Charles University in Prague

Faculty of Social Sciences

Institute of Economic Studies

MASTER THESIS

Evaluation of interest rates predictions: The case of Czech National Bank

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Declaration of Authorship

1. Hereby I declare that I have compiled this master thesis independently, using only the listed literature and sources.
2. I declare that the thesis has not been used for obtaining another title.
3. I agree on making this thesis accessible for study and research purposes.

Prague, July 29, 2013

Signature

Acknowledgments

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Abstract

This research focuses mainly on the evaluation of interest rates predictions (predictions of 3M PRIBOR rate) published by Czech national bank. In the first part of the thesis reasons and potential central bank´s benefits of the publishing of interest rate predictions are presented, based on the current academic literature. In the next chapters econometric and non-econometric evaluation of Czech national bank forecasts is provided. Furthermore, predictions from Czech Treasury, random walk process and my own autoregressive and vector autoregressive predictions were evaluated as well. It has been concluded that Czech national bank produces and publishes the most accurate based on non-econometric and econometric evaluation of all examined predictions. Moreover during the F-test evaluation procedure, the forecasts of Czech national bank proved themselves to be unbiased for the longest time horizon of all examined predictions.

JEL Classification	C53, E47, E53, C23, E50
Keywords	evaluation, predictions, interest rates, CNB

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Abstrakt

Práce se zaměřuje zejména na hodnocení predikcí úrokové míry (predikce 3M PRIBORu), které jsou publikovány Českou národní bankou. V první části práce jsou prezentovány důvody a potencionální benefity z publikování prognóz úrokových měr s ohledem na současnou odbornou literaturu. V dalších částech práce je prezentováno ekonometrické a neekonometrické hodnocení předpovědí České národní banky. Navíc byly vyhodnoceny taktéž predikce Ministerstva financí ČR a mé predikce z autoregresního a vektorově-autoregresního procesu. Těmito postupy bylo zjištěno, že Česká národní banka publikuje nejpřesnější odhady na základě ekonometrického i neekonometrického hodnocení ze všech sledovaných predikcí. Během F-testů se pak ukázalo, že predikce České národní banky jsou nevychýlené po nejdelší časový horizont.

Klasifikace JEL	C53, E47, E53, C23, E50
Klíčová slova	hodnoceni, predikce, PRIBOR, CNB

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Acronyms

RBNZ Reserve bank of New Zealand
BoE Bank of England
CNB Czech national bank
FOMC Federal Open Market Committee
MZ Minzer-Zarnowitz regression
MSE Mean squared error
3M PRIBOR Three month Prague intern banking offering rate
MPC Monetary policy comittee
AR Autoregressive
VAR Vector autoregressive

Master Thesis Proposal

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Proposed Topic:

Evaluation of interest rates predictions: The case of Czech National Bank

Topic Characteristics:

Czech national bank (CNB) is one of 5 national banks (NB) worldwide (along with NB of Israel, New Zealand, Norway and Sweden) publishing interest rate predictions. Publishing the interest rates forecasts leads to providing valuable information to financial markets and its players about expected development on financial markets. In case of CNB the 3M PRIBOR rates are forecasted. However there has not been published any academic work focusing on econometric evaluation of these CNB forecasts, although a study evaluating the predictions of Reserve bank of New Zealand exists (Goodhart and Lim, 2011). In my research I will examine the accuracy of interest predictions forecasted by Czech National Bank. Furthermore I will predict the 3M PRIBOR interest rates ex post using VAR methodology, instead of G3 model used by CNB and evaluate these predictions. G3 model, employed since 2007, is a dynamic stochastic general equilibrium model combining RBC and nominal rigidities used for forecasting future developments in Czech economy.

Hypotheses:

1. The precision of CNB interest rate forecasts decreases with the forecast horizon

2. The CNB interest rate forecasts are more precise than naive random walk forecasts

3. The CNB interest rate forecasts are more precise than those of professional forecasters (Komerční banka, Ministerstvo financí ČR)

Methodology:

For the purpose of estimation how the CNB 3M PRIBOR rates actually fit the real values I will use similar methodology as proposed in Goodhart and Lim 2011, more specifically Mincer-Zarnowitz fit regression. Mincer-Zarnowitz fit regression is simple OLS regression estimated using specified model. After estimation the joint hypothesis of coefficients is tested in order to find out whether the forecasts fit real values. To evaluate CNB forecasts vis-á-vis to professional forecasters same methodology will be employed. In order to predict my own 3M PRIBOR rates VAR methodology will be used.

Outline:

1.) General introduction of interest rate prediction
   i) The reasons behind i.r. publishing
   ii) The importance of i.r. forecast to financial markets
   iii) Market behaviour after the announcement of i.r. forecasts
2.) Methodological introduction
   i) Mincer-Zarnowitz fit regression
   ii) VAR modelling of interest rate
3.) Results from evaluation
   i) Results from CNB case
   ii) Comparison of CNB and KB, MFCR forecasts
   iii) Comparison of VAR prediction and G3 predictions
4.) Conclusions with possible further extension

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Author

Supervisor

Chapter 1
Introduction

Central bank transparency and financial stability has been an important topic of an academic and public discussions over the recent several years. And the theme has become even more important after the recent financial and economic crisis. In order to become more publicly open, the growing amount of central banks worldwide, decided to publish their unconditional numerical or verbal prognoses regarding various economic indicators such as inflation (most of the cases), exchange rate and interest rate predictions. The pioneer in becoming more transparent institution is, without a doubt, the Reserve bank of New Zealand (hereafter the RBNZ). RBNZ was the first central bank that has implemented inflation targeting to its monetary policy framework, and more importantly for my chosen topic, as the first central bank started in 1998 publishing the 3 months numerical short-term interest rates forecasts. There are various reasons behind providing the public with these forecasts and various public benefits coming from publishing the forecasts, I will focus on them afterward.

As important part of predicting procedure is ex post evaluation of the forecasts, in my diploma thesis I am focusing on the case of Czech national bank´s (hereafter the CNB) predictions of interest rate. CNB predicts and publicly releases the three months PRIBOR (3M PRIBOR is the benchmark interest rate at interbank deposit market, that is counted (fixed) by the agent for the Czech Forex Club quotations from reference banks for deposits sale (offer) CNB (2006)) forecasts together with predictions focusing on GDP growth, inflation and exchange rate since February 2008, on quarterly basis. The main task of my diploma thesis is to answer the question, how the predictions of 3M PRIBOR made by CNB accurate are. Furthermore I will compare my results with the conclusions Goodhart and Lim (2011) arrived at. And as an extension I will predict my own forecasts using different approach than is employed by CNB. Namely CNB uses G3 model for predictions. G3 model belongs to

a dynamic stochastic general equilibrium sets of model, that combines real business cycle theory and nominal rigidities [1]. In order to predict my own 3M PRIBOR rates the VAR and Box-Jenkins methodology will be employed. After creating the predictions using mentioned methodology, I will examine their accuracy as well, to find out whether different approach can produce more precise predictions or not. As I intend to enlarge the methodology approach employed in Goodhart and Lim (2011) in this thesis, not only econometric evaluation will be performed. Because CNB publishes the predictions in fan charts, in my thesis I want to explore how often is the predicted value above/equal/under the true value. This so called sign evaluation is further explained in methodology part. Further the predictions will be put under evaluation of mean squared error approach. Next graph represents CNB fan chart used for graphical representation of the released predictions.

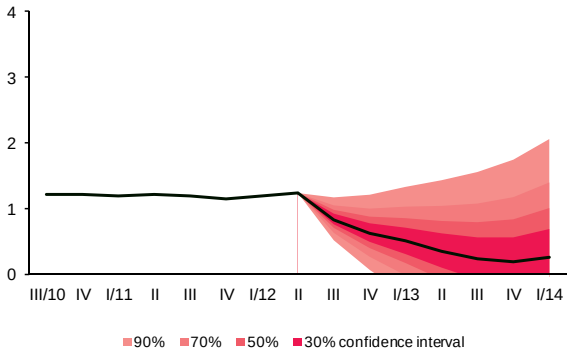

Figure 1.1.: CNB 3M PRIBOR forecast

However, in my thesis I will not focus only on central banks, but I will also examine the predictions of professional forecasters.l. From the market I have chosen predictions performed by Czech Treasury. Czech Treasury has been chosen as it forecasts 3M PRIBOR on same basis and for similar time horizon as CNB. They are released with predictions update of other macroeconomic variables on quarterly basis. Although for example the Czech commercial banks provide their own predictions usually published with their quarterly business results, however the predictions are for the four quarters time horizon (yearly average of 3M PRIBOR), which makes them incomparable to CNB predictions.

The main hypotheses of this thesis are following:

[1] The definition is borrowed from www.cnb.cz

- CNB 3M PRIBOR forecasts are more accurate than random walk process and no-change process[2].
- CNB 3M PRIBOR forecasts are more accurate than values predicted by Treasury.
- The precision of CNB 3M PRIBOR forecasts decreases with increasing time horizon.

The thesis is divided as follows. After the introduction part chapter 2 reviews related literature, focusing on recent academic papers providing interest rates predictions. After the literature overview part is situated part with focus on why the central banks release the numerical predictions of interest rates, what are the possible benefits from such activity. Closing chapter one is part with focus on importance of 3M PRIBOR in Czech economy and how the rate is computed by CNB. Then in Chapter two the data description is provided together with introduction to the evaluation methodology employed in this thesis. In chapter 3 and 4 the results of evaluation together with comments are provided. Chapter 5 is dedicated to the conclusions of this thesis and possible future enlargements.

[2] In this thesis the no-change process is considered as a process where predictions for time t+1, t+2, t+3 and t+4 are equal to value of 3M PRIBOR at time t.

Chapter 2
Theoretical reasons for publishing forecasts

2.1. Literature overview

As the topic of central bank´s transparency, and financial stability in general, recently became an important part of academic discussions, many authors put their effort onto the similar topic as I have chosen for my diploma thesis. Basically we can divide the authors, that focused on similar topic, into two groups. The first group of authors focused on theoretical reasons why the central banks should or should not publish the interest rate forecast (see for example Holmsen and Qvigstad (2008) or Mishkin (2004)). The second group of authors explore the accuracy of the forecasts using various approaches (see Goodhart and Lim (2011)). But to my best knowledge, there has not been published any academic work focusing on an econometric evaluation of CNB´s 3M PRIBOR predictions. Although other CNB´s forecasts of economic variables have been through examination (see Novotny and Rakova (2012) or Babecky and Podpiera (2011) or Antal et al. (2008)), the interest rate predictions remain unevaluated so far.

But CNB is not the only central bank that provides their predictions publicly available. Nowadays there are four more central banks that predict and more importantly also publish numerical interest rates forecasts. Namely these banks are central banks of Israel, New Zealand, Norway and Sweden, according to Franta et al. (2011). For example Goodhart and Lim (2011) explored the accuracy of predicting interest rates in case of central bank of New Zealand (RBNZ) and Bank of England (BoE). In case of RBNZ the original numerical forecasts published by the bank itself have been examined, for BoE the forecasts were derived from market yield curve. In order to

evaluate these predictions, the so called Minzer-Zarnowitz regression was employed. More space will be dedicated to the idea behind the Minzer-Zarnowitz regression in methodology part as same evaluation approach will be used in my thesis. Based on the results, authors came to several conclusions. Firstly, the accuracy of interest rates predictions decreases with increasing time horizon. In meaning that the predictions for next two quarters proved themselves to be highly accurate, for the quarter coming after the information value decreased, but still could be thought considerably accurate. For the fourth quarter time horizon the information value was declining the further the time horizon went, making these predictions for longer time periods practically useless (with almost no information value Goodhart and Lim (2011)). Another finding based on their research is the fact that the predictions made by RBNZ were found more accurate than simple random walk process (the difference between interest rate at time t and t-1 is equal to $\varepsilon_t \sim N(0.1)$). Furthermore the forecasts tended to be heavily biased depending on the economic cycle, e.g. in times of recession the predictions were usually better scenario than its real values Goodhart and Lim (2011). The bias of predictions depending on the part of economic cycle is displayed in graph 2.1 placed bellow.

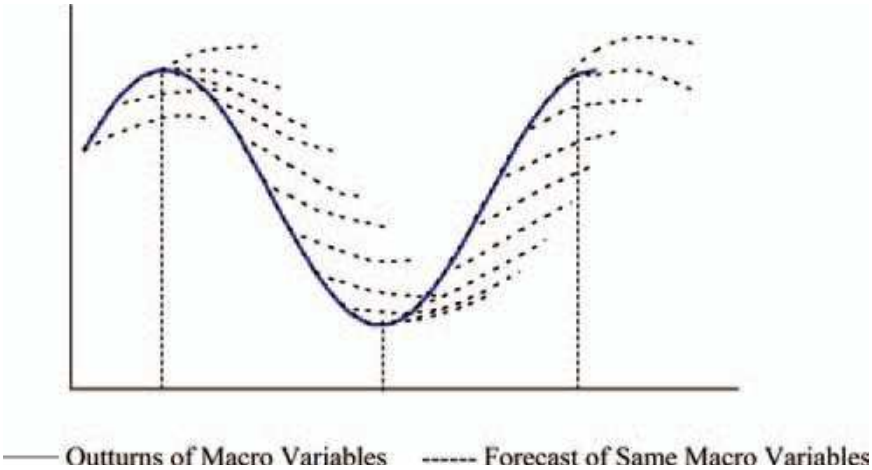

Figure 2.1.: Predictions bias on economic cycle Goodhart and Lim (2011)

Another authors, Rudebusch and Williams (2006), focused on non-econometric evaluation of interest rate (resp. federal fund rate) predictions in case of Federal Open Market Committee (FOMC)[1] that started releasing the predictions in 2003. It is

[1]FOMC is monetary policy committee of Federal reserve bank.

important to point out that FOMC does not release the numerical forecasts of federal fund rate, but rather their verbal opinion on the future path of interest rates Rudebusch and Williams (2006). Their findings suggest that even though there are some negative public responses to the federal fund rate releases, with this step to greater openness the FOMC still achieved less volatility on money market. Holmsen and Qvigstad (2008) focused on case of another central bank that publishes interest rate predictions, the central bank of Norway (Norges bank). In their work they examined the behavior of the money market in Norway after the release of interest rate predictions by Norges bank. Based on their research, they arrived at similar conclusion as Rudebusch and Williams (2006). Their findings suggest that market tends to be less volatile after the prediction are publicly released.

2.2. Positive effects of being transparent and publishing the forecasts

In the last 20 years the step away from constant interest rate assumption (short-term interest rate is assumed to be constant) to publishing numerical interest rates is considered to be a great step forward, not only to improve transparency of the central bank Filacek et al. (2007). Starting from broader point of view, the transparency and communication with public in the central banks behavior is academically considered as a beneficial part or attribute of monetary policy. The transparency of the central bank is considered positive as it has impact on creation of public expectations. And particularly the openness of central banks has been dramatically improved during last two decades. But one can ask how to measure and compare the openness of the central banks worldwide? Dincer and Eichengreen (2007) introduced so called transparency index. Their index covers political, economic, procedural, policy and operational aspects of monetary policy. Based on their index we can conclude, that worldwide 85 central banks out of 100 have improved their transparency and no bank has decreased its openness to public between 1998 and 2006.

When taking into account the most recent results on financial stability and transparency index (FST) from Horváth and Vasko (2012), we can clearly conclude that the trend in improving transparency continued up to year 2012 as well. The previously mentioned improvement in the central banks transparency is depicted in following graph. The graph represents continent's averages of financial stability and transparency index for the period 2000 to 2012. The improvement in the central

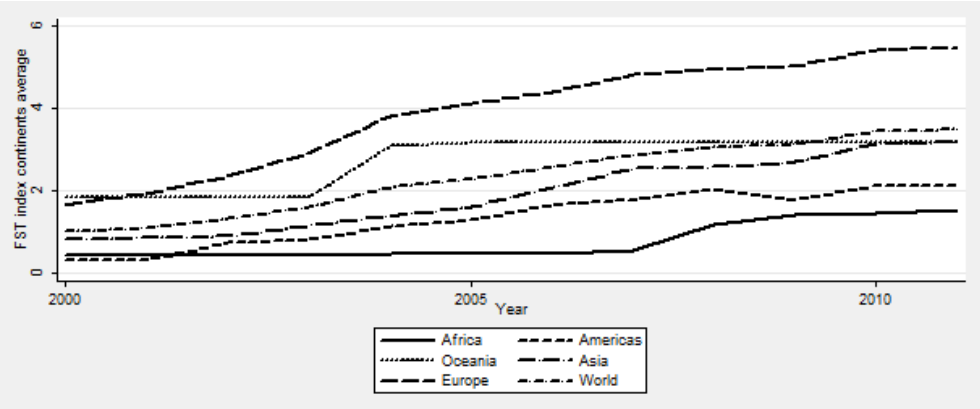

Figure 2.2.: Financial stability index borrowed from Horváth and Vasko (2012).

bank's transparency cannot be doubted.

But in recent decades there has been a shift in understanding the central bank's role and actions as well. As Woodford (2005) pointed out the whole process of inflation targeting nowadays is more or less managing the expectation procedure (all of five central banks publishing interest rate predictions are employing the inflation targeting to achieve their monetary goals). Or as Rudebusch and Williams (2006) found out the whole process of monetary policy has more or less shifted from past-earned central bank credibility to forward-looking credibility (public of course evaluates the prediction ex post as well). They find a name for this phenomena-forward looking view of monetary policy. And to add more, they stated that the whole process of monetary policy became rather process shaping the entire yield curve of interest rates. Furthermore, one of important benefit of the openness is the fact that it helps public to understand the central bank's action.

Step away from general introduction of importance of general transparency, there are basically three types of interest rate predictions that can be publicly released. Goodhart (2009) suggests the following division:

1. constant rate predicted on latest observable information
2. extracted and predicted from the yield curve s
3. chosen by monetary policy committee (hereafter MPC)

The first option of forecasting is not nowadays likely to happen, as „ extrapolating the current level of interest rates into the future will give implausible results and cannot therefore be either a sensible basis for internal decisions or a fruitful means

of communication with the private sector.“ Goodhart (2009). Although it has been used for example by Norges bank until 2002. The second is not the right choice either, as the market predictions are just guesses of possible future behavior of the central bank in setting the interest rates Goodhart (2009). That leaves us only the third option, to publish the predictions that are made by the central bank and MPC has voted and agreed on them. But the question that still remains to be answered is how the MPC should agree on future interest rate. Svensson (2006) solves this problem via use of future interest rate path median of individual members of MPC. The last point is in use of central banks of Norway and central bank of Sweden and Czech national bank as well.

When speaking about the form of publishing the predictions, Goodhart (2009) and Franta et al. (2011) highlight the importance of using the fan charts while providing the forecasts. The argument behind is the fact that central bank using fan charts can reduce the risk that public will accept the point estimate as unconditional commitment to hold the prediction at all costs. Furthermore if central bank intends to publish the forecast, these predictions must be well prepared. Otherwise it would lose accountability and credibility. And with use of fan chart, where not only point estimation is present, central bank can lower the risk it will be accused of being inaccurate.

But the question still remains to answer, why should the central bank provide their predictions to the public? Starting from broader point of view, Tarkka and Mayes (1999) focused on the benefits from such activity and they came to interesting conclusion. Firstly, the central bank should produce and release the forecasts because it lowers the uncertainty for other decision-makers. Secondly, publishing the predictions helps in cooperation of macroeconomic policies within the economy and provides kind of accountability for the central bank and helps it to learn from its past mistakes. When focusing on particular experiences from the central banks that publish their predictions we can use conclusion from Filacek et al. (2007). They focused on namely RBNZ, Norges bank and central bank of Sweden (Sveriges Riksbank). In general, according to Filacek et al. (2007), the experience from publishing is positive. Markets understood the conditional meaning of predictions. So indeed the release of predictions do have impact on the creation of public expectations.

It is important to point out that the expectations influence of publishing is met, when economic agents know at least some basic framework of reaction policy (how will central bank act in case of various shocks occurring) of central bank. Holmsen and Qvigstad (2008) found that furthest went Norges bank that in their monetary

reports publishes section, where they explain what particular shock had the influence on the interest rate prediction deviation. This particular action of Norges banks certainly helps public to understand what stood behind the deviation from forecast values of interest rate.

But not to speak only about the advantages of publishing the forecasts, there are authors that claim the releasing of predictions might be harmful, for example Rudebusch and Williams (2006). In their research they found out that there have been observed moments on the market, when interest rate predictions were misinterpreted by public. This public misinterpretation led to creation of over/under reaction of the expectations. Moreover they add that the public might see the interest rate predictions as central bank's unconditional commitment to keep up with the real rates with the predicted ones at all costs. Another disadvantage arises in the moment when public overestimates the accuracy of the central banks predictions. Than the forecasts are considered to be harmful to credibility and even more important the accountability of the central bank.

Another author finding the disadvantages is Mishkin (2004). The author proposed that the being too transparent institution and release publicly the predictions can cause the problems in communication of central bank's with public. Furthermore the achievement of long-term CB´s objectives may become harder. The problem lies in the fact, that the predictions must be agreed within the MPC. In order to publish the predictions the members of MPC must vote on the predictions and as Mishkin (2004) suggests the voting in such case is not easy to solve. The solution provided by Svensson (2006) was provided above. Furthermore the whole set of predictions made by central banks is unconditional as the changes in economy demands the change in predictions. Filacek et al. (2007) summarizes all the advantages and disadvantages using one phrase, the publishing the interest rates forecasts is double-edge weapon.

2.3. Computation and importance of 3M PRIBOR rate

Three month Prague inter-banking offering rate (usually abbreviated as 3M PRIBOR) is the benchmark interest rate at the interbank deposit market that is counted (fixed) by the agent for the Czech Forex Club quotations from reference banks for deposits sale (offer) CNB (2006). Generally speaking, 3M PRIBOR is the rate at which reference banks are willing to provide liquidity to other bank for three month time horizon. The

whole process of setting the rate belongs to the CNB. The importance of the rate lies in the fact that it is used as a reference rate for mortgages. The computation procedure involves the so called reference banks. Nowadays, there are seven banks marked as reference banks according to CNB. Namely these are Česká spořitelna, Komerční banka, ČSOB, ING bank, LBBW bank, Raiffeisenbank and Unicredit bank. According to CNB (2006) that stated the rules for computation of PRIBOR, the reference banks are asked to place their bids from 10:30 until 10:45 on working days. The highest and the lowest bid are excluded. Afterward the computation of 3M PRIBOR is simple arithmetic average of values received from reference banks. Then the rate is revealed to the public on CNB web pages.

Chapter 3
Methodology and data

3.1. Methodology

3.1.1. Evaluation procedure

Based on the current academic literature there are several approaches how to handle the evaluation of predictions. In order to find out how the CNB and other predictions performed in terms of overforecasting resp. underforecasting the 3M PRIBOR rate, the so called sign evaluation will be firstly performed. This evaluating procedure was carried out e.g. in CNB (2008) to show how often CNB overshoots or undershoots its inflation target. The evaluating itself runs according simple formula:

$$f(z) = \frac{1}{N}\sum_{t+1}^{N} z_{t+s}$$

where $f(z)$ is the sign evaluation function and z_{t+s} equals 1 if the forecast´s value is greater than the actual value and 0 otherwise.

Using this proposed approach I will be able to examine how often with increasing time horizon CNB, Treasury predicts over or under forecasts of 3M PRIBOR.

The usually often mentioned evaluation technique is so called mean squared error (MSE). This particular approach has been used p.e. in Audrino and Medeiros (2010) when evaluating their results from interest rates forecasts. The MSE evaluation runs using following formula:

$$MSE = \frac{1}{n} * \sum_{i=1}^{n} (IR_{t+h} - \hat{IR}_{t+h})^2$$

- where IR_trepresent the 3M PRIBOR rate at time t

- $\hat{IR}_t$ stands for the prediction of 3M PRIBOR at time t
- n is the number of observations
- h is increasing time horizon of the predictions

The MSE evaluation will start with predictions published in Q1 2008 forecasting the 3M PRIBOR for Q2 2008 and afterward. However, this simple procedure needs to be bench-marked with some other MSE results as MSE is the dimensionless variable. In order to benchmark the predictions of CNB I will compare the MSE from original predictions with my own forecast values, from Treasury, random walk and no change predictions.

In order to examine the predictions with the more advanced approach I will use the procedure used in Goodhart and Lim (2011). Namely the Minzer-Zarnowitz regression (hereafter MZ regression) will be employed Mincer and Zarnowitz (1969). The equation of MZ regression has following form:

$$IR_{(t+h)} = \beta_1 + \beta_2 * \hat{IR}_{(t,t+h)} + \varepsilon_t$$

- where $IR_{(t+h)}$ stands for interest rate at particular time t+h,
- the $\hat{IR}_{(t,t+h)}$ is the prediction forecast at time t for h time horizon.
- ε_t is the error term

The equation coefficients will be estimated using OLS estimation. Moreover, intuitively to have unbiased and accurate predictions one expects the coefficients $\beta_1 = 0$ and $\beta_2 = 1$. This proposed equality of coefficients will be tested using standard F-test on 5% significance level, if not stated otherwise. The undoubtable advantage of this approach is the fact, that I will be able to evaluate, how the forecast are accurate with increasing time horizon (with increasing h). Moreover the F-test allows to decide whether the predictions suffer from bias or not.

Furthermore, following the procedure proposed by Goodhart and Lim (2011) two more equations will be estimated. The first one:

$$IR_{(t+h)} - IR_t = \alpha_1 + \alpha_2 * (\hat{IR}_{(t,t+h)} - IR_t) + \varepsilon_t$$

- where $IR_{(t+h)}$ stands for interest rate at particular time t+h, $IR_t$is interest rate at time t
- the $\hat{IR}_{(t,t+h)}$ is the prediction forecast at time t for h time horizon.

Equation proposed in this way helps us to evaluate how accurately with increasing h (increasing time horizon) can the forecaster (CNB, Treasury or AR(2) and VAR) predict the future interest rate. As in the case of previous equation the coefficients will be estimated using OLS and again as one can expect the coefficients will be tested using F-test under null hypothesis: $\alpha_1 = 0$ and $\alpha_2 = 1$

Final equation for estimating the accuracy of predictions looks as follows:

$$IR_{(t+h)} - IR_{(t+h-1)} = \gamma_1 + \gamma_2 * (\hat{IR}_{(t,t+h)} - \hat{IR}_{(t,t+h-1)}) + \varepsilon_t$$

- where $IR_{(t+h)}$ stands for interest rate at particular time t+h, $IR_{(t+h-1)}$ is interest rate at time t+h-1
- the $\hat{IR}_{(t,t+h)}$ is the prediction forecast at time t for h time horizon and $\hat{IR}_{(t,t+h-1)}$ is the prediction made at time t for time horizon t+h-1
- ε_t is the error term

The equation asks how the forecaster is able to predict one quarter ahead moves of 3M PRIBOR with increasing time horizon. To explore the bias of predictions the F-test with restriction set: $\gamma_1 = 0$ and $\gamma_2 = 1$ will be employed.

3.1.2. Prediction procedure

For the purpose of my thesis I want to predict my own 3M PRIBOR rates for same time length (since Q1 2008 until Q4 2012). I will predict them and employ them in above proposed methodology and compare the results with the CNB results. To do so, I will employ firstly no change process, random walk generating process, simple Box-Jenkins methodology (namely AR(2) process). In order to create predictions with more advanced methodology I will use the VAR approach. As has been earlier mentioned CNB employes G3 model for predicting the variables, with use of AR and VAR methodology I want to explore whether employing the different methodology approaches will lead to significantly better or worse predictions than CNB produces.

Firstly the no change prediction generating process is for the purposes of this thesis defined as follows:

$$\hat{IR}_t = IR_{t-h}$$

where $\hat{IR}_t$ is the predicted value for time t and IR_{t-h} is the actual value of 3M PRIBOR at time t-h, where h runs from 1 to 4.

Secondly the random walk generating prediction process runs according to the following formula:

$$\hat{IR}_t = IR_{t-h} + \varepsilon_t$$

$\hat{IR}_t$ represents the predicted value for time t, IR_{t-h} is the actual value of 3M PRIBOR at time t-h, h runs from 1 to 4 and ε_t has the normal distribution $N(0, \frac{1}{100})$[1].

Next, before the actual estimation of AR process the unit root test must take place as interest rates are thought to be integrated of order 1 at least as mentioned in Goodhart (2009). To find out whether such relation is hidden in 3M PRIBOR data I will firstly perform the augmented Dickey-Fuller test (ADF test). The test has following specifications:

$$\Delta IR_t = \alpha_0 + \beta * IR_{t-1} + \sum_{i=1}^{n} \alpha_i * \Delta IR_{t-i} + \varepsilon_t$$

- where ΔIR_t is change of 3M PRIBOR t rate between time t-1 and t
- IR_{t-1} is 3M PRIBOR rate at time t-1
- ε_t is the error term

After the result of ADF test I will further with help of following model (AR(2)) predict the 3M PRIBOR rate as follows:

$$IR_t = \alpha_1 + \alpha_2 * IR_{t-1} + \alpha_3 * IR_{t-2} + \varepsilon_t$$

- where IR_t refers to 3M PRIBOR rate at time t
- IR_{t-1} is the 3M PRIBOR rate from previous period
- IR_{t-2} is the 3M PRIBOR rate from two quarters before period
- ε_t is the error term

Firstly the coefficients of above proposed equation will be estimated. After estimating the coefficients I will be able to forecast my own 3M PRIBOR rates h times ahead.

In order to apply more advanced technique I will employ features from VAR methodology approach. For the purpose of VAR predictions of 3M PRIBOR I will use model proposed by Borys and Horvath (2008). The data entering the VAR model will be: unemployment, CZK/EUR exchange rate, inflation and 3M PRIBOR rate. The used data in the model are on monthly basis provided by CNB database ARAD or Czech statistical office. The proposed VAR model has following specifications:

[1] The standard normal distribution had to be adjusted for the purposes of estimations, the original values of N(0,1) were divided by 10.

$$\begin{bmatrix} UN_t \\ INF_t \\ IR_t \\ FX_t \end{bmatrix} = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \end{bmatrix} + \Phi_1 * \begin{bmatrix} UN_{t-1} \\ INF_{t-1} \\ IR_{t-1} \\ FX_{t-1} \end{bmatrix} + ... + \Phi_p * \begin{bmatrix} UN_{t-p} \\ INF_{t-p} \\ IR_{t-p} \\ FX_{t-p} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2.t} \\ \varepsilon_{3,t} \\ \varepsilon_{4,t} \end{bmatrix}$$

- where IR_t is 3M PRIBOR rate at time t, UN_t stands for unemployment at time t, FX_t represents the exchange rate between Czech crown and Euro and INF_t is inflation at time t, the term t-p refers to time lag
- δ_1, δ_2, δ_3, δ_4 is vector of constants
- $\Phi_1 ... \Phi_p$ are the matrices of estimated coefficients
- $\varepsilon_{1,t}$, $\varepsilon_{2,t}$, $\varepsilon_{3,t}$, $\varepsilon_{4,t}$ are the residuals

The optimal time lag for estimations and more importantly for the predictions will be chosen based on combination of information criterions.

Important attribute of VAR is the question of stability. The stability of above proposed model will be tested using Chow test presented in Chow (1960). The test explores whether any structural break is present within the data set. The test has following form.

Let´s suppose that the tested model has above mentioned form:

$$\begin{bmatrix} UN_t \\ INF_t \\ IR_t \\ FX_t \end{bmatrix} = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \end{bmatrix} + \Phi_1 * \begin{bmatrix} UN_{t-1} \\ INF_{t-1} \\ IR_{t-1} \\ FX_{t-1} \end{bmatrix} + ... + \Phi_p * \begin{bmatrix} UN_{t-p} \\ INF_{t-p} \\ IR_{t-p} \\ FX_{t-p} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2.t} \\ \varepsilon_{3,t} \\ \varepsilon_{4,t} \end{bmatrix}$$

The meaning of variables is the same as in above proposed VAR model. The dataset will be further divided into two groups by the suspicious breaking point. Next, set of two equations will be estimated. Firstly, the following equation estimated on the data before the suspicious breaking point:

$$\begin{bmatrix} UN_t \\ INF_t \\ IR_t \\ FX_t \end{bmatrix} = \begin{bmatrix} \delta_{11} \\ \delta_{12} \\ \delta_{13} \\ \delta_{14} \end{bmatrix} + \Phi_{11} * \begin{bmatrix} UN_{t-1} \\ INF_{t-1} \\ IR_{t-1} \\ FX_{t-1} \end{bmatrix} + ... + \Phi_{1p} * \begin{bmatrix} UN_{t-p} \\ INF_{t-p} \\ IR_{t-p} \\ FX_{t-p} \end{bmatrix} + \begin{bmatrix} \varepsilon_{11,t} \\ \varepsilon_{12.t} \\ \varepsilon_{13,t} \\ \varepsilon_{14,t} \end{bmatrix}$$

And the second equation is estimated using the data after the suspicious breaking point, respectively:

$$\begin{bmatrix} UN_t \\ INF_t \\ IR_t \\ FX_t \end{bmatrix} = \begin{bmatrix} \delta_{21} \\ \delta_{22} \\ \delta_{32} \\ \delta_{24} \end{bmatrix} + \Phi_{21} * \begin{bmatrix} UN_{t-1} \\ INF_{t-1} \\ IR_{t-1} \\ FX_{t-1} \end{bmatrix} + ... + \Phi_{2p} * \begin{bmatrix} UN_{t-p} \\ INF_{t-p} \\ IR_{t-p} \\ FX_{t-p} \end{bmatrix} + \begin{bmatrix} \varepsilon_{21,t} \\ \varepsilon_{22.t} \\ \varepsilon_{23,t} \\ \varepsilon_{24,t} \end{bmatrix}$$

The null hypothesis of Chow´s test is that no breaking point is present within the data, respectively:

$$H_0 : \begin{bmatrix} \delta_{21} \\ \delta_{22} \\ \delta_{32} \\ \delta_{24} \end{bmatrix} = \begin{bmatrix} \delta_{21} \\ \delta_{22} \\ \delta_{32} \\ \delta_{24} \end{bmatrix} \wedge \Phi_{11} = \Phi_{21} \wedge \Phi_{1p} = \Phi_{2p}$$

Furthermore the Chow test statistics has following form:

$$\frac{SSR-(SSR_1+SSR_2)}{SSR_1+SSR_2} * \frac{n_1+n_2-2k}{k} \approx F(k, n_1+n_2-2k)$$

where

- SSR is sum of squared residuals from original model
- SSR_1 is sum of squared residuals from the model estimated on the data before the breaking point
- SSR_2 is sum of squared residuals from the model estimated on the data after the breaking point
- k is number of parameters
- n_1 and $n_1$are the numbers of observation in particular data-set
- $F(k, n_1+n_2-2k)$ is the Fisher-Snedecor distribution

3.2. Data and forecasts from CNB and Czech Treasury

In this section the description of the data set will be provided. For the purpose of the evaluation CNB 3M PRIBOR forecasts I firstly needed to gather the original values of 3M PRIBOR on quarterly basis. As has been mentioned before CNB started to publish the interest rates prediction with beginning of the first quarter of 2008. Intuitively my data set started with the original values in first quarter of 2008, continuing

until forth quarter of 2012. The whole data set counted for 19 observations, which is lower amount of observations than Goodhart and Lim (2011) has started their evaluation with. The original values of 3M PRIBOR are publicly available at CNB web pages and in my thesis I used the month ending values. The data set of original values of 3M PRIBOR had following descriptive statistics:

Summary statistics, using the observations	2008:1 - 2012:4
Mean	2.15
Median	1.88
Minimum	0.50
Maximum	4.05
Standard deviation	1.14
C.V.	0.58
Skewness	1.09
Ex. kurtosis	-0.46

Table 3.1.: 3M PRIBOR descriptive statistics

Furthermore, as proposed by Goodhart (2009) the interest rate path is statistically significant to contain the unit root within it. Starting with this proposal firstly the original values of 3M PRIBOR were put under testing of unit-root presence within the data. In order to find whether the unit-root is present in the original values of 3M PRIBOR Augmented Dickey-Fuller test was employed.

```
Augmented Dickey-Fuller test for PRIBOR
including 2 lags of (1-L)PRIBOR (max was 8)
sample size 25
unit-root null hypothesis: a = 1

   test with constant
   model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: 0.024
   lagged differences: F(2, 21) = 3.653 [0.0435]
   estimated value of (a - 1): -0.0761162
   test statistic: tau_c(1) = -1.13902
   asymptotic p-value 0.7025

   with constant and trend
   model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: -0.048
   lagged differences: F(2, 20) = 4.314 [0.0277]
   estimated value of (a - 1): -0.249619
   test statistic: tau_ct(1) = -2.77201
   asymptotic p-value 0.2077
```

Table 3.2.: ADF test for 3M PRIBOR

Based on the p-value I have to reject the null hypothesis of the time series does not contain the unit-root within it. Having in mind above presented results I can clearly conclude that 3M PRIBOR predictions from CNB suffer from similar problem as Goodhart and Lim (2011) found out in case of predictions of BoE and RBNZ. Furthermore thanks to ADF test I know for developing my own predictions of 3M PRIBOR I will have to transform the time series using most probably the first differentiation.

In the second step all the predictions by CNB since 2008 have been gathered into one data-set matched with its predicted values. As has been stressed out previously and can be seen from graph of 3M PRIBOR rate, is the fact that the time series does not seem to be stationary. Moreover from simple graphical preliminary analysis we can see that CNB predictions probably suffer from bias, as Goodhart and Lim (2011) found out in case of RBNZ and BoE. The graph bellow represents the original values of 3M PRIBOR (solid line) together with the predictions for next 7 quarters (dashed lines). Only predictions and the original values are depicted.

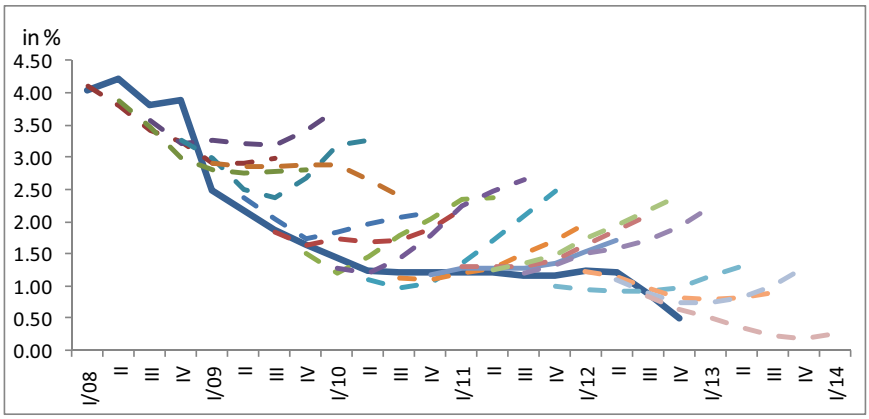

Figure 3.1.: 3M PRIBOR rates accompanied by its predictions from CNB

From the graph it can be clearly concluded that:

- Predictions during the decrease of 3M PRIBOR tend to be less steeper than original values.
- CNB predicts the reversal point (where decreasing trend turns to be increasing) more often than it really occurs.

- When the actual 3M PRIBOR rate is flat predictions are increasing in time, the only exception is the last forecast when the predictions are steadily decreasing.
- Since CNB started publishing the predictions the rates of 3M PRIBOR found themselves in decreasing environment.

As proposed earlier in my thesis I will focus on evaluation of predictions that are produced by the professional forecasters such as Czech Treasury. Originally I intended to focus my evaluation on the most important Czech commercial banks such as Česká spořitelna, Komerční banka and ČSOB. But unfortunately these credit institutions predict the values of 3M PRIBOR on quarterly bases, as in the case of CNB. But the predictions are the average of 3M PRIBOR rate for the whole following year. So for the reason of better comparison with CNB results I chose only the Czech Treasury´s predictions of 3M PRIBOR to work with. In following graph the Treasury´s predictions (four quarters ahead) with the original values of the PRIBOR rate are captured.

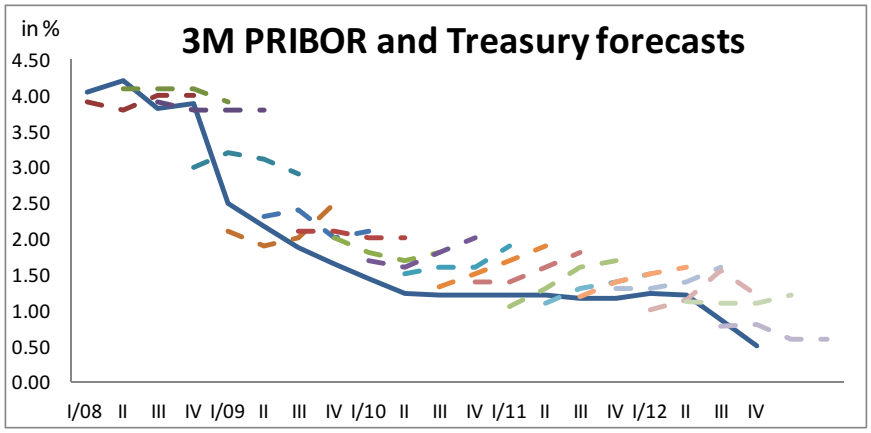

Figure 3.2.: 3M PRIBOR and Czech Treasury´s forecasts

As in previous case of CNB predictions we can derive several conclusion from graph:

- As in the case of CNB prediction the Treasury predictions during decrease of 3M PRIBOR tend to be less steeper than original values.
- Treasury´s forecasts tends to be almost only increasing in times when 3M PRIBOR is decreasing, which might but do not have to signalize the bias of predictions.
- Through observed period the predictions the rates of 3M PRIBOR found itself in decreasing environment.

Chapter 4
Evaluation results of CNB and Treasury

4.1. Evaluation of CNB predictions

4.1.1. Sign evaluation

As was proposed in methodology part, the first evaluation technique carried out is so called sign evaluation. Based on this criterion we can clearly conclude that CNB forecasts are more under predicting the real values with time horizon equal to one step ahead. With growing time horizon, however, the forecasts tend to be more over predicting the real values ending with ratio 94% of predictions are over-predicted in time horizon four quarters ahead. Following graph represents the ratios of over/under-predictions with respect to time horizon.

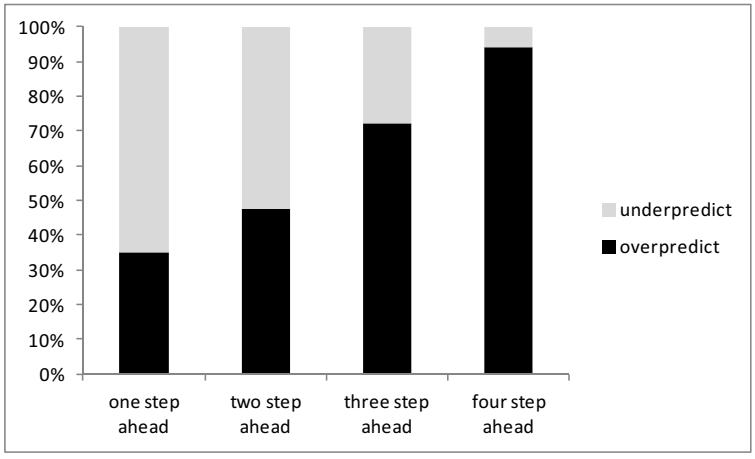

Figure 4.1.: Over/under predictions with respect to time horizon

The reasons behind this increasing number of over predictions probably lies in long term decreasing trend in 3M PRIBOR. As can be seen from figure 3.1 CNB allows in its predictions decreasing trend in 3M PRIBOR for two quarters ahead, but this decrease is usually followed by increasing values afterward.

4.1.2. Mean squared error evaluation

Before the actual evaluation process proposed by Goodhart and Lim (2011) I decided to employ MSE evaluation. As has been mentioned in methodology part, using MSE as a evaluation criterion enables to compare various prediction methods. Firstly I started MSE evaluation with one step ahead forecasts (one quarter ahead). Not to evaluate only predictions by CNB in this part, I decided to evaluate so called no change predictions (predictions for t+1 is equal value in t) and the predictions extracted from the adjusted random walk process. In order to obtain reasonable results with random walk process I had to slightly change the data generating process. In case of random walk, the change 3M PRIBOR should be equal to random number generated by normal distribution with zero mean and variance equal to one. But when employing this approach the changes were often higher than the original values, making the predictions practically useless. In order to unload this problem, simply the random values were divided by 10. After this slight adjustment the predictions made more sense. In the following table the MSE evaluation results are provided. On the first place is the forecaster with lowest MSE (with the most accurate predictions) followed by the second one etc.

First of all, the CNB predictions one quarter ahead counted for the least MSE. The RW process MSE was twice higher than MSE of CNB. For no-change process, the MSE counted for 161% of MSE of CNB.

Forecaster	MSE value
CNB	0.0847145
no change	0.1369550
RW	0.1713521

After one quarter ahead predictions for two quarters ahead forecasts were focused on. According to the original results from Goodhart and Lim (2011) the results should be still in reasonable boundaries. As in previous case I found out that predictions by CNB are the most precise as in the previous case. Although the MSE

for CNB predictions grew by 34% it still remained the lowest. In case of random walk and no change predictions, the adjusted random walk generated predictions with lower MSE than no change, unlike in previous case with one quarter ahead forecasts. Increase in MSE for RW skyrocketed by 96%, for no change 153%. This significant increase in MSE makes these predictions practically useless for predicting the 3M PRIBOR for longer period than one quarter ahead.

Forecaster	MSE value
CNB	0.1132435
RW	0.3351603
no change	0.3460800

The next coming MSE evaluation was focused on three quarters ahead predictions. The MSE increased by almost 36%, which is only by 1 percentage point higher than in previous case. Furthermore it clear to see that predictions generated by no change and random walk process are practically useless for this long horizon and most probably after. The MSE value skyrocketed by 107% in case of random walk process and by 104% in case of no change.

Forecaster	MSE value
CNB	0.1538091
RW	0.6931899
no change	0.7044400

The last remaining, the four quarters ahead predictions were put under the MSE evaluation as well. For CNB forecast the MSE significantly increased by 105% from previous value, which means that the predictions are becoming less informative, but nevertheless these predictions hold the first place as they still have lowest MSE value. In case of RW and no change predictions the MSE increased more slowly than in previous periods, for RW the increase counted for 52% and for no change 96%.

Forecaster	MSE value
CNB	0.314627913
RW	1.0546540
no change	1.3801800

- Predictions made by CNB have the lowest MSE in comparison to random walk process or no-change process, which means that their predictions were the most precise when evaluating using MSE.

- Adjusted random walk process performed worse than no-change for one quarter ahead predictions. However, the situation for predictions afterward changed, the adjusted RW showed lower MSE for predictions for two quarters ahead and further.

4.1.3. Minzer-Zarnowitz regression for CNB

The data set formed from real values of 3M PRIBOR and its predictions from CNB were divided to four groups[1]. First one containing the predictions one quarter ahead together with its corresponding values of 3M PRIBOR, second group with forecasts two quarters ahead with corresponding real values. For the third and fourth groups the idea was same as above. Firstly the model, commonly known as Minzer-Zarnowitz (MZ) regression, had to be estimated using OLS. For the predictions one quarter ahead the results are as follows:

$$\widehat{\text{Originalvalues}} = \underset{(0.482)}{0.0667659} + \underset{(15.730)}{1.01583}\,\text{onestepahead}$$
$$T = 19 \quad \bar{R}^2 = 0.9319 \quad F(1,17) = 247.44 \quad \hat{\sigma} = 0.29844$$
$$(t\text{-statistics in parentheses})$$

From the results can be clearly concluded that the constant term is close to zero and coefficient to predicted value is nearly one, as proposed by the model. The coefficient of determination counted nearly for 94%. In order to find whether the predictions are indeed statistically uneven from the real values the F-test must have been performed. The results were:

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[onestepahead] = 1	0.381785	0.2987

The p-value of the F-test is 0.38 which means we cannot reject the null hypothesis of $\beta_0 = 0$ and $\beta_1 = 1$. In case of one step ahead forecasts of 3M PRIBOR CNB performed with high R^2 that counted for nearly 94% and more importantly the F-test´s null hypothesis was not rejected, which makes the predictions statistically even to the real values. The CNB results for one quarter ahead are comparable with the one Goodhart and Lim (2011) arrive at in the case RBNZ or BoE.

[1] As proposed in Goodhart and Lim (2011)

Second MZ regression performed is two quarters ahead predictions evaluations. According to findings of Goodhart and Lim (2011) these predictions created by RBNZ were still reasonably accurate and unbiased. In case of CNB two quarters ahead forecasts the results are as follows:

$$\widehat{\text{Originalvalues}} = \underset{(0.18092)}{-0.0483358} + \underset{(0.089397)}{1.05276}\ \text{twostepahead}$$
$$T = 18 \quad \bar{R}^2 = 0.8901 \quad F(1,16) = 138.68 \quad \hat{\sigma} = 0.35045$$
$$\text{(standard errors in parentheses)}$$

In case of two quarters ahead, CNB performed with slightly lower R^2 than in previous case. The coefficient of determination of second equation counted for 89% and the estimated coefficients were around the proposed levels of $\beta_0 = 0$ and $\beta_1 = 1$. The F-test results follows:

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[twostepsahead] = 1	0.72109	0.337227

As in the previous regression the null hypothesis cannot be rejected. Which makes CNB predictions two quarters ahead statistically even to the real values and unbiased. When comparing to the results from Goodhart and Lim (2011) we can clearly conclude that CNB performs so far not worse than RBNZ or BoE.

The next regression carried out was with the data of original values of 3M PRIBOR and the predictions three quarters ahead. The estimated coefficients are as follows:

$$\widehat{\text{Originalvalues}} = \underset{(0.23311)}{-0.0459003} + \underset{(0.11508)}{0.950599}\ \text{threestepahead}$$
$$T = 17 \quad \bar{R}^2 = 0.8078 \quad F(1,15) = 68.237 \quad \hat{\sigma} = 0.39650$$
$$\text{(standard errors in parentheses)}$$

The R^2 again slightly decreased to almost 81%. The estimated coefficient β_1, unlike the previous regressions, was bellow 1. However, the results from F-test were as follows:

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[threestepsahead] = 1	0.355851	0.399006

The p-value nearly 36% did not allow to reject the null hypothesis of $\beta_0 = 0$ and $\beta_1 = 1$. Which makes CNB predictions still reasonable, accurate and unbiased.

The last MZ regression performed in this section is for the predictions four quarters ahead. The results are presented bellow:

$$\widehat{\text{Originalvalues}} = \underset{(0.29970)}{-0.0421351} + \underset{(0.14238)}{0.821572}\,\text{fourstepahead}$$
$$T = 16 \quad \bar{R}^2 = 0.0682 \quad F(1,14) = 33.294 \quad \hat{\sigma} = 0.42125$$
$$\text{(standard errors in parentheses)}$$

As in previous case the coefficient β_1 dropped bellow one. The coefficient of determination significantly decreased to 6.8%. The results from F-test suggest following:

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[fourstepsahead] = 1	0.00535842	0.572473

Based on the significantly low value of p-value I had to reject the null hypothesis of $\beta_0 = 0$ and $\beta_1 = 1$. Which, based on the MZ regression approach, makes the CNB predictions for four quarters ahead biased and inaccurate.

In this section four regression were performed, namely MZ regressions. Based on the results several conclusions can be drawn:

- CNB predicts reasonable forecasts of 3M PRIBOR up to three quarters ahead, afterward the predictions are biased and less accurate.
- Although CNB predictions for one year ahead are less accurate and biased, when comparing to the results from Goodhart and Lim (2011) it must be mentioned that the CNB prediction can bear international comparison (with results from RBNZ).
- In comparison with RW and no-change predictions[2] the CNB forecasts proved themselves to be unbiased for longer time horizon. The predictions from RW and no-change were biased from the beginning.

[2]The results from Minzer-Zarnowitz regression are provided in the Appendix A

4.1.4. Goodhart's approach to evaluation of CNB forecast

4.1.4.1. Evaluation of forecasts of the changes in interest rates

Apart from MZ regression, Goodhart and Lim (2011) proposed another set of two equations that I applied on CNB forecasts. The first equation has the following form:

$$IR_{(t+h)} - IR_t = \alpha_1 + \alpha_2 * (\hat{IR}_{(t,t+h)} - IR_t) + \varepsilon_t$$

Basically „it explores how forecaster with increasing h (time horizon) can predict the future interest rate changes from present level" Goodhart and Lim (2011). Again after the estimation of proposed model the coefficients are put under F-test with null hypothesis:$\alpha_0 = 0$ and $\alpha_1 = 1$. In following provided results tables the left-hand side of equation is labeled actualactual and the difference between predicted rate and current interest rate is labeled actualforecast.

Starting for time horizon equal to one quarter ahead (h=1) the estimated results are as follows:

$$\widehat{\text{actualactual}} = \underset{(0.080409)}{-0.126058} + \underset{(0.26205)}{0.500528}\,\text{actualforecast}$$
$$T = 18 \quad \bar{R}^2 = 0.1348 \quad F(1,16) = 3.6483 \quad \hat{\sigma} = 0.32252$$
$$\text{(standard errors in parentheses)}$$

Unlikely from results from Goodhart and Lim (2011) in case of RBNZ and BoE, theR^2 of proposed equation of CNB predictions was significantly lower than in MZ equation, only 13.48%. But however it was low, the F-test results came as follows.

The F-test, testing the restrictions $\alpha_0 = 0$ and $\alpha_1 = 1$, ended as follows:

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[actualforecast] = 1	0.130636	0.345326

Although the estimated equation proved itself with lower coefficient of determination, in the F-test I could not reject the null hypothesis. Both these two factors makes the predictions on one hand less useful, but on the other hand they are still unbiased.

Next estimated equation was for h=2, resp. how CNB is able to predict changes in 3M PRIBOR with horizon being equal to two quarters. The estimated results follows:

$$\widehat{\text{actualactual}} = \underset{(0.10199)}{-0.202029} + \underset{(0.20442)}{0.712370}\,\text{actualforecast}$$
$$T = 17 \quad \bar{R}^2 = 0.4106 \quad F(1,15) = 12.144 \quad \hat{\sigma} = 0.37495$$
(standard errors in parentheses)

Surprisingly the R^2 increased significantly to 41%. This increase suggests that CNB predicts the changes more accurate for two quarters ahead than for one quarter ahead.

In order to find whether the prediction of changes is biased the F-test was employed with following results:

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[actualforecast] = 1	0.153895	0.399006

The p-value of 0.15 suggests that null hypothesis cannot be rejected. The F-test and the results from regression above imply that the predictions of changes for time horizon of two quarters ahead are still in reasonable boundaries and are not biased.

In case of predictions of changes in 3M PRIBOR for time horizon equal to three quarters the estimated coefficient came out as follows

$$\widehat{\text{actualactual}} = \underset{(0.56924)}{-0.529791} + \underset{(0.39449)}{0.0124476}\,\text{actualforecast}$$
$$T = 16 \quad \bar{R}^2 = -0.0714 \quad F(1,14) = 0.00099564 \quad \hat{\sigma} = 0.70296$$
(standard errors in parentheses)

First of all, the important conclusion is that the value R^2 significantly dropped to useless -7%, the estimated coefficients are far from their model proposed values. To decide whether the prediction are biased the F-test was again employed.

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[actualforecast] = 1	0.00043228	1.1435

The p-value from F-test on proposed restriction set came out converging to zero. This fact together with above mentioned R^2 creates the CNB predictions practically useless, similar as in the case of RBNZ Goodhart and Lim (2011)

Last predictions evaluated using proposed model are the predictions with time horizon equal to four quarters. After the estimation it was clear that the predictions for

this time horizon are useless. The coefficients were estimated far from their proposed values and the value of R^2 counted for -5%.

$$\widehat{\text{actualactual}} = \underset{(0.69101)}{-1.12023} - \underset{(0.47333)}{0.255932}\,\text{actualforecast}$$
$$T = 15 \quad \bar{R}^2 = -0.0532 \quad F(1,13) = 0.29237 \quad \hat{\sigma} = 0.83702$$
(standard errors in parentheses)

Although the above mentioned estimation suggests that the predictions are practically useless, the F-test was involved. The results are provided below, the null hypothesis must have been rejected. This fact and the R^2 mark the four quarters ahead predictions with bias and uselessness.

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[actualforecast] = 1	0.00635918	1.14982

Using evaluation model borrowed from Goodhart and Lim (2011) I was able to explore how CNB is able to predict future changes in 3M PRIBOR rate from current value. The estimated regression and F-tests in proposed form helped to find out that:

- CNB is able to reasonably predict changes in 3M PRIBOR up to two quarters ahead.
- Starting with three quarters ahead time horizon the predictions have significantly low R^2 and moreover the F-test suggests that the predictions are biased, which makes the predictions of changes in future rate of 3M PRIBOR practically useless.
- When comparing the CNB results to RBNZ explored by Goodhart and Lim (2011) CNB predicts the future changes from current level not worse or better than RBNZ, but the value of R^2 was lower than in case of RBNZ.

4.1.4.2. Second equation

In this sub-chapter the following equation borrowed from Goodhart and Lim (2011) was estimated on the CNB forecasts. The equation asks, how with increasing time horizon is the forecaster successful in predicting the future moves in one quarter ahead. As in previous cases after the estimation the coefficients are put under F-test with null hypothesis: $\gamma_1 = 0$ and $\gamma_2 = 1$ in order to find out whether the predictions are biased or not.

$$IR_{(t+h)} - IR_{(t+h-1)} = \gamma_1 + \gamma_2 * (\hat{IR}_{(t,t+h)} - \hat{IR}_{(t,t+h-1)}) + \varepsilon_t$$

The left hand side of equation is further, in provided results, labeled as actual and the right-hand side is labeled forecast.

Starting with h=1 I ran the proposed regression on the data. This procedure helped to answer the question of how the CNB is able to predict future changes in 3M PRIBOR one quarter ahead with one quarter ahead time horizon. The value of R^2 of estimated equation was at almost 33%, but however the estimated coefficient seemed to be apart from the model proposed values: $\gamma_1 = 0$ and $\gamma_2 = 1$.

$$\widehat{\text{actual}} = \underset{(0.10091)}{-0.263374} + \underset{(0.28050)}{0.852300}\,\text{forecast}$$
$$T = 18 \quad \bar{R}^2 = 0.3263 \quad F(1,16) = 9.2324 \quad \hat{\sigma} = 0.39465$$
(standard errors in parentheses)

With help of F-test on specified restriction set, the null hypothesis of unbiased predictions cannot be rejected.

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[forecast] = 1	0.563921	0.332925

After one quarters ahead prediction the predictions two quarters ahead were focused on. Intuitively according to regression results CNB is less successful and accurate in predicting the changes of 3M PRIBOR in two quarters ahead than for one quarter ahead (this conclusion is derived purely from the slight decrease in value of R^2 in comparison with previous case). However, the estimated coefficients are slightly different than model proposed values. So in order to answer whether the values are statistically significantly different from proposed values the F-test was employed.

$$\widehat{\text{actual}} = \underset{(0.10514)}{-0.256823} + \underset{(0.29179)}{0.835189}\,\text{forecast}$$
$$T = 17 \quad \bar{R}^2 = 0.3101 \quad F(1,15) = 8.1927 \quad \hat{\sigma} = 0.40564$$
(standard errors in parentheses)

The F-test suggests that the coefficients are still statistically insignificant than from the proposed values. Which makes the predictions not only accurate but also unbiased.

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[forecast] = 1	0.0782638	0.451566

To go further in future, the forecasts for three quarters were evaluated. The coefficients were estimated differently from their model proposed values, the value of intercept was estimated roughly to -0.51, the proposed value should be 0 and the coefficient γ_2 was estimated to 0.85, which is as well different from proposed value. However ,the coefficient of determination slightly increased further when comparing to the previous case.

$$\widehat{\text{actual}} = \underset{(0.14028)}{-0.505932} + \underset{(0.29699)}{0.850764}\,\text{forecast}$$
$$T = 16 \quad \bar{R}^2 = 0.3245 \quad F(1,14) = 8.2058 \quad \hat{\sigma} = 0.55818$$
(standard errors in parentheses)

In order to find out whether the predictions are somehow biased, the F-test provided following results. Based on significantly low value of p-value the null hypothesis must have been rejected. The rejection suggests that the predictions are biased.

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[forecast] = 1	0.0100077	0.725457

The last estimated predictions using model proposed by Goodhart and Lim (2011), are the predictions with time horizon equal to four quarters. The estimated regression proved itself unpredictably with high value of coefficient of determination, which has been the highest from all four estimated model and equal to 57%. The coefficients were estimated in following way: intercept was estimated to be equal to 0.84 (far from its proposed value) and $\gamma_2$was estimated to 0.99 which is close to its proposed value.

$$\widehat{\text{actual}} = \underset{(0.12977)}{-0.841656} + \underset{(0.21623)}{0.997363}\,\text{forecast}$$
$$T = 16 \quad \bar{R}^2 = 0.5748 \quad F(1,14) = 21.276 \quad \hat{\sigma} = 0.51409$$
(standard errors in parentheses)

However, when the estimated coefficients were put under the F-test, the p-value of the test came out significantly low. Which suggests that the predictions are biased as in the previous case.

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[forecast] = 1	0.00012184	0.987607

In this subsection four regressions were estimated on CNB predictions of 3M PRIBOR. The estimated regression equations have asked how with increasing time horizon is the CNB successful in predicting the future moves in one quarter ahead. Based on the estimated results three conclusions can be made:

- CNB is able to create unbiased predictions in one quarter ahead future changes of 3M PRIBOR up to two quarters ahead, afterward the forecasts tend to be biased.
- Unexpectedly, the coefficient of determination was increasing when the forecasting horizon increased or was flat, this fact might be probably caused by the small number of available observation in the data set.
- When comparing the results from evaluation the CNB predictions to RBNZ predictions evaluated by same approach by Goodhart and Lim (2011), the CNB is according to the results able to predict the future moves in interest rate one quarter longer than RBNZ.

4.2. Evaluation of Treasury´s predictions

4.2.1. Sign evaluation

Professional forecasters, such as Czech Treasury, predict their own 3M PRIBOR rates. These predictions are usually revealed to public when quarterly macro-economic predictions are announced. From the whole set of professional forecasters I have chosen Treasury as it provides the forecasts on same basis as CNB and for similar time horizon, unlike the commercial banks. Following the similar pattern as in case of CNB predictions I firstly focus on sign evaluation. Similar as in the case of CNB the Treasury tends to over-predict the value of 3M PRIBOR. Moreover the trends is more significant with increasing time horizon. For three and four quarters ahead the ratio is 100% in favor for over-predicted values.

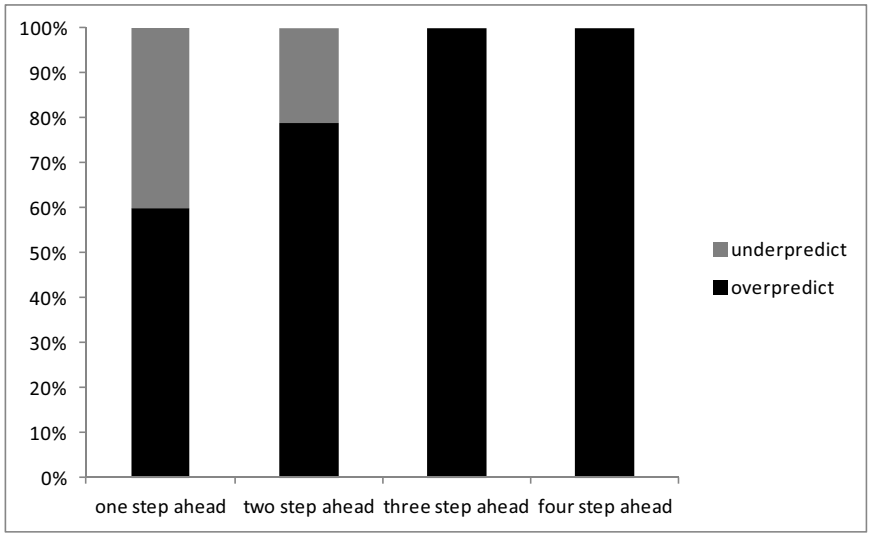

Figure 4.2.: Over/under predictions with respect to time horizon

4.2.2. MSE

Starting with the least advanced benchmark procedure I employed the Mean square error approach. The Treasury´s predictions were put under the MSE evaluation as in case of CNB. The evaluation process followed the proposed formula giving the following results:

MSE	Treasury	CNB	Treasury/CNB
one quarter ahead	0.059865	0.045809586	130.7%
two quarters ahead	0.101110526	0.100106714	101.0%
three quarters ahead	0.190157895	0.178459196	106.6%
four quarters ahead	0.378573684	0.290627913	130.3%

Table 4.1.: MSE of Treasury´s forecasts

First of all, in comparison with the CNB predictions the predictions from Treasury proved itself with higher MSE for the all observed periods. Which means that the Treasury´s predictions are less accurate than the predictions from CNB based on MSE evaluation. Although, there is difference in predictions´ MSE, the difference is not tremendous. It is interesting that the ratio of MSE of CNB to MSE of Treasury starts at 130.7% afterward is decreasing for two and three quarters ahead predictions and increasing back to 130.3% for predictions four quarters ahead.

4.2.3. Minzer-Zarnowitz regression for Treasury´s forecasts

Following the same procedure as in case of CNB forecasts I employed the MZ regression on the forecasts from Czech Treasury. For the Treasury´s predictions for one quarter ahead time horizon the results from regression are as follows.

$$\widehat{\text{actual}} = \underset{(0.10998)}{-0.0502889} + \underset{(0.052023)}{1.05653}\ \text{onestepahead}$$
$$T = 20 \quad \bar{R}^2 = 0.9059 \quad F(1,18) = 412.44 \quad \hat{\sigma} = 0.24380$$
(standard errors in parentheses)

Based on the R^2 from results we are able to conclude that the for one quarter ahead the predictions from Treasury are almost as same accurate as the forecasts from CNB. The coefficients were estimated significant from regression. The last performed test for one quarter ahead forecasts is the F-test.

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[onestepahead] = 1	0.363218	0.244673

The p-value proves itself to be high enough, so we cannot reject the null hypothesis even on 10% significance level, which means that the Treasury´s predictions for one quarter ahead period are unbiased and based on R^2 almost comparable to CNB predictions. In international comparison with Goodhart and Lim (2011) the Treasury´s forecasts for one quarter ahead are comparable with RBNZ results.

After the one quarter ahead period the Treasury´s forecasts for two quarters ahead are left to be evaluated. Following the same pattern as in previous case I estimated the MZ regression with following results:

$$\widehat{\text{actual}} = \underset{(0.13987)}{-0.224484} + \underset{(0.063756)}{1.02191}\ \text{twostepahead}$$
$$T = 19 \quad \bar{R}^2 = 0.6343 \quad F(1,17) = 256.92 \quad \hat{\sigma} = 0.27501$$
(standard errors in parentheses)

The predictions from Treasury are characterized by lower value of R^2 than the previous case, now equal to 63%. In comparison with CNB the predictions are less accurate when focusing just on the value of R^2. In order to find out more, the F-test with specified restrictions must be performed. As can be clearly seen from the F-test results the null hypothesis must be rejected on significance level of 5%.

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[twostepahead] = 1	0.0329278	0.317979

So not only the R^2 was lower when compared to CNB two quarters ahead predictions, but I have found that the Treasury´s predictions are biased as well. Basically what happened for CNB predictions for four quarters ahead takes place for Treasury´s predictions just for two quarters time horizon.

However, from the last F-test results one can assume that the prediction will be inaccurate for longer time horizon, I performed the MZ regression for the three quarters time horizon as well. The results are as follows.

$$\widehat{\text{actual}} = \underset{(0.15443)}{-0.124519} + \underset{(0.070081)}{0.890234}\,\text{threestepsahead}$$
$$T = 18 \quad \bar{R}^2 = 0.042 \quad F(1,16) = 161.36 \quad \hat{\sigma} = 0.28557$$
(standard errors in parentheses)

The value of coefficient of determination dropped significantly and in comparison with CNB predictions are incomparable. Furthermore the coefficients were estimated differently than proposed by the model.

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[threestepsahead] = 1	0.000289418	0.44802

In the F-test where the proposed restrictions were tested the results suggest that the null hypothesis must be rejected. Which means that the Treasury predictions for three quarters ahead tend to be biased, as the coefficients do not comply with the null hypothesis of proposed F-test. Such as has been discovered in previous case.

The last evaluated forecast from Treasury using Minzer-Zarnowitz regression are the forecasts for four quarters ahead of 3M PRIBOR. Running the same procedure as in previous cases I arrived at following results.

$$\widehat{\text{actual}} = \underset{(0.21737)}{0.0682544} + \underset{(0.098863)}{0.722638}\,\text{fourstepsahead}$$
$$T = 17 \quad \bar{R}^2 = 0.0766 \quad F(1,15) = 53.428 \quad \hat{\sigma} = 0.37228$$
(standard errors in parentheses)

The coefficients came out significant with overall low value of R^2 which reached almost 7.7%. But however as in last two cases, when the F-test with proposed null

hypothesis was employed, the null hypothesis had to be rejected. The rejection of null hypothesis suggests that the forecasts suffer from bias.

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[fourstepsahead] = 1	9.05744e-005	0.65047

For the purpose of evaluation of Treasury´s forecasts four regression models were estimated. Estimating MZ model allows me to compare the predictions of Treasury vis-a-vis the predictions from CNB and decide which are more accurate for predicting the future value of 3M PRIBOR.

For the Treasury´s prediction it has been discovered that:

- The predictions were accurate in meaning of having high R^2 for one and two quarters ahead, afterward it dropped.
- The F-test showed that the predictions suffer from bias starting with predictions two quarters ahead.
- In comparison with CNB the Treasury predicts less accurate future values of 3M PRIBOR with increasing time horizon. But the Treasury´s forecasts can bear comparison with CNB forecasts for one quarter ahead period.

4.2.4. Goodhart´s approach for Treasury´s forecasts evaluation

4.2.4.1. Evaluation of forecasts of the changes in interest rates

So far the just the Treasury´s original predictions for the 3M PRIBOR have been evaluated. But as in case of CNB I want to explore how Treasury is successful in predicting the future interest rate moves. Respectively, how is Treasury accurate in predicting future changes in 3M PRIBOR from current level. Borrowed model from Goodhart and Lim (2011) has been provided in methodology but just to recall it:

$$IR_{(t+h)} - IR_t = \alpha_1 + \alpha_2 * (\hat{IR}_{(t,t+h)} - IR_t) + \varepsilon_t$$

In provided results from estimation the left-hand side of equation is labeled as actual and the right-hand side is labeled as forecast.

Firstly the prediction of changes in interest rate for one quarter from current level were put under evaluation. The results suggest that the estimated coefficients are close to model values and the coefficient of determination proved itself with 55%.

$$\widehat{\text{actual}} = \underset{(0.056752)}{-0.105058} + \underset{(0.22187)}{1.03981}\,\text{forecast}$$
$$T = 18 \quad \bar{R}^2 = 0.5522 \quad F(1,16) = 21.964 \quad \hat{\sigma} = 0.23203$$
(standard errors in parentheses)

Further the F-test was used to explore whether the coefficients are truly statistically indifferent from proposed values. The p-value came out high which made the null hypothesis unrejectable on proposed level of significance of 5%. Based on the mentioned results I can conclude that Treasury´s prediction of future changes of 3M PRIBOR from current level for one quarter horizon are accurate and unbiased. Moreover they can bear comparison with CNB predictions.

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[forecast] = 1	0.173518	0.244063

Following the pattern as in case of CNB the next period evaluated are forecast with time horizon equal to two quarters. The estimated model showed the change in value of estimated model coefficients, estimated intercept jumped to almost -0.38. Moreover was drop in R^2 to 38%.

$$\widehat{\text{actual}} = \underset{(0.093292)}{-0.375354} + \underset{(0.33740)}{1.11058}\,\text{forecast}$$
$$T = 17 \quad \bar{R}^2 = 0.3807 \quad F(1,15) = 10.834 \quad \hat{\sigma} = 0.38434$$
(standard errors in parentheses)

During F-test the null hypothesis has been rejected which indicates that the predictions of changes in interest rates from current level for two quarters are less accurate and even more biased.

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[forecast] = 1	0.00410144	0.520803

For the predictions of changes in interest rate for three quarters from current level the estimated regression has following form. The coefficient of determination proved itself with high value but the estimated coefficients are far from their proposed values.

$$\widehat{\text{actual}} = \underset{(0.12160)}{-0.491730} + \underset{(0.32817)}{1.29753}\,\text{forecast}$$
$$T = 16 \quad \bar{R}^2 = 0.4938 \quad F(1,14) = 15.633 \quad \hat{\sigma} = 0.48319$$
(standard errors in parentheses)

The F-test employed on the estimated coefficients suggests that the null hypothesis must be rejected. Which means that the forecasts of future moves in 3M PRIBOR for three quarters from current level are less accurate and even biased in comparison to predictions from previous period.

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[forecast] = 1	0.00290185	0.686062

Finally, the last estimated regression using above proposed model is evaluating the ability of predictions to capture the changes in interest rate for four quarters from current environment. As in previous cases the estimated coefficients came out away from their proposed values. The intercept was estimated to roughly to -0.69 when proposed value is 0. The regression coefficient α_2 was estimated closely to its model value of 1. The model showed that however the time horizon increased the predictions perform well, as the coefficient of determination just slightly decreased.

$$\widehat{\text{actual}} = \underset{(0.15395)}{-0.687222} + \underset{(0.25950)}{0.960390}\,\text{forecast}$$
$$T = 15 \quad \bar{R}^2 = 0.4756 \quad F(1,13) = 13.696 \quad \hat{\sigma} = 0.59062$$
(standard errors in parentheses)

However, during the F-test the null hypothesis had to be rejected. Which leads to conclusion that the predictions carry bias within.

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[forecast] = 1	0.00228153	0.877907

Based on above mentioned OLS estimation results four conclusion can be derived:

- Treasury´s predictions are accurate and unbiased forecast for changes in 3M PRIBOR for time horizon equal to one quarter from current level.
- With increasing time horizon the forecasts become less accurate and even biased as the results from 4 F-tests performed in this sub chapter suggest.

- The estimated value of intercept has been slightly negative in the first equation but significantly increasing through the time, which suggests that the forecasts are indeed over-estimated, as pointed out earlier during sign evaluation procedure.

4.2.4.2. Second equation

The Treasury´s forecasts were chosen due to better comparison of results with CNB. But however, Treasury provides the predictions only for four quarters ahead. So when making the differences I could only create for three quarters ahead. Again the proposed model explores, how with increasing time horizon is the forecaster successful in predicting the future moves in one quarter ahead. As estimated regression suggests, the Treasury´s forecasts of future moves in 3M PRIBOR in one quarter ahead are not accurate for one quarter ahead period. The value of coefficient of determination was significantly low and the estimated coefficients were far from the proposed values.

$$\widehat{\text{actual}} = \underset{(0.089263)}{-0.169328} - \underset{(0.62764)}{0.266753}\,\text{forecast}$$
$$T = 19 \quad \bar{R}^2 = -0.0477 \quad F(1,17) = 0.18063 \quad \hat{\sigma} = 0.34790$$
$$\text{(standard errors in parentheses)}$$

F-test confirmed what was proposed above, the null hypothesis was rejected in favor of alternative hypothesis. Which signalizes that not even the predictions are more or less useless but they also tend to be biased.

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[forecast] = 1	0.00625171	0.443556

When evaluating the Treasury´s ability of forecast the moves of 3M PRIBOR one quarter ahead from today plus two quarters surprisingly the value of coefficient of determination significantly picked up. But apart from the R^2 the estimated coefficients were once again far from their proposed values. However, the last word belongs to result of F-test.

$$\widehat{\text{actual}} = \underset{(0.081944)}{-0.424471} + \underset{(0.44946)}{1.85481}\,\text{forecast}$$
$$T = 18 \quad \bar{R}^2 = 0.4853 \quad F(1,16) = 17.030 \quad \hat{\sigma} = 0.34494$$
$$\text{(standard errors in parentheses)}$$

As can be concluded from the results below the null hypothesis has to be rejected. On one hand there has been significant increase in R^2 but on the other hand F-test suggests that the predictions are biased.

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[forecast] = 1	0.000282771	0.541936

The last regression and F-test carried out for Treasury´s predictions was performed in order to evaluate the Treasury´s ability of predicting the future moves of 3M PRIBOR for one quarter ahead from today plus three quarters. As has been pointed out in previous case, the R^2 is significantly higher in comparison with first estimated equation in this sub-chapter. In comparison with previous equation the R^2 remained almost flat. The estimated coefficients were once again significantly far from the proposed values.

$$\widehat{\text{actual}} = \underset{(0.13088)}{-0.788255} + \underset{(0.16033)}{0.622275}\,\text{forecast}$$

$$T = 17 \quad \bar{R}^2 = 0.4678 \quad F(1,15) = 15.063 \quad \hat{\sigma} = 0.48081$$

(standard errors in parentheses)

The results from F-test complied with the results from estimated regression. The null hypothesis was rejected in favor for the alternative hypothesis.Which signalize that the predictions are biased.

F-test	restriction set	p-value	S.E. of regression
	1: b[const] = 0 2: b[forecast] = 1	2.46667e-006	1.06821

In this sub-chapter three regression were estimated on Treasury´s predictions. The proposed model for estimation asked how with increasing time horizon is the forecaster successful in predicting the future moves in one quarter ahead. The results can be concluded as:

- Based on the F-test results the Treasury´s forecasts were biased in all three equations.
- Surprisingly the Treasury is more able to predict the future moves of 3M PRIBOR one quarter ahead for two and three quarters from now rather than for one quarter ahead.
- When comparing the results to CNB the Treasury´s forecasts performed significantly lower.

Chapter 5
Evaluation of AR and VAR predictions of 3M PRIBOR

5.1. Forecasting using Box-Jenkins methodology

In this chapter the predictions created using the autoregressive and vector autoregressive methodology are evaluated. As has been mentioned in the introduction chapter, CNB employs for predicting G3 model, that belongs to a dynamic stochastic general equilibrium sets of model, that combines real business cycle theory and nominal rigidities[1]. With employing AR(2) and VAR methodology approaches I intend to test whether with help of these models I arrive at the significantly different predictions, than CNB that uses the G3 model. For the purpose of forecasting my own predictions of 3M PRIBOR I have firstly employed Box-Jenkins methodology as suggested in Dua (2004). In the estimation process the publicly available data for 3M PRIBOR rate on quarterly basis starting with the first quarter of 1993 were used. In order to create similar predictions as CNB performs, I started forecasting for first quarter of 2008 using available data from Q1 1993 to Q4 2007. Predictions for Q2 2008 were estimated using data from Q1 1993 to Q1 2008 and similarly for next coming quarters. As proposed in methodology part model used for prediction is AR(2) model. The optimal lag equal to two was selected based on Akaike Info Criterion, Hannan-Quinn Criterion Schwarz Criterion. In total 20 AR(2) prediction sets has been performed. In order to depict the predictions as in case of CNB and Treasury following graph represents the value of 3M PRIBOR and my AR(2) predictions.

[1] The definition is borrowed from www.cnb.cz

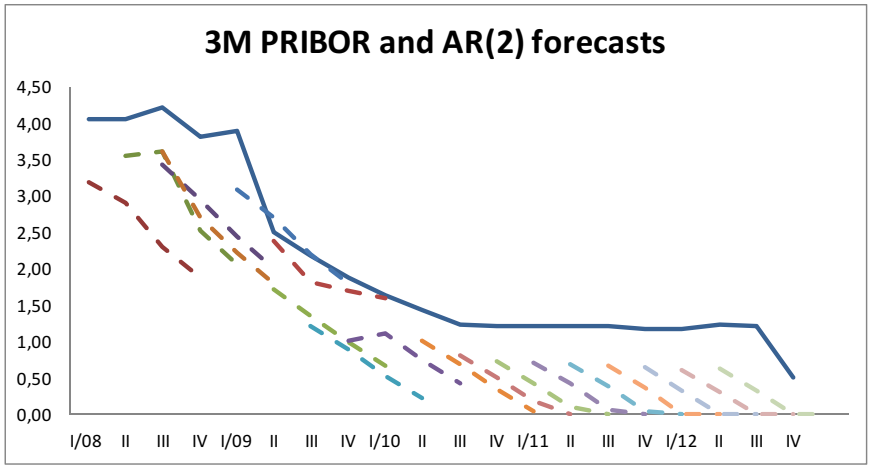

Figure 5.1.: 3M PRIBOR and AR(2) predictions

Preliminary graphical analysis suggests that predicting 3M PRIBOR using AR(2) proved itself with the significantly low forecasting power. Just from the graph it can be clearly conclude that predictions are almost every-time decreasing faster than the true values. Moreover, the forecasts three and quarters ahead since 2010 were often projected to negative values. What could be preliminary concluded from the graph above was also found out during sign evaluation. Sign evaluation as proposed in methodology part explores how often the predictions are over respectively under their true values. Applying this procedure on my forecasts using AR(2) process I can conclude only that my predictions were almost always under their true values. There were only two exceptions from the under-estimating pattern. The following graph represents the division between under and over estimation with respect to forecasting time horizon.

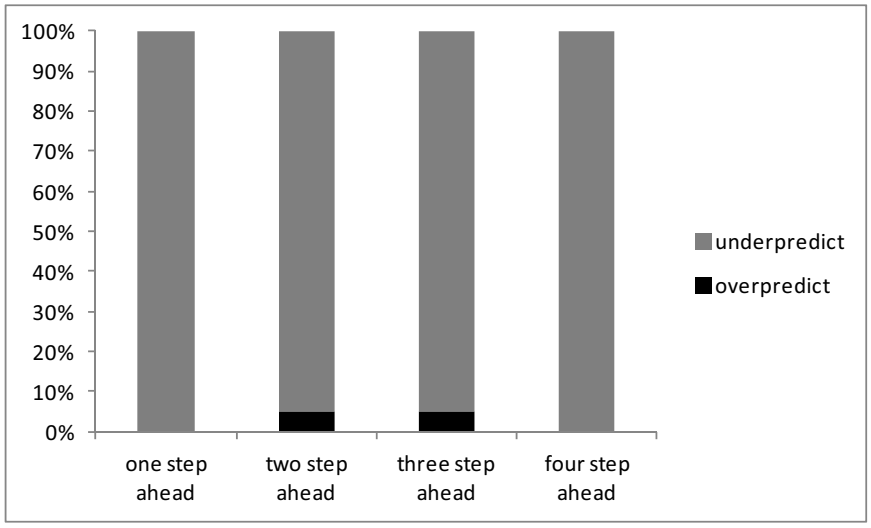

Figure 5.2.: Sign evaluation of AR(2) predictions

After the sign evaluation of my AR(2) predictions I employed MSE procedure to find, how the AR(2) forecasts perform in comparison to CNB predictions. Surprisingly the MSE of AR(2) predictions was decreasing with increasing forecasting horizon. When putting the MSE numbers in comparison with CNB MSE results the conclusion is that AR(2) predictions performed much less accurate than the CNB predictions. The MSE of AR(2) was maximal almost 7 times higher than the MSE for CNB and roughly 4 times higher for minimum ratio. However, with increasing time horizon of forecasts the ratios between AR(2) and CNB predictions tends to decline.

MSE	AR(2)	CNB	AR(2)/CNB
one quarter ahead	0,3113400	0.045809586	680%
two quarters ahead	0,5588684	0.100106714	558%
three quarters ahead	1,0605167	0.178459196	594%
four quarters ahead	1,1730059	0.290627913	404%

Table 5.1.: MSE of AR(2) predictions

So far based on sign evaluation and MSE evaluation AR(2) estimation does not seem to be the correct approach to model 3M PRIBOR. Further I will employ same

evaluation procedure as in case of CNB and Treasury on AR(2) predictions, namely MZ regression and approach proposed by Goodhart and Lim (2011) to employ more advanced evaluation methodology.

The AR(2) predictions were put under estimation of model introduced in methodology part, the MZ regression equation. Following table provides the summary of evaluation regressions performed in this sub-chapter.

time horizon	estimated coefficients		R^2	F-test p-value	result
	β_0	β_1		β_0=0 β_1=1	
t+1	0.471308	1.02916	0.9677	2.23361e-008	reject H_0
t+2	0.687807	0.991753	0.9179	4.42921e-007	reject H_0
t+3	0.953324	0.959132	0.7884	3.38665e-006	reject H_0
t+4	1.04083	0.878078	0.6624	1.15249e-005	reject H_0

Table 5.2.: Estimated MZ regressions for AR(2)

Starting with the predictions for one quarter ahead. After running the regression the estimated coefficient came out different than the values proposed by the model. The intercept, that was supposed to be ideally equal to zero, but was estimated to be equal to 0.47. However, the second coefficient was estimated closely to its proposed value of 1. The coefficient of determination was equal to almost 97% . However, in my opinion the significantly high value of R^2 was probably caused by lower number of observations rather than the precise values of AR(2) estimation. In order to explore whether any track of bias is present within the predictions of one quarter ahead 3M PRIBOR, the F-test was used. The results suggest that the predictions suffer from bias as the null hypothesis must have been rejected in favor of alternative hypothesis. Which indicates that the AR(2) predictions of 3M PRIBOR for one quarter ahead are biased. When focusing on predictions for two quarters ahead from the results I could conclude that as in previous case the coefficients were estimated slightly different than proposed. The intercept was estimated to roughly 0.69 which is significantly different from proposed value 0, β_1 was however estimated closely to one. Unfortunately as in previous case the null hypothesis in F-test was rejected. So my AR(2) predictions of 3M PRIBOR were biased. For the predictions for three quarters and four quarters ahead the estimated equation followed the previously drawn pattern.

The estimated coefficients were more or less different from proposed values. Moreover in both F-test the null hypothesis had to be rejected, which indicates that the predictions tend to be biased.

Following the evaluation pattern drawn in Goodhart and Lim (2011) I put my AR(2) predictions under evaluation of following equation:

$$IR_{(t+h)} - IR_t = \alpha_1 + \alpha_2 * (\hat{IR}_{(t,t+h)} - IR_t) + \varepsilon_t$$

The equation again describes how AR(2) process is able to forecast the future moves of 3M PRIBOR with increasing time horizon. The following table captures the regression results. Starting with the predictions of future moves one quarter ahead I explored that the estimated coefficient are far from proposed values: $\alpha_1 = 0$ and $\alpha_2 = 1$. Moreover the coefficient of determination for t+1 period proved itself to be significantly low. With use of F-test I was able to explore the bias of AR(2) predictions, the result was speaking clearly. The p-value of F-test came out significantly low, which means that I had to reject the null hypothesis in favor of alternative. So the AR(2) predictions for one quart ahead period are indeed biased. Similar situation, as in the previous, case was observed with the prediction of future moves from now plus two quarters. The estimated coefficients were even more distant from their proposed values than in previous case. However, the value of R^2 jumped to almost 4.4%[2] The F-test suggests that the prediction are biased as in previous case. When evaluating the predictions for future moves of 3M PRIBOR for three quarters ahead, on one hand the value of coefficient of determination significantly increased to almost 93%, but on the other hand the F-test indicates the bias of predictions. The tremendous increase in R^2 could not be probably counted to precision of the AR(2) predictions. Last regression performed using above proposed formula was for prediction of future moves for four quarters ahead. As has been proved in previous results the coefficients were estimated in different way than proposed by the model. However, the phenomena of high R^2 was observed in this estimation as well as in previous case. Apart from the high value of R^2, the F-test p-value was significantly low. Which signalizes the bias of predictions for four quarters ahead.

[2]However, the value of 4.4% still indicates that the AR(2) predictions are practically useless.

time horizon	estimated coefficients		R^2	F-test p-value	result
	β_0	β_1		β_0=0 β_1=1	
t+1	-0.119764	0.0799256	0,005	1.11743e-005	reject H_0
t+2	-0.0717678	0.263015	0.043955	3.41138e-005	reject H_0
t+3	0.687361	0.615004	0.926713	8.86355e-014	reject H_0
t+4	0.735152	0.727214	0.919186	7.41112e-011	reject H_0

Table 5.3.: Estimated future change equation for AR(2)

Last evaluation procedure performed for my AR(2) predictions was running according the following equation:

$$IR_{(t+h)} - IR_{(t+h-1)} = \gamma_1 + \gamma_2 * (\hat{IR}_{(t,t+h)} - \hat{IR}_{(t,t+h-1)}) + \varepsilon_t$$

The equation asks how the AR(2) process is able to predict one quarter ahead moves of 3M PRIBOR with increasing time horizon. In this section the difference in predictions up to three quarters ahead are evaluated as I initially created the predictions for four quarters ahead. When starting with the predictions of one quarter ahead[3] I arrived to comparable results as in case of Treasury or CNB. The coefficients were estimated more or less close to the proposed values of: $\gamma_1 = 0$ and $\gamma_2 = 1$. The value of coefficient of determination was around 27%. When focusing on the test of bias using F-test, the p-value of the test was around 15% which makes the null hypothesis unrejectable on 5% level of significance used in this thesis. No matter how the t+1 predictions were comparable to professional forecasters worse is to come. The predictions that should model the changes of 3M PRIBOR quarter ahead from today plus two quarters did not follow the success pattern drawn in previous estimation. The coefficients were estimated far from the proposed values. The value of R^2 dropped sharply to 11%. Furthermore the F-test discovered that these predictions carry bias within, the p-value indicated that the null hypothesis must be rejected. Last predictions evaluated in this section are the predictions for change in 3M PRIBOR rate one quarter ahead from today plus three quarters. The estimation procedure discovered that the coefficients were estimated in different way than the proposed values, moreover the R^2 value slightly dropped again to roughly 10%. Last but not least the F-test suggests that the forecasts using AR(2) are biased.

[3] How the AR(2) process is able to forecast the moves in 3M PRIBOR one quarter ahead from current value plus one quarter.

time horizon	estimated coefficients		R^2	F-test p-value	result
	β_0	β_1		β_0=0 β_1=1	
t+1	0.0921475	0.858897	0.271201	0.151665	not to reject H_0
t+2	0.147090	0.482368	0.114641	1.40428e-005	reject H_0
t+3	-0.0493431	0.635261	0.101307	3.42665e-006	reject H_0

Table 5.4.: Estimation of one quarter ahead change equation for AR(2)

In this section the predictions of 3M PRIBOR using AR(2) process were evaluated. Using MSE evaluation, sign evaluation and the same methodology approach proposed by Goodhart and Lim (2011) I was able to outline several conclusion regarding the AR(2) predictions:

- In comparison with CNB the MSE of AR(2) predictions is at least four times higher at minimum, at maximum six times.
- The AR(2) predictions in most of the cases underestimated the true value of 3M PRIBOR. Only in two cases out of 74 the predictions were above the true values. In comparison with sign evaluation of forecasts from CNB and Treasury the AR(2) behaved in completely different manners.
- The AR(2) process is not very much suitable for forecasting the 3M PRIBOR on quarterly basis. The linearity in forecasting process in AR(2) does not fit the real behavior in 3M PRIBOR. However, surprisingly the values of coefficient of determination in MZ regressions proved themselves to be significantly high.
- AR(2) predictions showed that that this methodology approach is not suitable for modeling the future changes in 3M PRIBOR as well. The AR(2) is not able to capture non-linear moves in the rate.
- The predictions most of the time proved themselves to be biased. Only in one case the F-test null hypothesis was not rejected.

5.2. Forecasting using vector auto-regressive methodology

As has been shown above the AR(2) process does not properly describe the behavior of 3M PRIBOR. In order to perform more precise forecasts I decided to employ

the vector auto-regressive methodology (VAR)[4]. Following the model proposed by Borys and Horvath (2008) I was able to create predictions of 3M PRIBOR. The predictions were estimated using program JMulti and are captured in the graph bellow. The optimal lag in VAR was set to three according to information criterions. To follow the same manner of predictions as in case of CNB, in total 20 VAR estimation has been performed accompanied by the predictions to four quarters ahead (12 moths ahead predictions). As I based the VAR prediction procedure on monthly data, the quarterly values were extracted from monthly predictions simply by the averaging. Furthermore the usually tested parameter of VAR model is the stability of the model, whether some breaking point is present within the data. To test the stability I employed Chow test and the suspicious breaking point was chosen the January 2005. This point was chosen, as CNB to this date changed the band target of inflation targeting to point target inflation targeting. According to results from Chow test[5] the p-value equal to zero indicates that the null hypothesis should be rejected. So indeed the data set should be divided into two separate data sets. However, the separation of the data would cause the significant loss of observations, which would impede the prediction process of 3M PRIBOR. So for my predictions purposes I decided not to split the data. From the preliminary graphical analysis, as can be seen from the graph bellow, the VAR captures the behavior of 3M PRIBOR rate better than previously used AR(2) process. The VAR forecasts, however, predicted the decreasing trend in rate more sharply than it actually happened[6]. When the rate was flat, the VAR was actually predicting the behavior of 3M PRIBOR accurately.

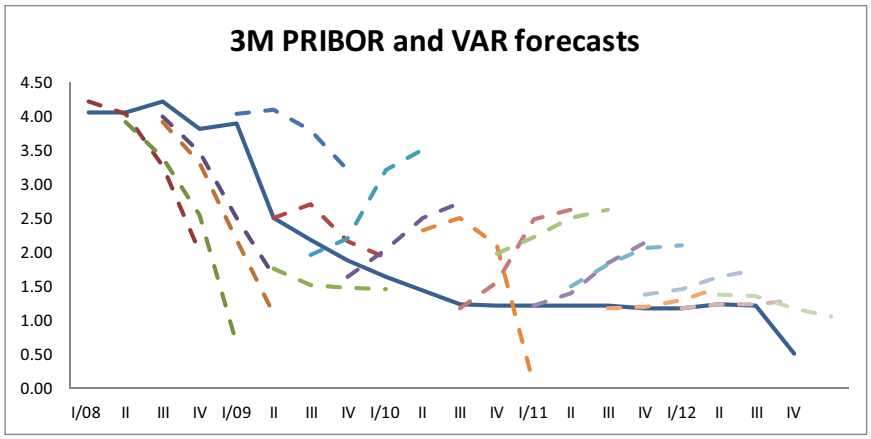

Figure 5.3.: 3M PRIBOR and VAR predictions

[4]However, it is not the norm that VAR always predicts more accurate forecasts than AR(p).
[5]The table with results is provided in the appendix.
[6]As can bee seen from the left side of the graph.

When exploring how often the VAR predictions are bellow or under the true value of 3M PRIBOR, the sign evaluation was employed. In previous section the AR(2) predictions were most of the time under estimating the true values, but in case of VAR the situation is completely different. The sign evaluation suggests that the VAR predictions are closer to the CNB and Treasury´s predictions, as over predictions more often took place than under predictions. For one quarter ahead the 55% of all predictions were over estimated. For the two and three quarters ahead the ratio even increased to 65% in favor of over predictions and afterward dropping to 60% for predictions four quarters ahead.

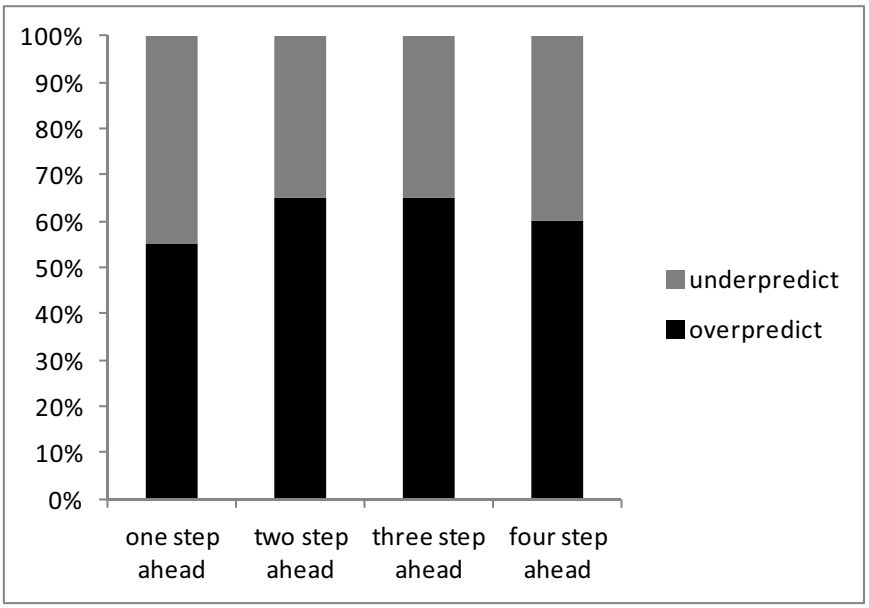

Figure 5.4.: Sign evaluation of VAR predictions

The simple graphical representation is not, however, enough to decide how the VAR predictions performed. The next evaluation procedure is based on previously mentioned and used Mean squared error. From the MSE evaluation of VAR predictions I can conclude that on one hand VAR performed better than AR(2) predictions but on the other hand it performed worse than Treasury´s forecasts. The MSE of VAR predictions starts at 231% and is increasing afterward up to 574% for four quarters ahead predictions.

MSE	VAR	CNB	VAR/CNB
one quarter ahead	0.1058800	0.045809586	231%
two quarters ahead	0.4292811	0.100106714	429%
three quarters ahead	0.8770389	0.178459196	491%
four quarters ahead	1.6686328	0.290627913	574%

Table 5.5.: MSE for VAR predictions

Next, the VAR predictions were put under the evaluation using MZ regression. From the results provided bellow it is clear that VAR performed significantly better than AR(2) predictions. The value of coefficient of determination was at almost 93% for period one quarter ahead, the estimated coefficients were put under the F-test and the result suggests that they are unbiased. For the forecasting horizon of two quarters on one hand I have witnessed considerable drop in R^2 to 47.6% but on the other hand the estimated coefficient proved themselves to be unbiased in F-test. So far the predictions for one and two quarters ahead performed accurately, but however worse is to come. When evaluating the predictions for three quarters ahead firstly the coefficients were estimated far from their model proposed values: β_0=0 and β_1=1. Moreover the R^2 decreased to negligible 2.7% and the null hypothesis of the unbias had to be rejected. Basically what happened in case of CNB for prediction four quarters ahead, took place for VAR predictions one quarter earlier. But when comparing the VAR results to Treasury´s results, the VAR performed so far in similar way as Treasury´s predictions. Last predictions evaluated by using MZ regression are the predictions for four quarters ahead. The situation drawn in previous period continued in this as well. The coefficient of determination dropped again and F-test p-value suggests the rejecting of null hypothesis, which indicates the bias in predictions.

time horizon	estimated coefficients		R^2	F-test p-value	result
	β_0	β_1		β_0=0 β_1=1	
t+1	-0.121704	1.00916	0.9299	0.390119	not to reject H_0
t+2	0.155009	0.752821	0.4760	0.0563335	not to reject H_0
t+3	1.37885	0.176731	0.0274	0.00175959	reject H_0
t+4	1.89057	-0.149904	0.0145	1.15312e-006	reject H_0

Table 5.6.: Estimated MZ regressions for VAR

Next, as in previous cases of CNB, Treasury and AR(2) the predictions were put under evaluation suggested in Goodhart and Lim (2011). Basically the proposed model discovers how the VAR process able to forecast the future moves of 3M PRIBOR with increasing time horizon. Starting with predictions for moves of one quarter ahead predictions the VAR does not seem to capture the true nature of moves in 3M PRIBOR. The estimated coefficients were distant from the model proposed values, moreover the value of R^2 was at negligible 6.6%. And last but not least the F-test suggest the rejection of null hypothesis, which indicates that the VAR prediction for moves in rate for one quarter ahead period are biased. Following the procedure drawn in previous cases the evaluation procedure moved forward to prediction of moves in rate for two quarters ahead. The value of coefficient of determination surprisingly increased to 30%, but however the coefficients were estimated differently than proposed. Furthermore based on the significantly low p-value the F-test suggests the rejection of unbias of coefficients. The predictions of move in PRIBOR rate for time horizon equals to three quarters did not performed better than the previous periods. The R^2 decreased to roughly 9.4% and the F-test p-value indicates that the predictions carry bias within. Last predictions evaluated are the forecasts predicting the moves in PRIBOR rate for four quarters ahead. One could not expect that these predictions will step out of the pattern outlined by previous results. The value of R^2 remained almost flat in comparison with the previous evaluation, at 9%. The p-value furthermore suggested that the null hypothesis of unbiased coefficients must have been rejected.

time horizon	estimated coefficients		R^2	F-test p-value	result
	β_0	β_1		β_0=0 β_1=1	
t+1	-0.220176	0.100022	0.065737	8.00923e-009	reject H_0
t+2	-0.458472	0.175950	0.302618	1.04302e-009	reject H_0
t+3	0.690387	0.619018	0.093737	3.24671e-014	reject H_0
t+4	0.716996	0.721445	0.090399	2.35088e-010	reject H_0

Table 5.7.: Estimated change regression for VAR

Next task was to explore the accuracy of VAR predictions of moves in 3M PRIBOR rates one quarter ahead with increasing time horizon. As in case of AR(2) process, in this section the difference in predictions up to three quarters ahead are evaluated as I initially created the predictions for four quarters ahead. Starting with time horizon

one quarter ahead I examined the predictions´ accuracy. The estimated coefficients for mentioned time horizon were calculated far from the values proposed by Goodhart and Lim (2011), respectively β_0=0 and β_1=1. When focusing on the value of coefficient of determination, its value performed at low roughly 12.5%. Furthermore in F-test, that explores whether the predictions are biased, the p-value indicated that the predictions carry bias within indeed. The next predictions put under evaluation were the forecasts of change in rate one quarter ahead with time horizon equal to two quarters. As has been shown in previous example, the predictions were estimated differently than proposed. The R^2 surprisingly increased to 26%, but however the F-test explored that the predictions are biased, as the null hypothesis was rejected. Last predictions evaluated using above proposed model are the predictions of moves in PRIBOR rate quarter ahead from today's value plus three quarters. Basically the results are comparable to derived above. The R^2 of the last equation was insufficiently low and furthermore the F-test indicated that the predictions are biased as well.

time horizon	estimated coefficients		R^2	F-test p-value	result
	β_0	β_1		β_0=0 β_1=1	
t+1	-0.220935	0.220727	0.124725	7.54206e-006	reject H_0
t+2	-0.241054	0.140084	0.262575	1.41918e-010	reject H_0
t+3	-0.167049	0.072332	0.076526	1.53369e-009	reject H_0

Table 5.8.: Estimation of one quarter ahead change equation for VAR

In this section the vector auto-regressive predictions were evaluated using the same methodology approach as in case of CNB and Treasury. Based on non-econometric and econometric evaluations procedures several conclusion can be drawn:

- VAR methodology created predictions that are more similar to the pattern drawn by CNB rather than AR(2) process, in meaning of under/over estimation of the true values of 3M PRIBOR.
- MSE evaluation proved that VAR forecasts are considerably more accurate than AR(2) when benchmarking to CNB, but however they are less accurate than Treasury´s predictions.
- The VAR approach performed better than AR(2) process in MZ regressions. VAR was able to predict reasonable values of 3M PRIBOR up to two quarters ahead, afterward the predictions became biased and useless. However, the

VAR predictions cannot bear the comparison with CNB or Treasury´s forecasts.

- But VAR methodology proved itself to be unable to predict the future moves of 3M PRIBOR rate, not the changes one quarter ahead nor the changes with increasing time horizon.

Chapter 6
Conclusion

In this master thesis I have focused mainly on evaluation of CNB predictions regarding 3M PRIBOR rate that have been released to the public since the first quarter of 2008. In the literature overview section the reasons to publish the interest rate predictions were presented based on the current academic literature. Further in my thesis the predictions from Czech Treasury, random walk process, no change process, my predictions from AR(2) and vector auto-regressive were evaluated. In total 53 regression equations were estimated and the same amount of F-tests was performed. The predictions were evaluated using methodology presented in Goodhart and Lim (2011), namely Minzer-Zarnowitz regression and two other equations evaluating the accuracy of predictions of the moves in 3M PRIBOR rate. Apart from econometric evaluation, the predictions were also evaluated using mean squared error approach and so called sign evaluation[1]. Moreover, I employed in my thesis autoregressive and vector autoregressive methodology in order to produce my own predictions of 3M PRIBOR and evaluate these predictions vis-a-vis to the predictions produced by G3 model that is in use in CNB. Based on the results that are presented in previous chapters several conclusions can be drawn. Firstly, CNB is able to predict the value of the 3M PRIBOR rate successfully up to 3 quarters ahead. Afterward the predictions tend to be biased and less informative, however, still performed better than the rest of evaluated predictions (Treasury, RW, AR(2), VAR). When comparing CNB results to the results Goodhart and Lim (2011) arrived at, CNB bears international comparison with evaluation results from Royal bank of New Zealand. Royal bank of New Zealand is also able to produce unbiased and accurate forecasts of interest rates up to three quarters ahead. The ability of predicting the future moves in 3M PRIBOR have also been put under the examination. Two sets of equations were estimated. The first equation examined the ability of predicting the future moves in the rate with

[1] Counting how often the predictions are above/bellow true values.

increasing time horizon. The second equation evaluates the forecaster's accuracy in modeling one quarter ahead moves of 3M PRIBOR with increasing time horizon. For the first equation, findings suggest that CNB is able to predict the moves reasonably for two quarters ahead, after this horizon the predictions are becoming biased and less informative, but unlike the RBNZ the value of coefficient of determination was significantly lower. For the second equation, CNB predicts accurately one quarter ahead moves in rate for two quarters ahead, which is one quarter longer time horizon than in case of Royal bank of New Zealand. When focusing on sign evaluation of predictions, one conclusion has to be mentioned. CNB usually over-predicts the real value of 3M PRIBOR and this trend is stronger with increasing time horizon. Furthermore, CNB predictions were evaluated as the most accurate, according to MSE evaluation procedure, in comparison with random walk process prediction, no change predictions[2], predictions published by the Czech Treasury and my own predictions from AR(2) and VAR. When focusing on performance of my AR(2) and VAR predictions of 3M PRIBOR, several conclusions can be drawn from the evaluation results. Firstly, AR(2) is not the suitable approach for predicting the 3M PRIBOR, as it most of the predictions under-estimates the true values of 3M PRIBOR and AR(2) linear trend of predicting does not capture the behavior of 3M PRIBOR. Moreover, the predictions of AR(2) process tend to be biased from one quarter ahead time horizon, unable to predict accurately future moves in the 3M PRIBOR rate. When comparing the mean squared error (MSE) of AR(2) it has been shown that it is at least 4 times higher than MSE of CNB predictions, at maximum 6 times higher. Totally AR(2) predictions proved themselves with highest MSE from all evaluated predictions. Secondly, when focusing on VAR predictions, they performed significantly more accurate than AR(2). The pattern in over/under-estimating of the real values was closer to CNB and Treasury according to the sign evaluation procedure. Moreover the MSE of VAR predictions showed to be considerably lower than AR(2), however higher than the MSE from Treasury. VAR methodology was able to create accurate unbiased predictions of 3M PRIBOR up to two quarters ahead. When focusing on VAR ability of predicting the future moves in PRIBOR rate, VAR predictions did not describe these future moves-not the changes one step ahead with increasing time horizon, nor the changes of 3M PRIBOR with increasing prediction horizon.

Possible future extension can on one hand involve employing different evaluation approach than Minzer-Zarnowitz regression, for example methodology presented in Diebold and Mariano (1995) that focuses on evaluation of point forecasts, different

[2]For one step ahead the prediction for time t equals to value in t-1, for two steps ahead prediction for time t equals to value in time t-2 etc.

from Minzer-Zarnowitz approach. Furthermore, as CNB publishes the prediction in fan charts, the evaluation of interval predictions can be employed as presented in Christoffersen (1998). On the other hand, different prediction procedure of 3M PRIBOR might be employed, such as the co-integrated VARGARCH model as proposed in Bauwens et al. (1997).

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Appendix A

Appendix A

time horizon	estimated coefficients		R^2	F-test p-value	result
	β_0	β_1		β_0=0 β_1=1	
t+1	0.000863506	0.902574	0.909243	0.0308807	reject H_0
t+2	-0.0117921	0.871952	0.822024	0.0325687	reject H_0
t+3	0.100165	0.781881	0.630324	0.0313252	reject H_0
t+4	0.284869	0.678778	0.454591	0.0245954	reject H_0

Table A.1.: Minzer-Zarnowitz regression for random walk

time horizon	estimated coefficients		R^2	F-test p-value	result
	β_0	β_1		β_0=0 β_1=1	
t+1	-0.0201541	0.923877	0.923840	0.0466505	reject H_0
t+2	-0.0186475	0.868722	0.821907	0.0232142	reject H_0
t+3	0.138118	0.767309	0.627794	0.0294427	reject H_0
t+4	0.387441	0.639446	0.418111	0.0241982	reject H_0

Table A.2.: Minzer-Zarnowitz regression for no change process

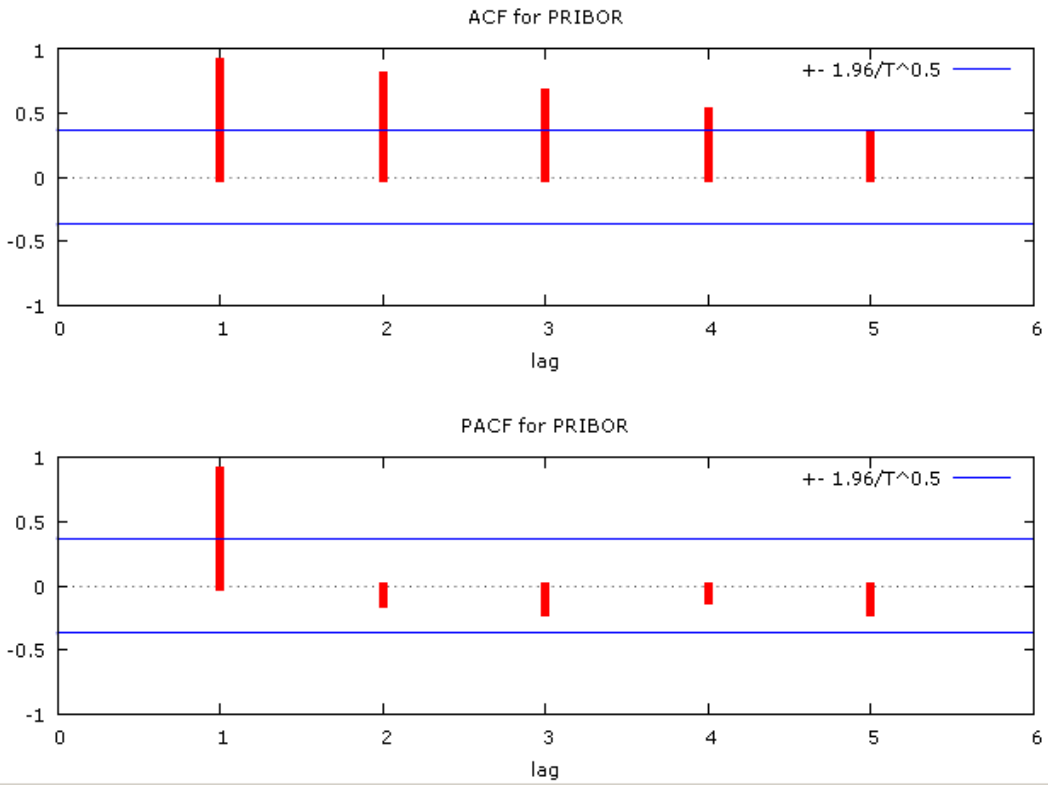

Figure A.1.: Autocorrelation function and partial autocorrelation function for 3M PRIBOR

Table A.3.: AR(2) predictions for 3M PRIBOR

		Sets of AR(2) predictions																		
Time	3M PRIBOR	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
I/08	4.05	3.19																			
II	4.04	2.90	3.54																		
III	4.21	2.30	3.60	3.43																	
IV	3.81	1.87	2.52	2.95	3.60																
I/09	3.89		2.06	2.44	2.69	3.08															
II	2.49			2.00	2.21	2.69	2.37														
III	2.17				1.80	2.20	1.81	1.71													
IV	1.88					1.80	1.70	1.35	1.00												
I/10	1.64						1.60	0.99	1.10	1.20											
II	1.43							0.66	0.75	0.88	1.00										
III	1.24								0.43	0.53	0.68	0.81									
IV	1.22									0.23	0.35	0.51	0.72								
I/11	1.22										0.05	0.18	0.43	0.70							
II	1.21											0.00	0.10	0.42	0.68						
III	1.20												0.00	0.07	0.39	0.60					
IV	1.17													0.00	0.04	0.37	0.64				
I/12	1.16														0.00	0.01	0.33	0.61			
II	1.23															0.00	0.00	0.30	0.63		
III	1.21																0.00	0.00	0.33	0.64	
IV	0.50																	0.00	0.00	0.32	0.44

Table A.4.: VAR predictions for 3M PRIBOR

		Sets of VAR predictions																		
Time	3M PRIBOR	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
I/08	4.05	4.22																			
II	4.04	4.02	3.91																		
III	4.21	3.26	3.39	3.99																	
IV	3.81	2.00	2.54	3.47	3.90																
I/09	3.89		0.65	2.50	3.30	4.02															
II	2.49			1.66	2.18	4.22	2.50														
III	2.17				1.09	4.16	2.71	1.75													
IV	1.88					3.65	2.16	1.51	1.64												
I/10	1.64						1.91	1.47	2.03	1.95											
II	1.43							1.45	2.50	2.20	2.32										
III	1.24								2.73	2.10	2.50	1.17									
IV	1.22									3.51	2.10	1.56	1.97								
I/11	1.22										0.05	2.47	2.21	1.21							
II	1.21											2.62	2.50	1.40	1.49						
III	1.20												2.61	1.84	1.82	1.16					
IV	1.17													2.14	2.05	1.19	1.38				
I/12	1.16														2.09	1.29	1.45	1.17			
II	1.23															1.47	1.63	1.23	1.38		
III	1.21																1.73	1.23	1.35	1.03	
IV	0.50																	1.30	1.17	0.78	0.86

```
*** Fri, 19 Jul 2013 12:35:01 ***
CHOW TEST FOR STRUCTURAL BREAK
On the reliability of Chow-type tests...,
B. Candelon, H. Lütkepohl, Economic Letters 73 (2001), 155-160

sample range:                  [2000 M4, 2012 M9], T = 150
tested break date:             2005 M1 (57 observations before break)

break point Chow test:         183.5506
 bootstrapped p-value:         0.0000
 asymptotic chi^2 p-value:     0.0000
 degrees of freedom:           66

sample split Chow test:        152.6419
 bootstrapped p-value:         0.0000
 asymptotic chi^2 p-value:     0.0000
 degrees of freedom:           56

Chow forecast test:            1.6729
 bootstrapped p-value:         0.0100
 asymptotic F p-value:         0.0001
 degrees of freedom:           372, 162
```

Figure A.2.: Chow test for the stability of VAR

Appendix B
Content of Enclosed CD

There is a CD enclosed to this thesis which contains empirical data and results from Gretl and JMulti programs.

- Folder 1: AR(2) and VAR estimated equations
- Folder 2: Empirical data