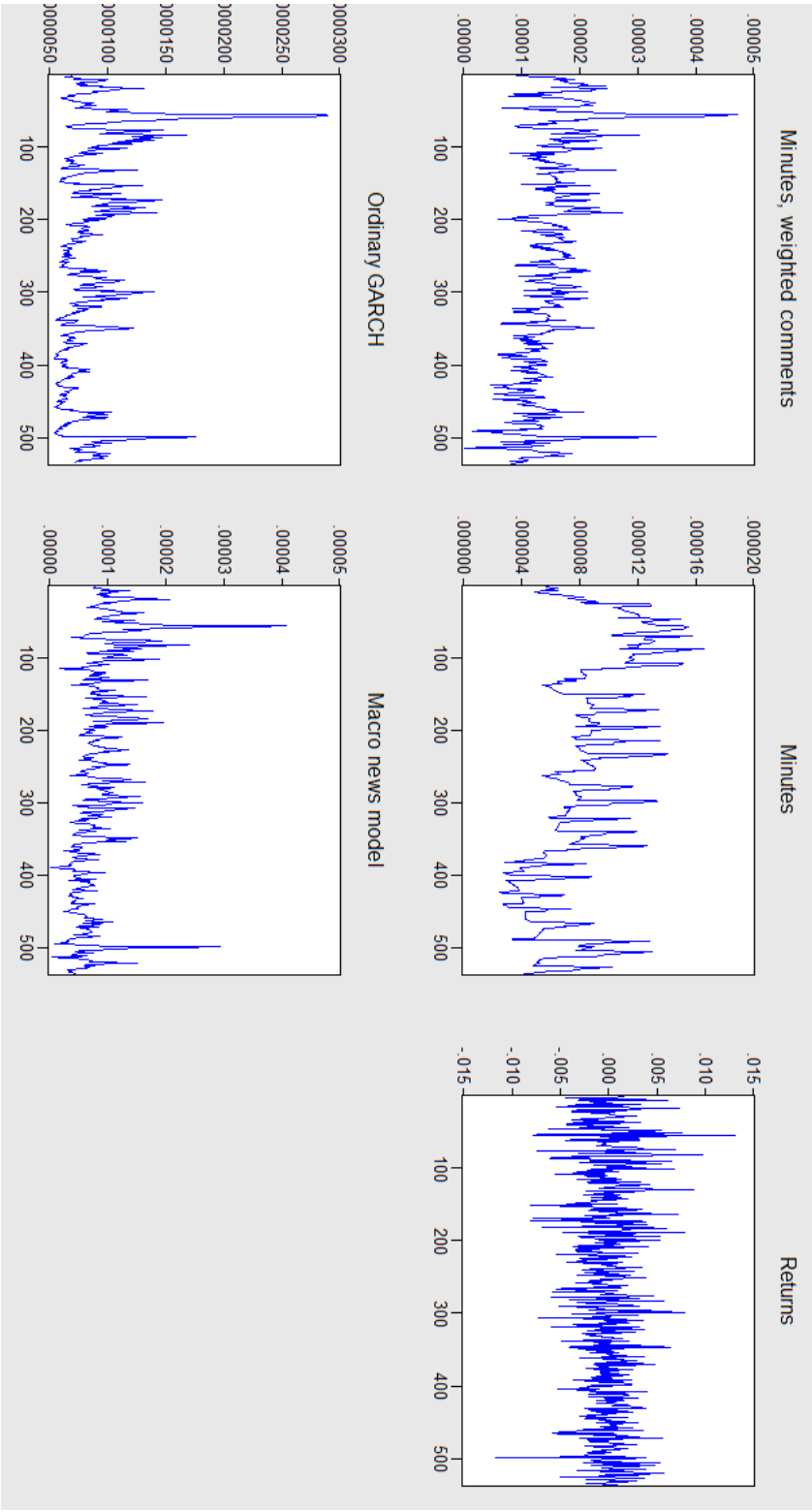

Figure A.2: GARCH variance series from different GARCH models with different external regressors.

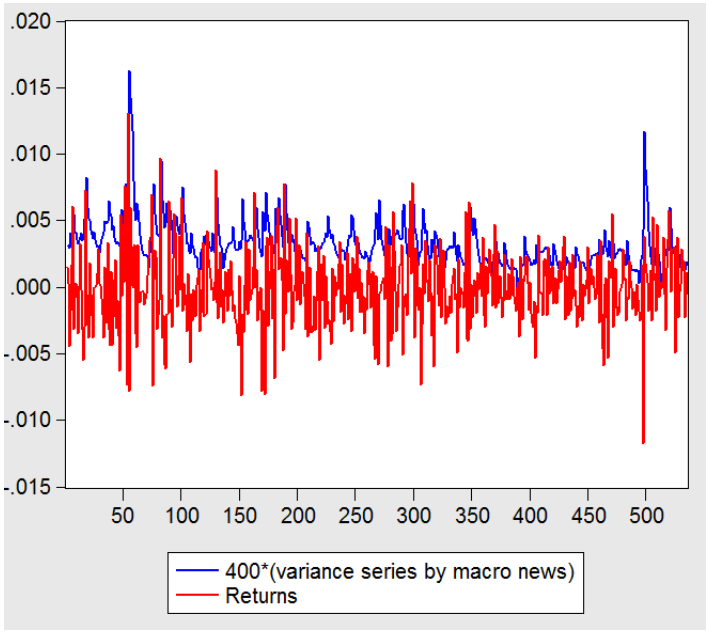

Figure A.3: GARCH variance series from the macro news model fitted to the returns series.

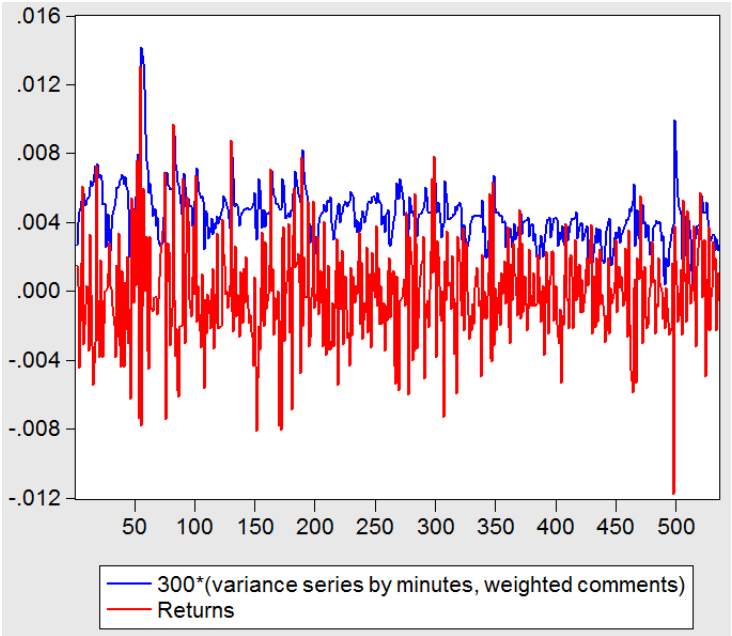

Figure A.4: GARCH variance series from the CNB's communication model fitted to the returns series.

Appendix B

Econometric analysis

The contents of the attached compact disk (CD):

- **dataset10.wf1**: the data set for Eviews with the regression models and graphs of conditional volatility.