Charles University in Prague
Faculty of Social Sciences

Institute of Economic Studies

Bachelor Thesis

2005 **Michal Miklovič**

Charles University in Prague
Faculty of Social Sciences

Institute of Economic Studies

BACHELOR THESIS

Reaction Functions of the CNB and the NBS

Author: Michal Miklovič
Consultant: PhDr. Michal Hlaváček, Ph.D.
Academic Year: 2004/2005

Declaration

I hereby declare that I have elaborated this thesis on my own and that I have used only the sources listed.

Prague, 23 May 2005

………..…………………………
Michal Miklovič

Abstract

The objective of this bachelor thesis is to estimate reaction functions capturing the systematic parts of monetary policies conducted by the CNB and the NBS after they abandoned fixed exchange rate regimes in the second half of 1990s. Following an examination of the past actions of the banks two appropriate specifications of the reaction functions are proposed. The results indicate that the CNB took into account expected future inflation development as well as contemporaneous performance of the economy when setting its monetary policy instruments. The NBS did not commit itself to reaching specific values of inflation and due to this absence of a clear strategy we are not able to model the systematic part of the NBS monetary policy.

Abstrakt

Cieľom predkladanej bakalárskej práce je odhadnúť reakčné funkcie zachytávajúce systematickú časť monetárnych politík vykonávaných ČNB a NBS po opustení režimov fixného kurzu v druhej polovici deväťdesiatych rokov minulého storočia. Preskúmanie minulých krokov oboch bánk je nasledované navrhnutím dvoch vhodných špecifikácií reakčných funkcií. Výsledky naznačujú, že ČNB brala pri určovaní nástrojov monetárnej politiky do úvahy očakávaný budúci vývoj inflácie a aj výkonnosť ekonomiky v čase rozhodnutia o nastavení týchto nástrojov. NBS sa nezaviazala dosiahnuť špecifické hodnoty inflácie a kvôli tejto absencii jasnej stratégie nie sme schopní modelovať systematickú časť monetárnej politiky NBS.

Acknowledgements

I am grateful to Michal Hlaváček of the Faculty of Social Sciences, Charles University for supervising my work on this thesis. I would also like to thank Martin Netuka of the Faculty of Social Sciences, Charles University for helpful comments on earlier drafts of this thesis.

Contents

1 Introduction

Both the Czech National Bank and the National Bank of Slovakia (CNB and NBS henceforth, respectively) play an important role in the Czech and the Slovak economies and, in fact, they are supposed to do so. Then, it is natural that economists and market agents spend time analysing their behaviour. There is a wide range of possible approaches to the study of central banks' actions. First of all, we have to decide what we would like to examine – whether the systematic part of monetary policy or monetary policy shocks and their effects on the economy. Consequently, a proper method of identifying these two parts should be selected. One option is to draw conclusions from minutes of the bank board meetings, which would require a thorough and methodical study of them. This approach would not result in a quantitative relationship between actions of a central bank and indicators of economic development and there is one considerable drawback – interpretation of the minutes is subjective and thus can be 'biased'. The second possibility would involve using the banks' prediction models and data available when decisions on monetary policy settings were made to specify the systematic part of monetary policy and monetary policy shocks. Finally, we could estimate both a reaction function capturing the systematic part of monetary policy and monetary policy shocks using VAR models.

A reaction function was chosen to describe the systematic parts of monetary policies of the CNB and the NBS. This choice was motivated by simplicity of the reaction function concept compared to other options outlined above and by the possibility to interpret obtained results in a straightforward manner. Another virtue of a reaction function is that it represents a quantitative relationship between indicators of economic performance and actions of the banks.

As was just stated, the reaction function of a particular central bank treats settings of monetary policy instruments, e.g. the level of interest rate, as a function of a certain set of information. This broad definition allows for various specifications of reaction functions: both descriptive and prescriptive, simple ones taking into account only a few explanatory variables, e.g. inflation and the output gap, as well as optimal ones derived from a central bank's loss function. Since the scope of this thesis is limited, we have to pick a single specification.

Now, let us sketch two possible approaches to the specification of a reaction function. We could choose the so-called normative approach leading a to prescriptive rule derived as a solution to an optimisation problem and making sure that monetary policy goals set in advance will be met. The other option is selecting the positive approach leading to a monetary policy rule that best describes the past actions of a central bank, i.e. a descriptive rule.

This thesis is focused on the approximation of the past actions of the CNB and the NBS and, of course, on the comparison of the econometrically estimated reaction functions. We will not attempt to say how they should have acted or how they ought to act in the future because that would require exact knowledge of the central banks' loss functions (mainly weights assigned to different objectives) and of the transmission mechanisms and we do not possess it. Expert judgement is also in question because all available information cannot be incorporated into the decision-making process, though the most important pieces should definitely be extracted somehow. With the benefit of hindsight there is almost no problem to select indicators that should have been paid more attention to, but decision making in real time does not have this privilege.

It is believed that this thesis and its conclusions could be of interest and importance due to several reasons. First is the ability of the estimated rules to model the behaviour of each bank, i.e. decisions on monetary policy settings in the light of published figures. Regularities and systematic responses to certain economic indicators will show up in the estimates. On the other hand, discretion would reduce their explanatory power. Secondly, the estimated reaction functions could provide a benchmark for the banks against which they could compare every 'new' decision. Thirdly, anticipating future steps of the CNB and NBS could be enhanced by the results of our analysis. And finally, modelling the banks' behaviour increases the understanding of how these banks operate which is indeed important for success of their monetary policies.

The remainder of the thesis is organised as follows. In Section 2 we discuss key concepts related to the model selection and also provide some related definitions. Section 3 is focused on the actual monetary policy conduct of both banks. In Section 4 we derive two reaction function specifications and choose the appropriate econometric method to estimate them. Section 5 contains details about some aspects of the estimation and, consequently, we present and discuss the results there. Finally, Section 6 concludes.

2 Key Concepts and Definitions

2.1 Monetary Policy and Rules

Reaction functions are often referred to as monetary policy rules or modifications of the specific rule proposed by Taylor (1993). The word 'rule' might cause the impression that a reaction function states how a particular central bank should act a priori or should have acted in the past. But, on the other hand, a reaction function could also be an approximation of the actual behaviour of a monetary authority. Whereas the former case calls for a rule that a central bank should follow or should have followed, in the latter case there would be no observable or functional relationship between settings of monetary policy instruments and information on economic development, if there were not any systematic use of the information in the process of monetary policy decision making. Therefore, every reaction function is based on the assumption that the monetary authority does have a contingency plan or a strategy.

Let us now turn our attention to defining and contrasting monetary policy rules with discretion.[1] Pure discretion means setting monetary policy instruments each period independently of any plan and with no intention to be in line with previous decisions. That is the reason why discretionary policy can be characterised as "the "inconsistent," the "cheating," or the "short-sighted" solution."[2] A rule, on the contrary, requires a systematic – i.e. using a fixed and organised plan[3] – approach to decision making at least during a couple of periods, thus leaving no room for 'random' choices. Examples of monetary policy rules include those involving fixed settings, e.g. a constant growth rate of the money supply, so-called responsive rules warranting changes in monetary policy instruments in case of changes in selected macroeconomic indicators and, last but not least, targeting rules specifying target variables and their targets.[4] As can be seen, monetary policy rule does not necessarily equal to a fixed setting once and for all or a formula with fixed coefficients that has to be 'obeyed'.

[1] The following discussion is based on Taylor (1993).
[2] Taylor (1993), p. 198.
[3] "Fixed and organised" means set or agreed upon a priori. Any plan in this sense has to be set a priori, i.e. for the future.
[4] Svensson (2002) also requires specification of the loss function to be minimised.

Now comes the important question: what makes rules superior to discretion? Firstly, it is credibility[5] that a central bank could gain, if it acts according to a rule. Discretion makes predictability of a monetary authority's future decisions more difficult and does not facilitate the understanding of current decisions. Secondly, discretion is not time consistent and tempts into subordinating monetary policy to short-term benefits and neglecting long-term losses. The contrary is true for a policy based on a rule. Thirdly, rules make it easier for economic agents to formulate expectations and reduced uncertainty (when compared to an environment where discretion prevails) improves the possibility of their expectations being close to the actual state of the economy.

Since a particular monetary policy rule is not supposed to be followed forever, one has to be cautious not to confuse discretion with a transition from one rule to another that is thought to yield better results in the future. Identification of monetary policy transitions is an integral part of any reaction function estimation. If economic agents formed their expectations on the basis of all available data, i.e. formed rational expectations, this transition would be 'smoother' and would bring positive results earlier. Adaptive and static expectations would make it more difficult to communicate and explain new strategy and also economic costs associated with the transition are likely to be higher in this case due to nominal rigidities, e.g. wages and prices set advance.

2.2 Systematic Part of Monetary Policy and Monetary Policy Shocks

"Many economists think that a significant fraction of the variation in central bank policy action reflects policy makers' systematic response to variations in the state of the economy."[6] Settings of monetary policy instruments thus cannot be seen as pure outcomes of any rule. In reality any contingency plan is not followed 'absolutely' and, definitely, a certain fraction of a monetary policy adjustment could be regarded as a monetary policy shock. In formal notation:

$$S_t = f(I_t) + \nu_t$$

where S_t is monetary policy setting at time t, f is a function of information on economic developments, I_t, available at the time when the decision on S_t is made, i.e. f is the systematic part of monetary policy, and ν_t is a monetary policy shock – a

[5] Credibility of a central bank has indeed a beneficial effect on the economy it operates in.
[6] Christiano et al. (1998), p. 5.

random variable. Monetary policy shocks (unsystematic parts of monetary policy) are stochastic and therefore modelling monetary policy as a "systematic response to variations … in the economy" or as a contingency plan means modelling its systematic part.

Several explanations of these shocks are possible. To begin with, ν_t could be caused by random "exogenous shocks to the preferences of the monetary authority,"[7] for example, by changes in the relative weights of different variables in the loss function or by a "stochastic change in the transmission mechanism or of its perception."[8] It is important to bear in mind, though, that longer lasting and permanent changes are, in fact, transitions from one rule to another. Some authors argue that another source of monetary policy shocks is the willingness to avoid disappointing expectations of private agents because of the costs associated with it, which might stray the monetary authority from a rule-determined path and lead to self-fulfilment of private agent's expectations. Lastly, there is also the problem of how to react to new and incomplete data that are subject to significant revisions, e.g. output and thus the output gap too. A rule or a contingency plan cannot precisely capture the procedure for handling such data. But a central bank has no other option than to use real time data and try to extract the 'right' information from it. For this reason, the monetary policy shock cannot be dispensed with. On the contrary, resorting to the use of revised data when estimating a central bank's reaction function due to incompleteness and inconsistency of real time data might overestimate ν_t by adding to it a proportion of the discrepancy between real time and revised data.

3 The Actual Conduct of Monetary Policies

After having decided to estimate descriptive rules the next step is to specify the sample period and also the response variable and the explanatory variables in the reaction function. In other words, we need to find the instrument to be regarded as a function of selected objects of information sets available to policy makers as well as market agents and to specify the just mentioned 'selected objects' of economic data sets. At the same time, it is necessary to search for monetary policy transitions in order to avoid estimating a reaction function for two different monetary policy

[7] Christiano et al. (1998), p. 6.
[8] Navrátil (2004), p. 624.

regimes. So we have to examine how the banks operated in selected periods, with which instruments they sought to influence the economy and what were their goals.

Each bank's conduct of monetary policy stems from the legal framework in operates in, since it sets the monetary policy objectives. The CNB is required by the Act on the CNB to "maintain price stability" and if price stability as the primary objective is not put at risk it also should "support the general economic policies of the Government leading to sustainable economic growth."[9] The NBS has the same primary objective as the CNB, i.e. maintaining price stability, as set by the Act on the NBS. The second objective is, however, slightly different – the NBS "shall support the economic policy of the Government,"[10] while adhering to its primary objective (meaning putting it first).

Initially, both banks operated under fixed exchange rate regimes after the split of Czechoslovakia. The Czech Republic experienced economic turmoil in May 1997 and the CNB was forced to abandon the fixed exchange rate. Following the Asian 'flu' the Czech koruna came under a speculative attack and the CNB was not able to prevent[11] a significant devaluation of the koruna. Similar fate befell the Slovak koruna[12] in October 1998. The NBS was no longer able to defend the Slovak koruna against depreciation; the official reason for abandoning the exchange rate was rapidly shrinking foreign exchange reserves.

3.1 Monetary Policy of the CNB from January 1998

In the aftermath of these crises the crucial question was what kind of monetary policy to adopt. In December 1997 the CNB announced its adoption of the inflation targeting strategy that was supposed to crack down on rising inflation and, consequently, to decrease inflation (i.e. stabilise prices) and to anchor inflation expectations, which play an important role in the process of disinflation. Short and medium term targets for y-o-y net inflation in December were published and the CNB "committed itself to setting its monetary policy instruments so as to"[13] reach them. So-called escape clauses, i.e. exceptions[14] from attaining the inflation targets, were defined during the

---

[9] The Act on the CNB (Act No. 6/1993 Coll., on the Czech National Bank).
[10] The Act on the NBS (Act No. 566/1992 Coll., on the National Bank of Slovakia).
[11] Widening the fluctuation band, strong tightening of monetary policy (rising interest rates) and interventions were not sufficient.
[12] Similar scenario could be observed: widening the band, tightening and interventions.
[13] Coats et al (2003), p. 11.
[14] In general, they can be characterised as abrupt changes in exogenous (i.e. outside the CNB's control) determinants of inflation, e.g. sudden changes in crude oil prices and in the koruna's exchange rate that

strategy's refinements in 1999 and the monetary policy focus moved closer to a medium-term horizon. In April 2001 the CNB has moved to a 'full-fledged' inflation targeting. Since then, target ranges and the continuous target trajectory are expressed in terms of headline inflation – CPI inflation. This kind of monetary policy conduct could obviously be dubbed 'forward looking' and that ought to have implications for our considerations of an appropriate reaction function.

The monetary policy transition occurred at the end of 1997 and inflation targeting 'began' in January 1998. The refinements did not alter the targeting strategy significantly enough to warrant another monetary policy transition. Therefore the year 1998 and the subsequent ones will be included in the sample period for which the reaction function will be estimated.

The CNB states the following: "The main monetary policy instrument takes the form of repo tenders."[15] The CNB does not concentrate on controlling monetary aggregates. The repo tenders affects, via the transmission mechanism, aggregate demand and thus the output gap and inflation pressures. Short-term interest rates on the inter-bank market are results of the operations of the CNB and influence private sector's lending and borrowing decisions that influence the economy. Therefore either the repo rate or e.g. 3M PRIBOR are suitable candidates for the response variable in an estimated reaction function describing the bank's answer to economic developments.

3.2 Monetary Policy of the NBS from January 1999

The NBS did not commit itself to reaching certain values of inflation after it abandoned the fixed exchange rate. In the 1999 Monetary Programme (released in 1998) the bank mentioned its "aim to keep net inflation at a level of 5 to 7%."[16] Net inflation was probably selected due to anticipated rises in regulated prices and indirect taxes and high likelihood of a rather sharp depreciation of the koruna, which turned out to be the reality. But, on the other hand, the NBS characterises from an ex-post view the policy it conducted from October 1998 to December 1999 as "quantitative monetary-policy control (through M2)" [17] with its main objective being currency stability and mentions "monitoring net inflation" as opposed to targeting net inflation.

are not in line with economic fundamentals. For a detailed list of the escape clauses see Coats et al (2003), pp. 12 and 13.

[15] Source: http://www.cnb.cz/en/d.php.

[16] NBS (1999a), p. 3.

[17] NBS (2003c), p. 12.

This is in accordance with another target set in the Programme – a 6% rise in money supply y-o-y in December 1999. Next year it was stated that "core inflation will gradually become a target for the NBS."[18] In the beginning of 2000 the NBS opted for "qualitative monetary-policy control (through key interest rates)" and price stability was declared to be the "main goal of MP [monetary policy]."[19] The Act on the NBS was substantially amended in 2001 and made price stability the main objective. Thus, the switch to qualitative monetary policy was 'confirmed' by the law. Since 2001 the NBS includes medium-term outlook (three-year) in its Monetary Programmes and updates them in the course of each year – usually in May. In this way, the NBS wants to "inform the public about anticipated macroeconomic development and … in particular to provide information about presumed development of inflation, whereby the programmed interval of its development has represented the implicit monetary policy target."[20]

Clearly, the NBS changed the exchange rate regime in 1998, but its monetary policy conduct did not change in other respects until the beginning of 2000. So, unlike in the case of the CNB, we will not take the year after the exchange rate crisis into account when estimating the reaction function because, in fact, the monetary policy transition occurred almost one and a half years after that crisis. What is more, the 'target'[21] for December 1999 was set in terms of net inflation while the subsequent ones were set in terms of core inflation.

The NBS did not follow such a well defined, consistent and easy-to-grasp (for the public) rule as the CNB after the respective exchange rate problems. Therefore the proposed form of reaction function could have limited explanatory power. However, the NBS was 'forward looking', e.g. in March 2001 it lowered the repo rate "with regard to the expected favourable trend in consumer prices"[22] and in 2002 it raised the rates because this step was consistent with the then economic outlook. The NBS also characterised repo tenders as its main monetary policy instrument.[23] Thus, it influenced the economy with the same 'tools' as the CNB did.

[18] NBS (2000a), p. 2.
[19] NBS (2003c), p. 13.
[20] NBS (2004c), p. 2.
[21] The word 'target' is a bit problematic here. It will be made clear why in the section 5.2.1.
[22] NBS (2003c), p. 13.
[23] Source: NBS (2003c), p. 13.

4 The Model and the Data

4.1 The Original Taylor Rule

Monetary policy rules are often called Taylor rules or modifications of the original rule proposed by Taylor (1993). He put forward this formula[24]:

$$i = \pi + 0.5y^{gap} + 0.5(\pi - 2) + 2\ ,$$

where i is the federal funds rate, π "is the rate of inflation over the previous four quarters"[25] and y^{gap} is the output gap calculated in the following way: $y^{gap} = 100(Y - Y^*)/Y^*$ where Y is real GDP and Y^* is trend real GDP obtained by fitting a log-linear trend through real GDP[26]. The last term in the above equation was said to be the 'equilibrium' real interest rate, let us denote it as r^*. The Fed's inflation target, π^{tar}, was assumed to be constant throughout the whole examined period and equal to 2. The interest rate in a period (quarter) p was determined by the selected indicators 'valid' for the same period (i.e. the quarter p). Then we can write:

$$i_t = \pi_t + 0.5y_t^{gap} + 0.5(\pi_t - \pi^{tar}) + r^*\ .$$

For the sake of a straightforward interpretation let us make a few rearrangements leading to:

$$i_t = 1.5(\pi_t - \pi^{tar}) + 0.5y_t^{gap} + (r^* + \pi^{tar})\ .$$

Inserting the specific values of the inflation target and the real interest rate (as proposed by Taylor) yields:

$$i_t = 1.5(\pi_t - 2) + 0.5y_t^{gap} + 4\ .$$

"If both the inflation rate and real GDP are on target, then the federal funds rate would equal 4 percent, or 2 percent in real terms."[27] In case of a positive output gap or inflation gap (or both) the funds rate would increase. Their negative values would imply a decrease in the funds rate. According to this (simple) rule the Fed placed more emphasis on reaching the inflation target than on business cycle smoothing, which is clearly indicated by the coefficients 1.5 and 0.5. Closely related to this is the so-called Taylor principle that requires the coefficient on the inflation gap to be larger than one (>1) in order to effectively control inflation. If it were less than one, a rise in inflation would be accompanied by an insufficient rise in nominal interest rates and

[24] Notation was changed in order to be consistent with other formulas in this paper.
[25] Taylor (1993), p. 202.
[26] Source: Orphanides (1998).
[27] Taylor (1993), p. 202.

real interest rates would decrease. Such a situation could be characterised as an accommodative reaction to inflation

Several issues are associated with the original Taylor rule. First of all, Taylor argued that the Fed should use this rule at least as a benchmark when making its decisions. In other words, he advocated a prescriptive (normative) approach. But this instrumental rule, as any other instrumental rule, is incomplete because it cannot replace the complicated decision making process of the Fed or the NBS and the CNB. Commitment to such a rule would neglect expert judgement that plays a significant role in settings of monetary policy instruments. Furthermore, Taylor did not specify any 'rules for deviations' from the rule he proposed. We have chosen a descriptive perspective and thus will avoid these problems.

The second issue concerns econometric estimation of the rule. Taylor did not estimate the coefficients; he merely put forward their values and found the specification a surprisingly good description of the actual policy performance. But, unlike the author, the Fed could not use revised figures on the period (quarter) p when deciding on interest rate setting in that period. They could only use previous period's data which are subject to substantial revisions. As Orphanides (1998) shows, using the real-time data leads to a significant discrepancy between the actual settings and the rule-based ones. To increase the plausibility of our results it is advisable to rely on the real-time data as much as possible and/or use a model that is able to cope with this data problem.

Lastly, there is also the question whether the Fed reacted to predetermined variables or to forecasts based on them, i.e. whether the Fed was forward looking or not. There is not only an empirical evidence[28] suggesting that the Fed considered possible future developments expressed in terms of inflation forecasts as well as theoretical reasons for a forward-looking behaviour – especially lags with which monetary policy settings influence the economy. The CNB and the NBS are both considered to be forward looking and therefore we would rather refrain from using the original Taylor rule. A reaction function allowing for expected variables would better describe actions of any inflation targeting central bank – it would not be 'mechanistic'

[28] See e.g. Clarida et al. (1998a) and Orphanides (1998). The evidence includes estimated reaction functions and testimonies of the Fed's chairman Greenspan.

and would incorporate expert judgement of a central bank's staff needed in the construction of inflation forecasts over a sufficiently long horizon.[29]

4.2 The Quest for an Appropriate Reaction Function

As was previously stated, in this thesis we focus on describing the past actions of the banks in terms of a reaction function. In other words, we try to identify systematic parts of their monetary policies. To achieve this goal we will econometrically estimate a descriptive instrumental monetary policy rule for each bank.

Now comes the question of selecting the explanatory variables as well as further specifying the response variable. It could be either the two-week repo rate or one of the short-term interest rates on the inter-bank market that is highly (and positively) correlated with the repo rate. In our approach it is a function of information on economic developments, I_t, but a monetary policy shock, ν_t, should not be neglected:

$$i_t = f(I_t) + \nu_t .$$

Interest rate setting at time *t*, i_t, comprises a systematic response as well as a shock. In order to be able to estimate the banks' reaction functions we have to choose their form and specify the explanatory variables. In fact, these two tasks cannot be separated.

Since both the CNB and the NBS exhibit signs of forward-looking behaviour, the following simple reaction function could come into our minds:

$$i_t = f(\pi_{t+n} - \pi_{t+n}^{tar}) + \nu_t$$

where π_{t+n} is the actual inflation at time (*t*+*n*) and π_{t+n}^{tar} is the target inflation for time (*t*+*n*). But this specification has a considerable flaw: if a central bank in successful in its operations, i.e. inflation target is reached, we would only observe changes in interest rate settings at time *t* that affect inflation with a lag, e.g. *n* months and the inflation gap at time (*t*+*n*) would be zero. What is more, it violates the concept of systematic part of monetary policy in that any actual future inflation gap does not belong to the information set available at time *t*. For these reasons we should not use such a specification of reaction functions.

A much better idea is to perceive interest rate settings as a function of an expected inflation gap:

---

[29] Inflation forecast in the horizon of the most effective transmission is not predetermined.

$$i_t = f(E[\pi_{t+n}] - \pi_{t+n}^{tar}) + \nu_t \, .$$

The capital letter "*E*" means expected. In this case we have to make clear two points: [1] the expected inflation at time (*t+n*) is forecasted at time *t* on the assumption [2] that interest rate will be constant at least in the next *(n+1)* periods and equal to i_{t-1}. Therefore, $E[\pi_{t+n}]$ is conditioned on the information set I_t. If $E[\pi_{t+n}]$ were unconditional, the expected inflation gap would be zero because it should take into account future changes in interest rates aiming at reaching the inflation target. Then, the last equation ought to be rewritten as follows:

$$i_t = f(E[\pi_{t+n}] - \pi_{t+n}^{tar} \mid i_{t+a} = i_{t-1}) + \nu_t ; \;\; a = 0,1,2,\ldots$$

The information set I_t is used to make the conditional forecast. Should a zero inflation gap be expected, interest rate settings would be unchanged. This type of reaction function might be a description of 'pure inflation targeting'.[30]

As can be seen, the conditional forecasts of future inflation are needed. But there is a problem: the CNB published conditional inflation forecasts until April 2002 and from July 2002 onwards it publishes unconditional forecasts. The NBS published inflation forecasts only twice a year, in January and May, and did not indicate that they were conditioned on anything. Therefore, another specification of reaction functions should be sought or the one above should be modified in an appropriate way.

Which other (except for the just discussed inflation gap) explanatory variable should enter into our specification of reaction function? Output gap is used in a number of studies. Svensson (2002) argues that a good monetary policy ought to aim at a stable and low inflation as well as at stabilising the output growth or smoothing the output gap.[31] On the other hand, it would not be reasonable to consider the forecasted output gap because it is directly related to the inflation forecast. It is possible to use the forecasted present output gap provided that there is a significant gap between it and the inflation forecast. Its inclusion might be justified by [1] the second objective(s) of both banks; and [2] by the fact that a supply shock could have

[30] Meaning that a central bank focuses solely on reaching an inflation target (and does not take into account e.g. the output gap or its smoothing).
[31] He calls this type of monetary policy "flexible inflation targeting."

opposing effects on inflation and the output gap and we would like their weights to show up in the estimated reaction functions.[32]

Other suitable 'candidates' for the explanatory variables might be nominal or real exchange rates, current accounts' deficits, public finance stance etc. But all of them are related to the forecasted inflation gap and the contemporaneous output gap. For instance, expansive fiscal policy fuels inflation pressures by stimulating the aggregate demand and leads to a positive output gap. A strengthening currency contributes to a decrease in inflation pressures but to the detriment of economic growth by reducing competitiveness of exporters. Clearly, all potential explanatory variables are highly correlated. Therefore, including an exchange rate or the magnitude of public budget deficits into the reaction function besides the already mentioned forecasted inflation and output gaps would be counterproductive because it would reduce the explanatory power of these gaps. That is not wanted since price stability is the main goal of both the CNB and the NBS. It would also blur the extent to which the banks adhere to the second objective – their concern about sustainable economic growth and smoothing of economic cycles. Summing up, it would be advisable to refrain from adding another variables to the reaction function.

4.3 The Baseline Specification

All specifications of the reaction functions reflect the legal framework in which the banks operate and thus we do not assume any external constraints, e.g. a commitment to maintaining a fixed exchange rate, imposed on them. The output gap will be included in the baseline specification of the reaction function because of the reasons mentioned earlier. Our derivation of the reaction function stems from Clarida et al. (1998a). It was argued that interest rate settings are suitable candidates for the response variable in the reaction function. Therefore, we construct the reaction function as follows. In each period when interest rates are decided upon it is assumed that each central bank has a nominal 'target rate', i_t^*, based on the state of the economy:

$$i_t^* = i^* + \beta(E[\pi_{t+n} \mid I_t] - \pi_{t+n}^{tar}) + \gamma(E[y_t^{gap} \mid I_t]) \qquad (1)$$

where i^* is the long-term equilibrium nominal interest rate, π_{t+n} is the rate of inflation at time (t+n), π_{t+n}^{tar} is the inflation target for the period (t+n), y_t^{gap} is the output gap at

[32] An AD shock usually has the same effects on both the output gap and inflation. The output gap's inclusion is not so 'clear'.

time t. We will use the same definition of the output gap as Taylor (1993), i.e. $y^{gap} = 100(Y - Y^*)/Y^*$, where Y is real GDP and Y^* is a measure of the output gap, which will be, however, different from that used by Taylor (1993). I_t comprises all available information to the central bank at time t and the operator E stays for 'expected'. The subscript n captures the lag with which monetary policy is thought to influence the economy. It equals to the length of the most effective transmission. As can be easily inferred, the expectations are conditioned on the information set I_t, which comprises i_{t-1} and not i_t which is the result of the decision making process. Unlike Clarida et al. (1998a), we allow for different inflation target in each period. It better describes the disinflation process in both the Czech Republic and the Slovak Republic (CR and SR henceforth, respectively) after the respective currency crises. If the output gap is closed and the expected inflation is on target, the 'target rate' (i_t^*) is equal to the long-term equilibrium nominal interest rate. Should neither of the gaps be zero, then the deviation from the equilibrium rate depends on the coefficients β and γ.

The above definition of the 'target rate' completely ignores "the tendency of central banks to smooth changes in interest rates."[33] Fears of loosing credibility due to unexpected and large changes in interest rates, adverse effects of 'surprising' capital markets and preferring gradual changes to rapid ones account for interest rate smoothing. We suppose that both banks take into account the 'target rate' as well as the rate in the preceding period, i.e. at time $(t-1)$, when setting the rate in period t. So we arrive at:

$$i_t = (1-\rho)i_t^* + \rho i_{t-1} + \nu_t \tag{2}$$

where $\rho \in [0,1]$ indicates the extent of interest rate smoothing and ν_t is a random exogenous monetary policy shock which is assumed to be i.i.d. Inserting the equation (1) into (2) yields:

$$i_t = (1-\rho)i^* + (1-\rho)\beta(E[\pi_{t+n} \mid I_t] - \pi_{t+n}^{tar}) + (1-\rho)\gamma E[y_t^{gap} \mid I_t] + \rho i_{t-1} + \nu_t \tag{3}$$

which is the baseline specification to be estimated. Rearranging (3) produces:

$$i_t = (1-\rho)i^* + (1-\rho)\beta\{\pi_{t+n} - \pi_{t+n}^{tar}\} + (1-\rho)\gamma y_t^{gap} + \rho i_{t-1} + \varepsilon_t \tag{4}$$

where the error term

$$\varepsilon_t \equiv -(1-\rho)\{\beta(\pi_{t+n} - E[\pi_{t+n} \mid I_t]) + \gamma(y_t^{gap} - E[y_t^{gap} \mid I_t])\} + \nu_t \tag{5}$$

The term $(\pi_{t+n} - E[\pi_{t+n} \mid I_t])$ is the inflation forecast error and $(y_t^{gap} - E[y_t^{gap} \mid I_t])$ stands for the output gap forecast error. From (4) it is possible to estimate β, γ, ρ and

[33] Clarida et al. (1998a), p. 1038.

i^* without the knowledge of the central banks' forecasts of inflation and the output gap. Therefore, estimating the equation (4) is convenient for us.

Before proceeding to the estimation we have to address two crucial issues. First, and the more demanding one, is deriving π_{t+n}^{tar} from each bank's monetary programmes. The CNB did not publish a continuous inflation target until 2001[34], but only end year targets. The NBS did not commit itself to an explicit target until the beginning of 2005. So, we have to infer what the targets for each month were.

Secondly, it is necessary to choose a proper method to estimate the equation (4). In order to do so, we have to examine its properties. Let us begin with checking the relationship between the error term and the explanatory variables. The exogenous monetary policy shock, ν_t, affects inflation at time (*t*+*n*), π_{t+n}, because it enters into the interest rate settings at time *t* which influence the economy with a lag that is assumed to equal to *n*. An external shock leading to a nonzero ν_t could also have an effect on the real economy and then ν_t might be correlated with y_t^{gap}. Both the inflation forecast error and the output gap forecast error are not correlated with the explanatory variables π_{t+n} and y_t^{gap} since they are independent of the actual values of inflation and output gap because they are random variables. i^* is a constant and π_{t+n}^{tar} is set before time *t* and although monetary policy is subordinated to it, actual inflation at time (*t*+*n*) and its forecast are not correlated with it, they are the results of the CB's operations, external shocks and also domestic and foreign developments outside the CB's control. Nevertheless, the error term, ε_t, is correlated with the explanatory variables due to the effects of the exogenous monetary policy shock on future inflation and contemporaneous output gap.

The relationship between ε_t and I_t ought to be addressed as well. The first component of the error term "is a linear combination of forecast errors and is thus orthogonal to any variable in the information set."[35] Thus, it is not correlated with i_{t-1}. ν_t is uncorrelated with lagged variables in I_t since it is i.i.d. Summing up, ε_t is orthogonal to I_t in case it contains only lagged variables.

[34] The continuous target begins in January 2002.

[35] Clarida et al. (1998b), p. 9.

We should also find out whether the error terms are serially correlated. The linear combination of the forecast errors follows an MA(n-1) process.[36] Substantial revisions of the statistical data, which are inputs into the monetary policy decision-making mechanism, available to the banks occur only on a quarterly basis. As a result, the forecasts errors for previous months in the MA(n-1) process might be correlated and thus also the error terms might not be independent in time. The presence of ν_t – an i.i.d. random variable influencing future inflation – in ε_t could also account for autocorrelation ε_t owing to its effect on the forecast errors. For these reasons, we conclude that the error terms are serially correlated.

4.4 The 'Pure Inflation Targeting' Specification

In addition to the baseline specification of the reaction function – equation (1) – we will also estimate the so-called 'pure inflation targeting' version:

$$i_t^* = i^* + \beta(E[\pi_{t+n} \mid I_t] - \pi_{t+n}^{tar}) . \tag{6}$$

Taking into account the interest rate smoothing and rearranging produces:

$$i_t = (1-\rho)i^* + (1-\rho)\beta\{\pi_{t+n} - \pi_{t+n}^{tar}\} + \rho i_{t-1} + \varepsilon_t \tag{7}$$

where the error term:

$$\varepsilon_t \equiv -(1-\rho)\beta(\pi_{t+n} - E[\pi_{t+n} \mid I_t]) + \nu_t . \tag{8}$$

It would be easy to show that correlation is present between the explanatory variables and the error term as well as among the error terms, and that ε_t is orthogonal to I_t. Therefore, the equation (7) has the same properties as the equation (4).

4.5 The Econometric Method

We cannot use the standard ordinary least squares (OLS) to estimate the coefficients in the equations (4) and (7) due to correlation between the explanatory variables and the error term. Thus, it is necessary to resort to a method capable of dealing with this problem and with (possibly) heteroscedastic and autocorrelated disturbances. Generalised method of moments (GMM henceforth) is used to estimate coefficients in simple linear reaction functions. It rests on the fact that ε_t is orthogonal to lagged variables in I_t. Let z_t be a subset of the information available to the central bank at time t when it sets i_t (i.e. $z_t \subset I_t$) and comprise lagged values of variables that help forecast the regressor(s) in the 'target rate' equations (1) and (6). Then we can write:

[36] Source: Clarida et al. (1998), p. 1040. It means that the linear combination of the forecast errors is a sum of the forecast errors for previous months based on the information set I_t.

$E[\varepsilon_t \mid z_t] = 0$. Expressing ε_t in terms of the response variable and the explanatory variables yields:

$$E[i_t - (1-\rho)\{i^* + \beta[\pi_{t+n} - \pi_{t+n}^{tar}] + \gamma y_t^{gap}\} - \rho i_{t-1} \mid z_t] = 0$$

for the equation (4) and the following for the equation (7):

$$E[i_t - (1-\rho)\{i^* + \beta[\pi_{t+n} - \pi_{t+n}^{tar}]\} - \rho i_{t-1} \mid z_t] = 0 .$$

GMM is the appropriate technique for estimating the equations (4) and (7) given the above orthogonality conditions. For details on the estimation procedure refer to Appendix A.

A set of instruments, z_t, is crucial in the estimation. In the baseline specification of the reaction function, it includes lagged values of the explanatory variable, the output gap, inflation rate and twelve month (12M) interest rate on the inter-bank market because each of them is useful for forecasting the inflation and output gaps.

4.6 The Data and the Data Processing

Monthly data will be used to estimate the reaction functions. Data on the CR were collected from the ARAD database available on the CNB's web page, from the Czech Statistical Office website and from Eurostat website. Data on the SR were obtained from Information Service at the Statistical Office of the SR and from the NBS web page. All the data were valid as of 30 March 2005. Two different measures of the output gap were constructed:

i. The first one is based on the quarterly real GDP figures (in 1995 constant prices). The Hodrick-Prescott filter (HP filter hereafter) with λ=1600 was used to obtain a measure of the potential output and, consequently, output gaps were calculated and transformed from quarterly into monthly frequency by fitting a cubic spline curve[37] to the quarterly values.

ii. The second one is based on the industrial production index (IPI hereafter), where 'the average month of 2000 = 100'. The HP filter with λ=129600[38] was used to unmask the trend and, afterwards, output gaps were calculated.

[37] "A cubic spline is a segmented function consisting of third-degree (cubic) polynomial functions joined together so that the whole curve and its first and second derivatives are continuous." Source: SAS Institute (2002).

[38] This value was suggested by Ravn and Uhlig (2001) and used by Carstensen and Colavecchio (2004).

It was decided to use a short-term inter-bank rate as the response variable. The reasons are twofold – firstly, both central banks have the short-term rates under their control and the repo rate is not their sole determinant. Yields of the outstanding central bank's treasury bills, willingness to accept the whole demand during the repo tenders (auctions) and interventions on the foreign exchange market also influence the short-term rates, although only to a small extent. Secondly, the repo rate is a discrete variable, i.e. it does not change smoothly – the smallest change was 0.25% in both the CR and the SR. On the other hand, the short-term rates could attain any positive real value. The specific rate used in the estimation of the reaction functions will be selected a bit later.

The data were processed in the statistical package SAS® version 9.1. To be specific, coefficients in the reaction functions were estimated using the "model" procedure and the "expand" procedure was used to construct the output gaps.

5 The Estimation and the Results

5.1 The CNB

5.1.1 Issues in the Estimation

Prior to estimating the reaction functions for the CNB, it is inevitable to specify the monthly inflation targets. It was decided to express them in terms of the headline inflation rate (total CPI). Firstly, for the period of net inflation targeting, we interpolate the end year targets – summarised in Table 1 – into corresponding monthly targets.[39]

Table 1: The CNB's inflation targets in terms of net inflation

Year	Target range	Target month	Set in
1998	5.5% - 6.5%	December 1998	December 1997
1999	4% - 5%	December 1999	November 1998
2000	3.5% - 5.5%	December 2000	December 1997
2001	2% - 4%	December 2001	April 2000
2005	1% - 3%	December 2005	April 1999

Source: Coats et al. (2003), p. 11.

We adopt a linear approach to inflation targets: we assume that the pace of disinflation was meant to be stable in each forecast's horizon. The midpoints of the

[39] We follow Navrátil (2004) in constructing the monthly targets.

target intervals were taken to be the targets. The target horizon in the reaction function, i.e. the length of the most effective transmission denoted by *n*, plays a role in switching from one target to another – a newer one: e.g. the midpoint of the target set in November 1998, i.e. 4.5% net inflation in December 1999, was not in line with the trajectory implied by the targets for December 1998 and December 2000, both were set in December 1997. For this reason, the trajectory had to be recalculated using the target for the month *n* periods ahead (i.e. November 1999 if *n* = 12) of the month in which the change was made and the 'newest' target for the periods to come[40] (i.e. the target for December 2000). The trajectory was adjusted to all new targets in this manner. Secondly, 2 percentage points were added to every monthly net-inflation target in order to estimate the targets in terms of headline inflation.[41] Finally, the trajectory obtained in the second step is modified (lowered, to be precise) so as to smoothly join the midpoint of the forecast 'corridor' set in April 2001 in terms of headline inflation – see Table 2 for details on this 'corridor'. This would mean that in the period of net inflation targeting the CNB targeted lower inflation than the one derived from the published targets. In support of this claim, Navrátil (2004) notes that the CNB "took advantage of (the) so-called opportunistic disinflation"[42] and its inflation targets were probably lower than those implied by the official targets.

Table 2: The CNB's inflation targets in terms of headline inflation

	Target range	Target month	Set in
Range starts	3% - 5%	January 2002	April 2001
Range ends	2% - 4%	December 2005	

Source: Coats et al. (2003), p. 13.

Before carrying out the estimation, we need to choose the horizon of the inflation forecast in the reaction function. The CNB is assumed to respond to deviations of the one-year-ahead forecasted inflation from its target, i.e. *n* in the equation (4) is equal to 12. The assumption springs from the following:

[40] In this first case of adjusting the target trajectory, the target for November 1999 was changed (lowered when compared to that based on the targets set in December 1997) because the CNB Board discussed the new target when deciding on the interest rate settings. Therefore it seems unlikely that it stuck to the target implied by the targets for December 1998 and December 2000 (set in December 1997), as it was more than 0.8% higher than the new target for December 1999.
[41] Navrátil (2004) claims that the additional 2% "roughly matches the past reality", p. 628 n.9.
[42] Navrátil (2004), p. 628.

i. In the quarterly projection model (QPM) of the CNB the reaction function specification involves expected inflation, i.e. forecasted by the CNB on the basis of a contemporaneous information set, for the next four quarters.[43]

ii. Inflation targets for the end of 1998, 1999 and 2001 were published only twelve months in advance.

iii. It is rather common to use (n=12) – a number of empirical studies opted for this number. Using the same value will allow us to compare the estimates.

Closely related to the forecast horizon is the selection of the period for which the reaction function will be estimated. We restrict our attention to the era of inflation targeting. Transition from one monetary policy to another was announced at the end of 1997 and was effective from January 1998. Due to the data availability – we need the actual values of one-year-ahead inflation for each month in the sample period, the last month taken into consideration is February 2004.

The average three-month Prague Inter-bank Offering Rate (3M PRIBOR) was chosen to be the response variable. It approximates the two-week repo rate (2W repo) in the CNB's prediction model[44] and is closely tied with it,[45] indeed.

5.1.2 The Estimation Results

Finally, let us discuss the results. They are presented in Table 3. As can be seen, the parameter estimate $\hat{\beta}$ is larger than unity in all specifications of the reaction function. Thus, a one percent decrease in the expected inflation gap induces a more than one percent fall in the nominal 'target rate' (1) and therefore a decrease in the corresponding 'target' real interest rate,[46] which is in line with the Taylor principle. In other words, the CNB sought to lower real interest rates due to a favourable inflation development.

The fact that the estimate of $\hat{\beta}$ for the pure inflation targeting specification exceeds that for the baseline specification suggests a simultaneous occurrence of the inflation and output gaps with the same sign. This situation could be labelled as a 'demand shock'. A significant monetary contraction during and following the 1997 currency crisis triggered a decline in economic activity but also succeeded in reducing inflation. Global economic slowdown after the September 11, 2001 attacks

[43] Source: Coats et al. (2003), p. 70.
[44] Source: Navrátil (2004), p. 628.
[45] Refer to Appendix B for a plot of 3M PRIBOR against 2W repo rate.
[46] In the framework of the Fisher Equation: $r = i - \pi$, which implies $\triangle r = \triangle i - \triangle \pi$.

contributed to a weaker economic performance in the CR by demanding less exports and thus to a reduction in inflationary pressures.[47]

Table 3: Parameter estimates for the CNB

RF specification	$\hat{\rho}$	$\hat{\beta}$	$\hat{\gamma}$	$\hat{i}^*$	J-statistic
baseline - GDP	0.96 (0.0014)	1.43 (0.1562)	0.82 (0.0715)	3.37 (0.1941)	7.00
baseline - IPI	0.95 (0.0034)	1.45 (0.2971)	0.88 (0.0458)	4.99 (0.4130)	6.74
pure inflation targeting	0.96 (0.0012)	1.87 (0.1940)	- -	3.62 (0.2203)	6.77

Note: standard errors of parameter estimates are in parenthesis. All parameter estimates are significant at 1% level and the overidentifying conditions are not violated (at 5% significance level).
The instruments are: 3M PRIBOR (12 lags), inflation rate (12 lags), 12M PRIBOR (6 lags) for 'pure inflation targeting' and these three plus output gap (6 lags) for 'baseline' specifications.

The parameter estimate $\hat{\gamma}$ shows that the CNB responded to the evolution of the real economy independently of its effort to meet the inflation targets. A one percent rise in the output gap results in a 0.82-0.88 increase in the 'target rate'.

The degree of interest rate smoothing estimated by $\hat{\rho}$ might seem to be quite large but it is necessary to bear in mind that it captures monthly smoothing adjustment and the estimated magnitude is not unusual.[48] We cannot interpret the above results in the following way: the CNB responds to a one percent deviation of the expected inflation from its target with a 1.87 percent increase in its key monetary policy instrument (or 'forces' the real rate to go up by 0.87) according to the pure inflation targeting specification. The central bank waits for the confirmation of an unexpected development in the economy and, as new data come in, acts to reach its objectives. This process is captured by the smoothing adjustment.

[47] The CR experienced a strong y-o-y GDP growth during 1994-1996 and a negative one in 1998 and 1999. After a short recovery, the growth slowed in 2002. Monthly headline inflation (y-o-y) fell from 13.4 in February 1998 to 1.2 to September 1999. In the second half of 2002 it began to drop (after a period of mild increases) and reached negative values in the first half of 2003. Interest rates were highest in the second half of 1997 and the first half of 1998. Total exports growth in 2002 (y-o-y) was significantly lower than in the previous as well as in the successive years. See Appendix B for details.

[48] See the parameter estimates in e.g. Clarida et al. (1998) and Favero (2001) for the Federal Reserve and Hayo and Hofmann (2003) for the ECB and the Bundesbank. Note that the inflation forecast horizon is twelve months – the same as we opted for.

Now, let us turn our attention to the role played by the inflation and output gap coefficients, β and γ. We will focus on a simple example: in case of a persistent one percent positive inflation gap the interest rate set by the CNB (i_t) would gradually increase by more than one percent in the horizon slightly longer than one year in the pure inflation targeting setting. It can be shown that the longer is the horizon the closer is the actual rate set by the bank to the 'target rate'. If β were less than one, the real rate would never increase and the target inflation would not be reached. Therefore, effective control of inflation requires β to be larger than one.

The estimates of the long-term equilibrium nominal interest rate ranging from 3.37 to 4.99 are plausible ones. In the beginning of the studied period the interest rates were high and declined subsequently to the levels of 2 percent. The estimates of i^* are closer to the recent values of interest rates, which do not spark inflationary pressures in the economy.

5.2 The NBS

5.2.1 Issues in the Estimation

First of all, let us reiterate that the NBS did not clearly commit itself to reaching certain values of inflation, i.e. inflation targets, until the Monetary Programme of the NBS until the year 2008 was issued at the end of 2004. In the Monetary Programmes for the years 2000 – 2004 and their updates (revisions) it used phrases like: "core inflation could reach a value in the range of … at the end of December" and "the monetary programme target for … is to keep core inflation within the range of" [49] in one single document. Statements such as "core inflation is expected to fluctuate within" and "core inflation should be in the interval"[50] do not convey a meaning that the NBS would strive for reaching certain levels of core inflation. The 'forecasts' were usually changed in the revised programmes – see Table 4, which further reduces their suitability for being dubbed 'targets'. So the NBS did not restrict itself by such a strong rule as the CNB did and, therefore, the NBS had more room for discretion.

We excluded the year 1999 from the sample period for which the reaction function will be estimated when discussing how the NBS conducted monetary policy.

[49] NBS (2001a), p. 18 and p. 30.

[50] 1st quotation: NBS (2002a), p. 18; 2nd quote: NBS (2002b), p. 42.

So we are left with the period 2000 – now[51]. Each year in December the NBS published a monetary programme for the subsequent year with forecasts of end-year inflation. An interested reader might remember that a medium term outlook was not included in the programmes until December 2001, i.e. it was included in the Monetary Programme for 2002 for the first time. Due to this fact, in November[52] 2000 and 2001 there was an inflation forecast (or as the NBS puts it “an implicit target”) only for December. Thus, we cannot choose the horizon in the reaction function *n* to be 12, as in the case of the CNB, because it does not correspond to the actual behaviour of the NBS. It is not appropriate to assume that the NBS had an internal forecast or target for the next twelve months. As a result, we resort to estimating the reaction function for the period January 2000 – December 2004 with (*n*=0). The period ends in December 2004 due to the switch to another monetary policy framework – explicit inflation targeting – on January 1, 2005.

Table 4: Forecasts of core inflation published by the NBS

Forecast month	Forecast range	Published in
December 2000	4.5% - 5.8%	December 1999
December 2000	4.7% - 5.8%	May 2000
December 2001	3.2% - 5.3%	December 2000
December 2001	3.6% - 5.3%	May 2001
December 2002	3.2% - 4.7%	December 2001
December 2002	3.2% - 4.7%	May 2002
December 2003	2.7% - 5.0%	December 2002
December 2003	2.1% - 3.6%	May 2003
December 2004	1.2% - 3.5%	December 2003
December 2004	1.9% - 3.4%	May 2004

Sources: NBS (2000a), NBS (2000b), NBS (2001a), NBS (2001b), NBS (2002a), NBS (2002b), NBS (2003a), NBS (2003b), NBS (2004a), NBS (2004b).

By setting (*n*=0) we estimate the response of the NBS to predictions of contemporaneous explanatory variables. It does not mean, however, that the NBS completely neglected possible future development, since inflation in a certain period contains some information about its future development. Estimating a forward-looking version of the reaction function, e.g. with (*n*=6) or (*n*=12), for a period starting in January 2002 would not yield plausible results because the sample period

[51] It is interesting to note that the inter-bank rates were much more volatile in 1998 and 1999 than in the period 2000 – 2004, i.e. after the NBS switched to ‘qualitative monetary-policy control.’ See Appendix C for details.
[52] In December new monetary programmes were released and included forecasts for the coming year.

would ‘too short’. GMM is based on asymptotic theory and “may perform poorly in small samples.”[53]

With (n=0) the error terms are not serially correlated, there is no MA process in them and the exogenous monetary shock affects only the contemporaneous inflation forecast error since the forecast horizon is zero. But, on the other hand, the error term is correlated with the explanatory variables and orthogonal to the information set comprised of lagged variables.

The NBS is assumed to respond to the development of core inflation on account of the claim that core inflation would eventually become its target. Monthly inflation pseudo-targets were interpolated from the midpoints of the end year ‘implicit target’ intervals summarised in Table 4. When doing so, we used forecasted values of inflation for the end of next year and forecasts for the end of contemporaneous year from the monetary programmes published in December. From the updated ones we used forecasts of inflation for the end of contemporaneous year and actual figures for the end of the previous year. Since the updates were usually released in May, ‘new’ forecasts were considered to be valid from June.

The response variable will be the average three-month Bratislava Inter-bank Offering Rate (3M BRIBOR). Firstly, the repo rate was not the only rate set by the NBS. Until the beginning of 2002 the ‘discount rate’ was different from the repo rate and its use was abolished with the introduction of the ‘basic interest rate of the NBS’ in 2003. Secondly, the repo rate itself did not exist until May 29, 2000.[54] On the other hand, short-term inter-bank rates are under control of the NBS regardless of the rate it uses. Thirdly, this choice will ensure compatibility with the reaction function of the CNB.

5.2.2 The Estimation Results

A quick look at the parameter estimates presented in Table 5 might suggest that the NBS behaved strangely in the sample period. Two negative values of $\hat{\beta}$ and one positive but less than unity violate the Taylor principle. A negative value of $\hat{\gamma}$ for the baseline (GDP) specification is also not in line with what would be expected from a shrewd central bank. All the estimates of β and γ are not significant, though, so the

[53] Hayo and Hofmann (2003), p. 3.

[54] See http://www.nbs.sk/SDDS/UROK/DISKONTA.HTM for a review of the three rates used by the NBS. Refer to Appendix C for a plot of 3M BRIBOR against 2W repo rate in the period 2002 – 2004 and for other selected Slovak macroecnomic indicators.

NBS might have disregarded the deviation of the contemporaneous core inflation forecast from its pseudo-target as well as the contemporaneous output gap forecast. The NBS did not operate in the explicit inflation targeting framework in the sample period nor did it commit itself to reaching certain well-specified[55] goals, unlike the CNB. Therefore, specifying the explanatory variables amounts to a bit of guesswork. Putting (n=0) was a reasonable choice considering how the NBS presented its policy to the public, although it was forward looking. But the results show that this choice was wrong and/or the NBS did not stick to a well-defined contingency plan, i.e. its behaviour could be characterised as discretion. Summing up, the absence of a clear monetary policy strategy in the sample period is the underlying problem and, because of it, we are not able to model the systematic part of the NBS monetary policy.

Table 5: Parameter estimates for the NBS

RF specification	$\hat{\rho}$	$\hat{\beta}$	$\hat{\gamma}$	$\hat{i}^*$	J-statistic
baseline - GDP	0.89 (0.0227)	-0.62 (0.4654)	-0.11 (0.0726)	5.96 (0.3879)	24.70
baseline - IPI	0.91 (0.0271)	0.21 (0.5669)	0.56 (0.3579)	5.99 (0.4759)	23.73
pure inflation targeting	0.92 (0.0287)	-0.35 (0.6797)	- -	5.67 (0.7565)	19.20

Note: standard errors of parameter estimates are in parenthesis. All estimates of the smoothing parameter and the long-term equilibrium nominal interest rate are significant at 1% level and the overidentifying conditions are not violated (at 5% significance level). The estimates of beta and gamma are not significant at 10% levels in all specifications.
The instruments are: 3M BRIBOR (12 lags) and core inflation rate (12 lags) for 'pure inflation targeting' and these two plus output gap (6 lags) for 'baseline' specifications.

The degree of interest rate smoothing is similar to that of the CNB. The NBS was also not willing to surprise economic agents by sudden abrupt changes in the interest rates. The estimates of the long-term equilibrium nominal interest rate seem to be plausible, they are approximately in the middle of the actual historical monthly values.

[55] An example of a commitment to a well-specified goal is: 'the NBS will act so as to achieve a two per cent core inflation in the horizon of two years.'

6 Conclusion

We endeavoured to estimate simple linear reaction functions capturing the systematic parts of monetary policies of both the CNB and the NBS. We chose the positive approach leading to a description of the past actions of a particular central bank. Baseline specification of the reaction function including the deviation of conditional forecast of future inflation and the contemporaneous output gap as well as pure inflation targeting specification comprising only the deviation were estimated.

The results indicate that the CNB systematically responded to inflation pressures and performance of the Czech economy. Furthermore, its behaviour could be characterised as ‘best international practice’ because the parameter estimates are close to those obtained e.g. by Clarida et al (1998a) for the Bundesbank and the Federal Reserve and by Hayo and Hofmann (2003) for the Bundesbank and the European Central Bank. The CNB adhered to its objectives and clearly communicated its inflation targeting strategy and also the targets. This helped to stabilize the economy after the 1997 turmoil and since 1999 the CR enjoys low levels of inflation and a solid economic growth. Therefore, we perceive the CNB to be a credible and transparent institution and consider its actions as predictable[56].

The NBS, on the other hand, did not commit itself to specific goals. As a result, the parameter estimates for the inflation and output gaps are not significant and, for this reason, we cannot draw any conclusions from them. Without the knowledge of what precisely the NBS wanted to achieve it is not possible to separate the systematic part of its monetary policy. It is thought that in the sample period 2000 – 2004 the NBS lagged behind the CNB in terms of credibility, predictability and transparency. But that is likely to change in the following years. At the end of 2004 the NBS published the Monetary Programme of the NBS until the Year 2008 announcing the adoption of explicit inflation targeting from the beginning of 2005. Gavura and Reľovský (2005) describe the recently developed quarterly prediction model (QPM) of the NBS, which is similar to the QPM used by the CNB[57] and includes a reaction function with four-quarters-ahead forecast of inflation.

[56] A central bank is said to be transparent if it clearly states what its anticipation of future development is and reveals its contingency plan. The notion ‘predictable’ means that economic agents expect the actual monetary policy decisions. Credibility stands for economic agents’ belief that future inflation will be in line with its target, in other words, that the contingency plan is compatible with announced targets of monetary policy. Source of these definitions: Navrátil (2004).

[57] Described in Coats et al (2003).

Thus, monetary policy conducts of the CNB and the NBS are expected to be similar in the period starting from January 2005 and terminating when either the CR or the SR adopts the euro. What is more, we will be able to study how the banks will cope with the external constraint in the form of an exchange rate fluctuation band in the period of membership in the exchange rate mechanism (ERM2).

References

Batini, N., and A. Haldane. "Forward-Looking Rules for Monetary Policy." Working Paper No. 6543, NBER, 1998.

Beblavý, M. "Exchange Rate and Exchange Rate Regime in Slovakia: Recent Developments." Working Paper No. 5, ICEG EC, 2002. Available at http://icegec.hu/eng/publications/publ_main.htm.

Carstensen, K., and R. Colavecchio. "Did the Revision of the ECB Monetary Policy Strategy Affect the Reaction Function?" Working Paper No. 1221, Kiel Institute for World Economics, University of Kiel, 2004.

Christiano, L., M. Eichenbaum, and C. Evans. "Monetary Policy Shocks: What Have We Learned and to What End?" Working Paper No. 6400, NBER, 1998.

Clarida, R., J. Gali, and M. Gertler. "Monetary Policy Rules in Practise: Some International Evidence." *European Economic Review*, vol. 42, 1998a, pp. 1033-1067.

Clarida, R., J. Gali, and M. Gertler. "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory." Working Paper No. 6442, NBER, 1998b.

Coats, W., D. Laxton, and D. Rose (eds.). *The Czech National Bank's Forecasting and Policy Analysis System*. Prague: Czech National Bank, 2003.

Czech Statistical Office. *Statistical Yearbook of the Czech Republic 1998*. Prague: Czech Statistical Office, 1998.

Favero, C. *Applied Macroeconometrics*. Oxford: Oxford University Press, 2001.

Favero, C., and R. Rovelli. "Modelling and Identifying Central Bank's Preferences." Discussion Paper No. 2178, Centre for Economic Policy Research, 1999.

Gavura, M., and B. Reľovský. "A Simple Model of the Transmission Mechanism of Slovakia's Economy." *Biatec*, vol. 13, no. 4, 2005, pp. 12-20.

Gerdesmeier, D., and B. Roffia. "Empirical Estimates of Reaction Functions for the Euro Area." Working Paper No. 206, European Central Bank, 2003

Greene, W. *Econometric analysis*. 5th ed., Upper Saddle River, N.J.: Prentice Hall, 2003.

Hansen, L. "Large Sample Properties of Generalised Method of Moments Estimators." *Econometrica*, vol. 50, 1982, pp. 1029-1054.

Hayo, B., and B. Hofmann. "Monetary Policy Reaction Functions: ECB versus Bundesbank." Working Paper No. B24-2003, Center for European Integration Studies, Rheinische Friedrich-Wilhelms-Universität Bonn, 2003.

Judd, J., and G. Rudebusch. "Taylor's Rule and the Fed: 1970-1997." *Economic Review (Federal Reserve Bank of San Francisco)*, 1998, no. 3, pp. 3-16.

Kotlán, V., and D. Navrátil. "Inflation Targeting as a Stabilisation Tool: Its Design and Performance in the Czech Republic." *Czech Journal of Economics and Finance*, vol. 53, no. 5-6, 2003, pp. 220-241.

Mehra, Y. "A Forward-Looking Monetary Policy Reaction Function." *Economic Quarterly (Federal Reserve Bank of Richmond)*, vol. 85, no. 2, 1999, pp. 33-53.

Navrátil, D. “Systematická složka měnové politiky ČNB v režimu cílování inflace.“ *Politická ekonomie*, vol. 52, 2004, pp. 623-636. [In Czech]

NBS. “The Monetary Programme of the National Bank of Slovakia for the Year 1999.” *Biatec*, vol. 7, no. 1, 1999a, pp. 2-3.

NBS. “Updated Monetary Programme of the NBS for 1999.” *Biatec*, vol. 7, no. 7, 1999b, pp. 2-4.

NBS. “The Monetary Programme of the NBS for the Year 2000.” *Biatec*, vol. 8, no. 1, 2000a, pp. 2-3.

NBS. “Revised Monetary Programme of the NBS for 2000.” *Biatec*, vol. 8, no. 6, 2000b, pp. 2-3.

NBS. *Monetary Programme for the Year 2001*. Bratislava: NBS, 2001a (available at http://www.nbs.sk/MPOL/MPROG_A.HTM).

NBS. “The Revised Monetary Programme of the NBS for 2001.” *Biatec*, vol. 9, no. 6, 2001b, pp. 28-35.

NBS. *Monetary Programme of the NBS for 2002 and Forecast for 2003 – 2005*. Bratislava: NBS, 2002a (available at http://www.nbs.sk/MPOL/MPROG_A.HTM).

NBS. *Revised Monetary Programme of the NBS for 2002*. Bratislava: NBS, 2002b (available at http://www.nbs.sk/MPOL/MPROG_A.HTM).

NBS. *NBS Monetary Program for 2003 and Outlook for 2004 – 2006*. Bratislava: NBS, 2003a (available at http://www.nbs.sk/MPOL/MPROG_A.HTM).

NBS. *Updated NBS Monetary Program for 2003*. Bratislava: NBS, 2003b (available at http://www.nbs.sk/MPOL/MPROG_A.HTM).

NBS. *The National Bank of Slovakia 1993 – 2002*. Bratislava: NBS, 2003c.

NBS. *Monetary Programme of the NBS for 2004 and Outlook for 2005 – 2007*. Bratislava: NBS, 2004a (available at http://www.nbs.sk/MPOL/MPROG_A.HTM).

NBS. *Updated Monetary Programme of the NBS for 2004*. Bratislava: NBS, 2004b (available at http://www.nbs.sk/MPOL/MPROG_A.HTM).

NBS. *Monetary Programme of the NBS until the Year 2008*. Bratislava: NBS, 2004c (available at http://www.nbs.sk/MPOL/MPROG_A.HTM).

Newey, W., and K. West. “A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix.” *Econometrica*, vol. 55, 1987, pp. 703-708.

Orphanides, A., “Monetary Policy Rules Based on Real-Time Data.” Working Paper No. 3, Finance and Economics Discussion Series, The Federal Reserve Board, 1998.

Ravn, M., and H. Uhlig. “On Adjusting the HP-Filter for the Frequency of Observations.” Working Paper No. 479, Center for Economic Studies & Ifo Institute for Economic Research (CESifo), 2001.

SAS Institute Inc. “SAS OnlineDoc® 9.” http://v9doc.sas.com/sasdoc/, 2002.

Svensson, L. “What Is Wrong with Taylor Rules? Using Judgement in Monetary Policy through Targeting Rules.” Working Paper No. 9421, NBER, 2002.

Taylor, J. “An Historical Analysis of Monetary Policy Rules.” Working Paper No. 6768, NBER, 1998.

Taylor, J. “Discretion versus Policy Rules in Practice.” *Carnegie-Rochester Conference on Public Policy*, vol. 39, 1993, pp. 195-214.

Wooldridge, J. “Applications of Generalised Method of Moments Estimation.” *The Journal of Economic Perspectives*, vol. 15, no. 4, pp. 87-100.

Online Data Sources

The ARAD time series database: http://wdb.cnb.cz/cnbeng/docs/ARADY/HTML/index_en.htm

The Czech Statistical Office: http://www.czso.cz/eng/redakce.nsf/i/home

Eurostat: http://europa.eu.int/comm/eurostat

NBS web page: http://www.nbs.sk/

Appendix A – GMM method

We will focus on the estimation[58] of the baseline specification of the reaction function, application of GMM to the 'pure inflation targeting' specification of the reaction function is analogous. The equation (4) can be rewritten in the following simple form:

$$i_t = \mathbf{x}_t'\boldsymbol{\alpha} + \varepsilon_t \qquad \text{(A.1)}$$

where $\mathbf{x}_t'$ is a row vector ($\mathbf{x}_t' = [1 \quad \{\pi_{t+n} - \pi_{t+n}^{tar}\} \quad y_t^{gap} \quad i_{t-1}]$), ε_t is the error term defined in (5) and $\boldsymbol{\alpha}$ is a column vector. Merging all T ($t = 1, \ldots, T$) equations into one, we get:

$$\mathbf{Y} = \mathbf{X}\boldsymbol{\alpha} + \boldsymbol{\varepsilon} \qquad \text{(A.2)}$$

where:

$$\boldsymbol{\alpha} = \begin{bmatrix} (1-\rho)i^* \\ (1-\rho)\beta \\ (1-\rho)\gamma \\ \rho \end{bmatrix}, \; \mathbf{Y} = \begin{bmatrix} i_1 \\ \vdots \\ i_T \end{bmatrix}, \; \mathbf{X} = \begin{bmatrix} 1 & \{\pi_{1+n} - \pi_{1+n}^T\} & y_1^{gap} & i_0 \\ \vdots & \vdots & \vdots & \vdots \\ 1 & \{\pi_{T+n} - \pi_{T+n}^T\} & y_T^{gap} & i_{T-1} \end{bmatrix}, \; \boldsymbol{\varepsilon} = \begin{bmatrix} \varepsilon_1 \\ \vdots \\ \varepsilon_T \end{bmatrix}.$$

The fact $E[\varepsilon_t \mid \mathbf{z}_t] = 0$ implies that $E[\mathbf{z}_t\varepsilon_t] = E[\mathbf{z}_t(i_t - \mathbf{x}_t'\boldsymbol{\alpha})] = \mathbf{0}$. Consequently, the population moment equation is:

$$E\left[\frac{1}{T}\sum_{t=1}^{T}\mathbf{z}_t(i_t - \mathbf{x}_t'\boldsymbol{\alpha})\right] = E[\overline{\mathbf{m}}(\boldsymbol{\alpha})] = E\left[\frac{1}{T}\mathbf{Z}'(\mathbf{Y} - \mathbf{X}\boldsymbol{\alpha})\right] = \mathbf{0} \qquad \text{(A.3)}$$

where $\mathbf{Z}$ is a $(T \times l)$ matrix in which $\mathbf{z}_t'$ is its t[th] row. Then, the empirical moment equation is:

$$\left[\frac{1}{T}\sum_{t=1}^{T}\mathbf{z}_t(i_t - \mathbf{x}_t'\hat{\boldsymbol{\alpha}})\right] = \overline{\mathbf{m}}(\hat{\boldsymbol{\alpha}}) = \frac{1}{T}\mathbf{Z}'(\mathbf{Y} - \mathbf{X}\hat{\boldsymbol{\alpha}}).$$

The number of instruments (l) will exceed the number of explanatory variables (i.e. l>4) and the system (of empirical moment equations) will be overidentified. Then, $\overline{\mathbf{m}}(\hat{\boldsymbol{\alpha}}) = \mathbf{0}$ will have no unique solution. In this case, $\hat{\boldsymbol{\alpha}}$ is chosen to minimise the following quadratic form:

$$q = \overline{\mathbf{m}}(\hat{\boldsymbol{\alpha}})'\mathbf{W}\overline{\mathbf{m}}(\hat{\boldsymbol{\alpha}}) \qquad \text{(A.4)}$$

where $\mathbf{W}$ is a symmetric positive definite weighting matrix (an $(l \times l)$ matrix). The first order condition for the GMM estimator ($\hat{\boldsymbol{\alpha}}$) is:

---

[58] In deriving the GMM estimator we follow Greene (2003), Ch. 18.

$$\frac{\partial q}{\partial \hat{\boldsymbol{\alpha}}} = \frac{\partial \overline{\mathbf{m}}(\hat{\boldsymbol{\alpha}})'}{\partial \hat{\boldsymbol{\alpha}}} \mathbf{W}\overline{\mathbf{m}}(\hat{\boldsymbol{\alpha}}) + \{\overline{\mathbf{m}}(\hat{\boldsymbol{\alpha}})'\mathbf{W}\frac{\partial \overline{\mathbf{m}}(\hat{\boldsymbol{\alpha}})}{\partial \hat{\boldsymbol{\alpha}}'}\}' = \mathbf{0}$$

and can be simplified in the following way:

$$\frac{\partial q}{\partial \hat{\boldsymbol{\alpha}}} = 2\frac{\partial \overline{\mathbf{m}}(\hat{\boldsymbol{\alpha}})'}{\partial \hat{\boldsymbol{\alpha}}} \mathbf{W}\overline{\mathbf{m}}(\hat{\boldsymbol{\alpha}}) = 2\overline{\mathbf{G}}(\hat{\boldsymbol{\alpha}})'\mathbf{W}\overline{\mathbf{m}}(\hat{\boldsymbol{\alpha}}) .$$

Realising that

$$\overline{\mathbf{G}}(\hat{\boldsymbol{\alpha}})' = \frac{\partial \overline{\mathbf{m}}(\hat{\boldsymbol{\alpha}})'}{\partial \hat{\boldsymbol{\alpha}}} = \frac{\partial\{\frac{1}{T}\mathbf{Z}'(\mathbf{Y}-\mathbf{X}\hat{\boldsymbol{\alpha}})\}'}{\partial \hat{\boldsymbol{\alpha}}} = \frac{\frac{1}{T}\partial(\hat{\boldsymbol{\alpha}}'\mathbf{X}'\mathbf{Z})}{\partial \hat{\boldsymbol{\alpha}}} = \tfrac{1}{T}\mathbf{X}'\mathbf{Z}$$

we obtain:

$$\frac{\partial q}{\partial \hat{\boldsymbol{\alpha}}} = 2(\tfrac{1}{T}\mathbf{X}'\mathbf{Z})\mathbf{W}(\tfrac{1}{T}\mathbf{Z}'\mathbf{Y} - \tfrac{1}{T}\mathbf{Z}'\mathbf{X}\hat{\boldsymbol{\alpha}}) = \mathbf{0} \qquad \text{(A.5)}$$

Since 2 and $1/T$ are constants, they are irrelevant to the solution and we can drop them out of (A.5) and write:

$$\mathbf{X}'\mathbf{Z}\mathbf{W}(\mathbf{Z}'\mathbf{Y} - \mathbf{Z}'\mathbf{X}\hat{\boldsymbol{\alpha}}) = \mathbf{0}$$

which implies

$$\hat{\boldsymbol{\alpha}} = (\mathbf{X}'\mathbf{Z}\mathbf{W}\mathbf{Z}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{Z}\mathbf{W}\mathbf{Z}'\mathbf{Y} \qquad \text{(A.6)}$$

The choice of the weighting matrix is crucial in GMM estimation. “The weighting matrix is obtained by inverting a consistent estimator of the variance-covariance matrix of the moment conditions.”[59] So we have:

$$\mathbf{W} = \{\text{Asy.Var}[\sqrt{T}\overline{\mathbf{m}}(\boldsymbol{\alpha})]\}^{-1} = \boldsymbol{\Phi}^{-1} \qquad \text{(A.7)}$$

Recalling the definition of $\overline{\mathbf{m}}(\boldsymbol{\alpha})$ we arrive at:

$$\boldsymbol{\Phi} = \tfrac{1}{T}\text{Asy.Var}[\mathbf{Z}'(\mathbf{Y}-\mathbf{X}\boldsymbol{\alpha})] = \tfrac{1}{T}\text{Asy.Var}[\mathbf{Z}'\boldsymbol{\varepsilon}]$$

and hence

$$\boldsymbol{\Phi} = \tfrac{1}{T}\mathbf{Z}'E(\boldsymbol{\varepsilon}\boldsymbol{\varepsilon}')\mathbf{Z} = \tfrac{1}{T}\mathbf{Z}'\boldsymbol{\Omega}\mathbf{Z} \qquad \text{(A.8)}$$

where $\boldsymbol{\Omega}$ is the true variance-covariance matrix of error terms that is unknown and, therefore, we have to estimate it. But how? Since $\boldsymbol{\varepsilon} = \mathbf{Y} - \mathbf{X}\boldsymbol{\alpha}$ it might seem that an estimate of $\boldsymbol{\alpha}$ is needed to be available in the process of its (own) estimation. This problem is solved by using

$$\hat{\boldsymbol{\varepsilon}}_{\mathbf{I}} = \mathbf{Y} - \mathbf{X}\hat{\boldsymbol{\alpha}}_{\mathbf{I}}$$

to estimate **$\boldsymbol{\Omega}$,** i.e. to produce $\hat{\boldsymbol{\Omega}}$, and, consequently, $\hat{\boldsymbol{\Phi}}$ where $\hat{\boldsymbol{\alpha}}_{\mathbf{I}}$ is an estimator of $\boldsymbol{\alpha}$ obtained by minimising

$$q = \overline{\mathbf{m}}(\hat{\boldsymbol{\alpha}})'\mathbf{W}_{\mathbf{I}}\overline{\mathbf{m}}(\hat{\boldsymbol{\alpha}}),$$

[59] Wooldridge (2001), p. 90.

in which the true variance-covariance matrix of the error terms is estimated by $\mathbf{I}$[60]. Due to autocorrelation in ε_t it is necessary to use a heteroscedasticity and autocorrelation consistent (HAC) estimator of **Ω,** e.g. Newey-West autocorrelation consistent covariance estimator[61].

Summing up, GMM estimation proceeds as follows. In the first step, the weighting matrix is:

$$\mathbf{W_I} = \{\tfrac{1}{K}\mathbf{Z}'\mathbf{I}\mathbf{Z}\}^{-1} = \{\tfrac{1}{K}\mathbf{Z}'\mathbf{Z}\}^{-1} = \hat{\mathbf{\Phi}}_{\mathbf{I}}^{-1}$$

and thus the GMM estimator (A.6) collapses into this 2SLS estimator:[62]

$$\hat{\boldsymbol{\alpha}}_{\mathbf{I}} = (\mathbf{X}'\mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\mathbf{Y}\,.$$

Then we use $\hat{\boldsymbol{\varepsilon}}_{\mathbf{I}}$ to produce $\hat{\mathbf{\Omega}}$ using a HAC estimator and then we construct the estimated optimal weighting matrix

$$\hat{\mathbf{W}} = \hat{\mathbf{\Phi}}^{-1} = \{\tfrac{1}{K}\mathbf{Z}'\hat{\mathbf{\Omega}}\mathbf{Z}\}^{-1} \qquad \text{(A.9)}$$

and, in the second step, insert it into the equation (A.6) to obtain the GMM estimator:

$$\hat{\boldsymbol{\alpha}} = (\mathbf{X}'\mathbf{Z}\hat{\mathbf{W}}\mathbf{Z}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{Z}\hat{\mathbf{W}}\mathbf{Z}'\mathbf{Y} \qquad \text{(A.10)}$$

Note that the GMM estimation procedure outlined here leads to the estimates of ρ, $(1-\rho)\beta$, $(1-\rho)\gamma$ and $(1-\rho)i^*$. It would be rather easy to separate the parameter estimates $\hat{\rho}$, $\hat{\beta}$, $\hat{\gamma}$ and $\hat{i}^*$, but it would be more intricate to calculate their standard errors. One possible way to obtain the errors is to use the delta method.[63] We do not have to proceed in this way, though, because the statistical package we used to estimate the parameters is able to produce their estimates and standard errors directly.

The orthogonality conditions represented by the equation (A.3) form the very basis of 'our' econometric estimation of the reaction functions. We presented theoretical reasons for their validity. It is also possible to check statistically whether they are (not) violated using the so-called J-statistic:

$$J = Tq = T\bar{\mathbf{m}}(\hat{\boldsymbol{\alpha}})'\hat{\mathbf{W}}\bar{\mathbf{m}}(\hat{\boldsymbol{\alpha}})$$

which can be simplified to get the following expression:

$$J = \hat{\boldsymbol{\varepsilon}}'\mathbf{Z}\{\mathbf{Z}'\hat{\mathbf{\Omega}}\mathbf{Z}\}^{-1}\mathbf{Z}'\hat{\boldsymbol{\varepsilon}}\,.$$

---

[60] Assuming that the population moment equation holds, $\hat{\boldsymbol{\alpha}}_{\mathbf{I}}$ is a consistent (but inefficient) estimator of $\boldsymbol{\alpha}$. Source: Greene (2003), p. 546.

[61] Defined in Greene (2003) on page 205.

[62] Thus, we regress the actual output gap and the (future) inflation gap on the set of instruments, $\mathbf{z}_t$, available at time *t*. So, in fact, we produce estimates (forecasts) of these gaps based on a subset of the information set I_t.

[63] Refer Greene (2003), pp. 913 and 914 for a detailed description of this method.

J converges in distribution to χ^2 with ($l-4$) degrees of freedom.[64]

It should be borne in mind that GMM estimators belong to the so-called 'large sample' ones and they as well as their properties 'rely on' central limit theorems and on the ergodic theorem. If these laws are met, $\hat{\boldsymbol{\alpha}}$ converges in probability to its true parameter vector ($\boldsymbol{\alpha}$) and it has a normal distribution with mean $\boldsymbol{\alpha}$ and variance-covariance matrix:[65]

$$\mathbf{V} = \tfrac{1}{K}[\overline{\mathbf{G}}(\boldsymbol{\alpha})'\mathbf{W}\overline{\mathbf{G}}(\boldsymbol{\alpha})]^{-1} = \tfrac{1}{K}[\overline{\mathbf{G}}(\boldsymbol{\alpha})'\boldsymbol{\Phi}^{-1}\overline{\mathbf{G}}(\boldsymbol{\alpha})]^{-1}$$

where

$$\overline{\mathbf{G}}(\boldsymbol{\alpha}) = \frac{\partial\overline{\mathbf{m}}(\hat{\boldsymbol{\alpha}})}{\partial\hat{\boldsymbol{\alpha}}'} = -\tfrac{1}{K}\mathbf{Z}'\mathbf{X}.$$

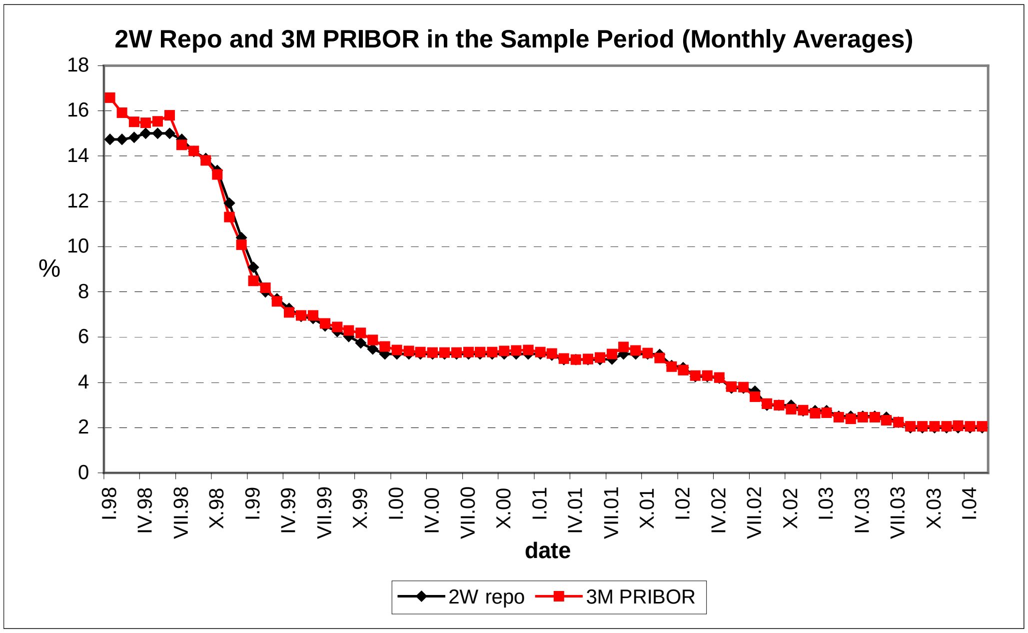
Then the variance-covariance matrix **V** can be estimated by:

$$\hat{\mathbf{V}} = [\mathbf{X}'\mathbf{Z}\hat{\boldsymbol{\Phi}}^{-1}\mathbf{Z}'\mathbf{X}]^{-1}.$$

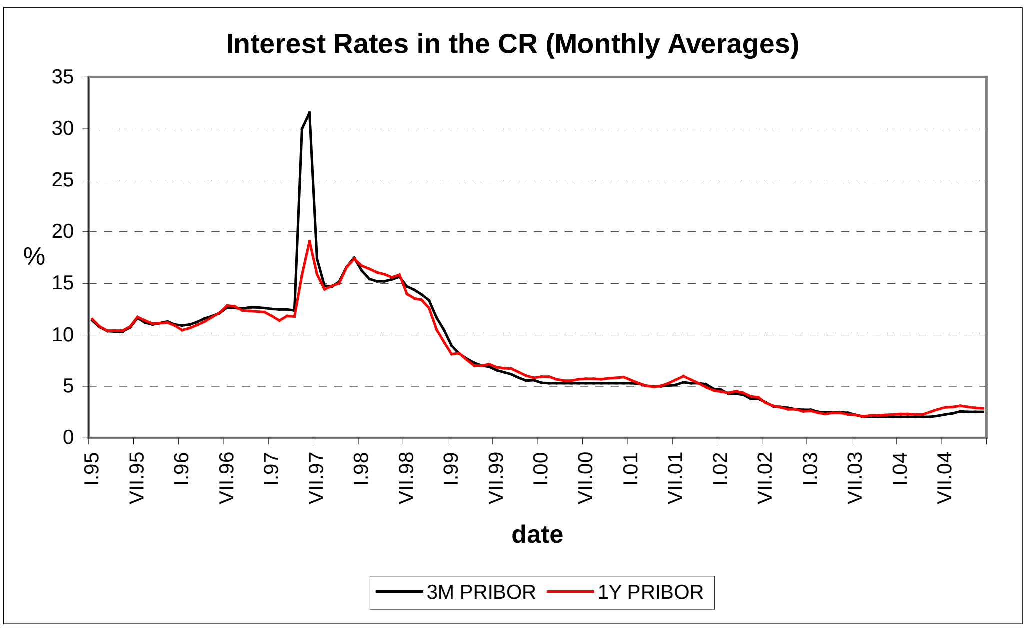
[64] In general: $J \xrightarrow{d} \chi^2[l-p]$ where *p* is the number of estimated parameters and *l* is the number of instruments.

[65] A proof is sketched in Greene (2003), p. 543 – 544.

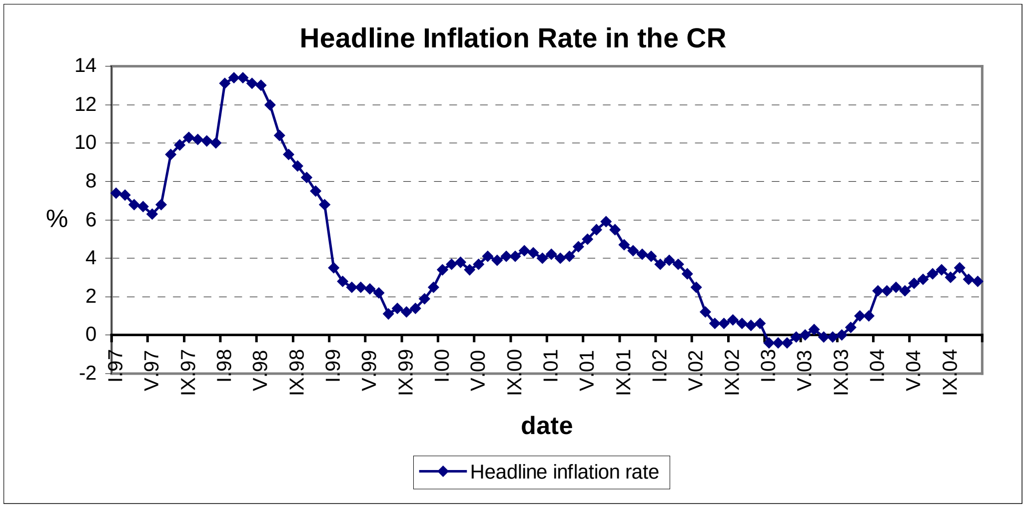
Appendix B – Selected Macroeconomic Indicators for the CR



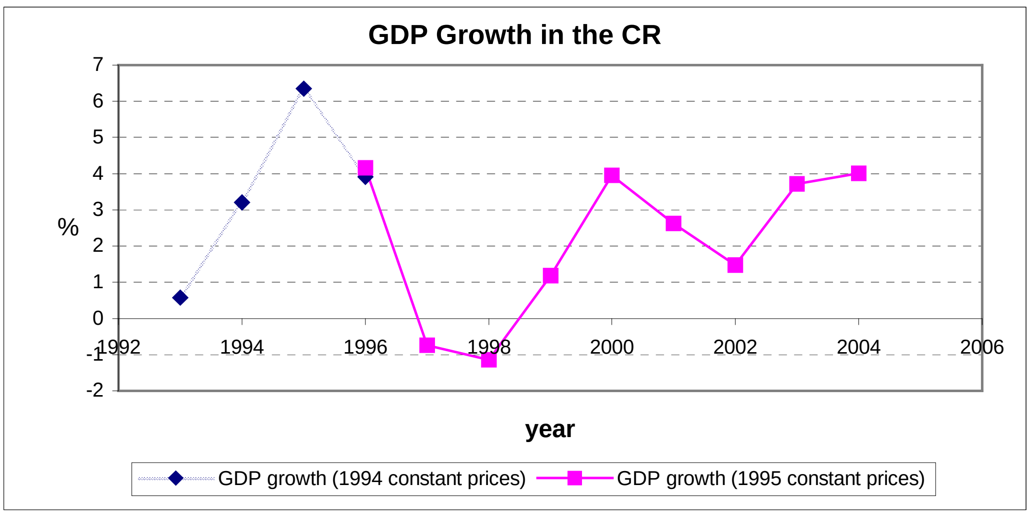
Source: the ARAD database.



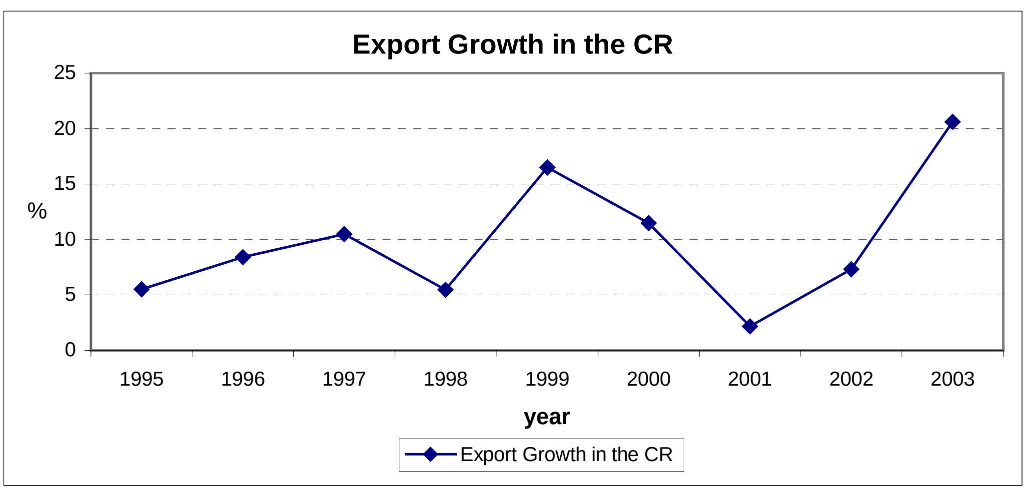
Source: the ARAD database.



Source: the Czech Statistical Office website.

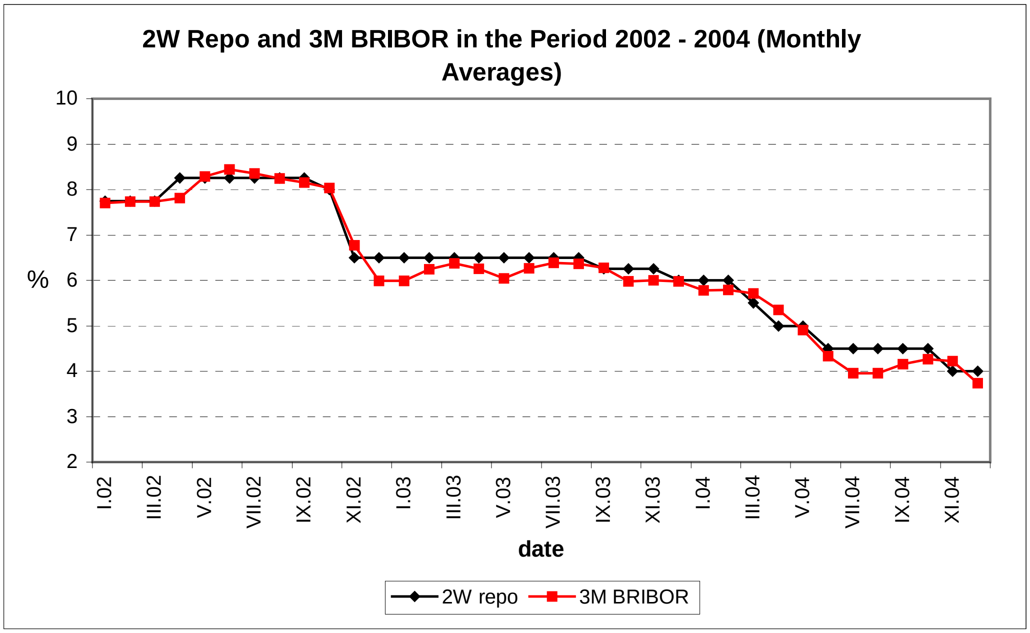


Source: GDP growth (1995 constant prices): the ARAD database; GDP growth (1994 constant prices): Czech Statistical Office (1998) – absolute values, growth figures calculated by the author.

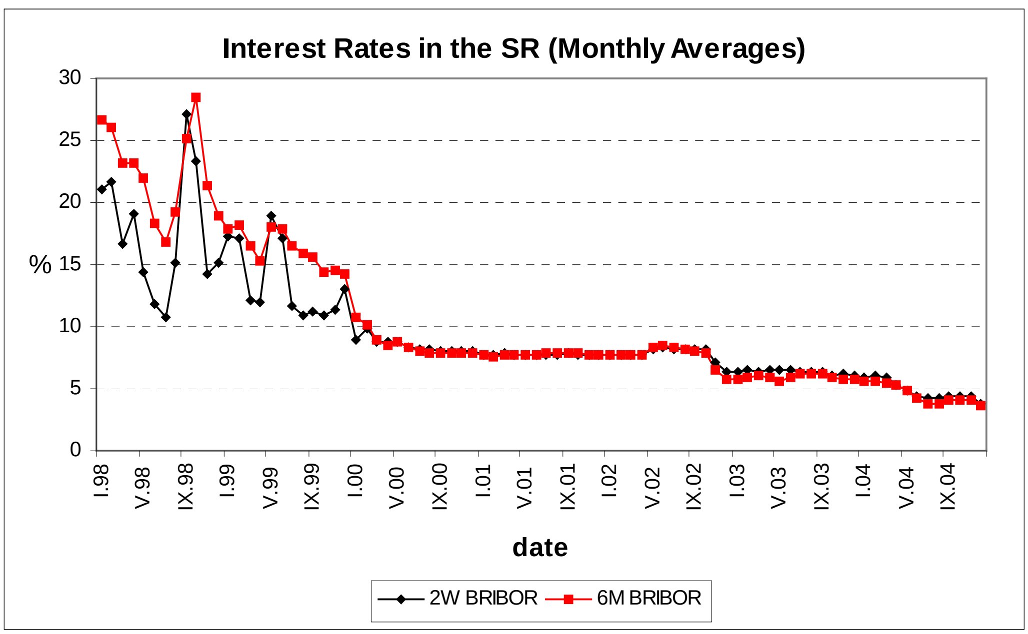


Source: the ARAD database.

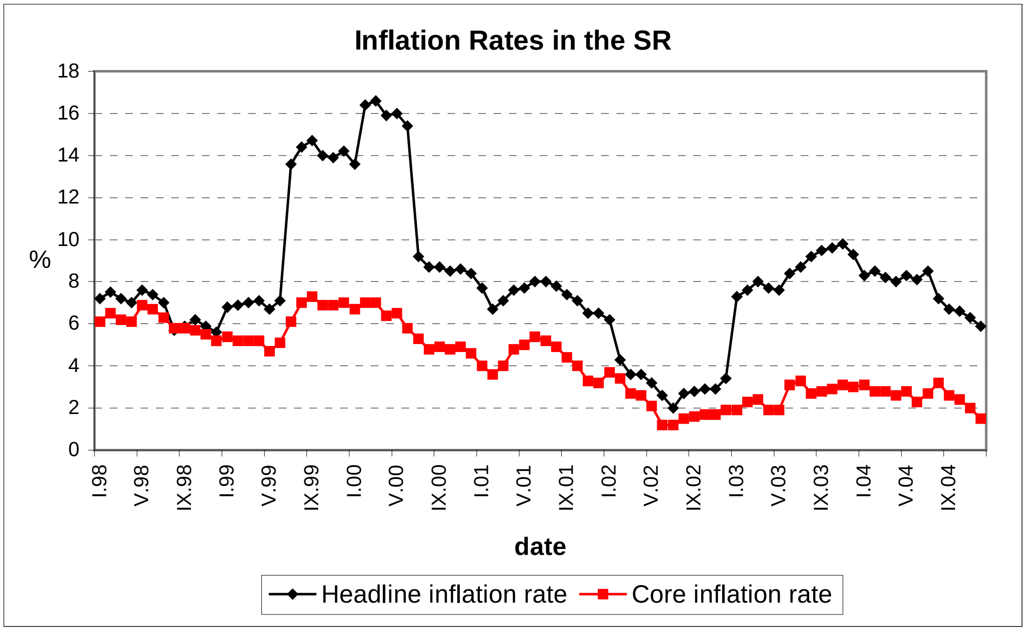
Appendix C – Selected Macroeconomic Indicators for the SR



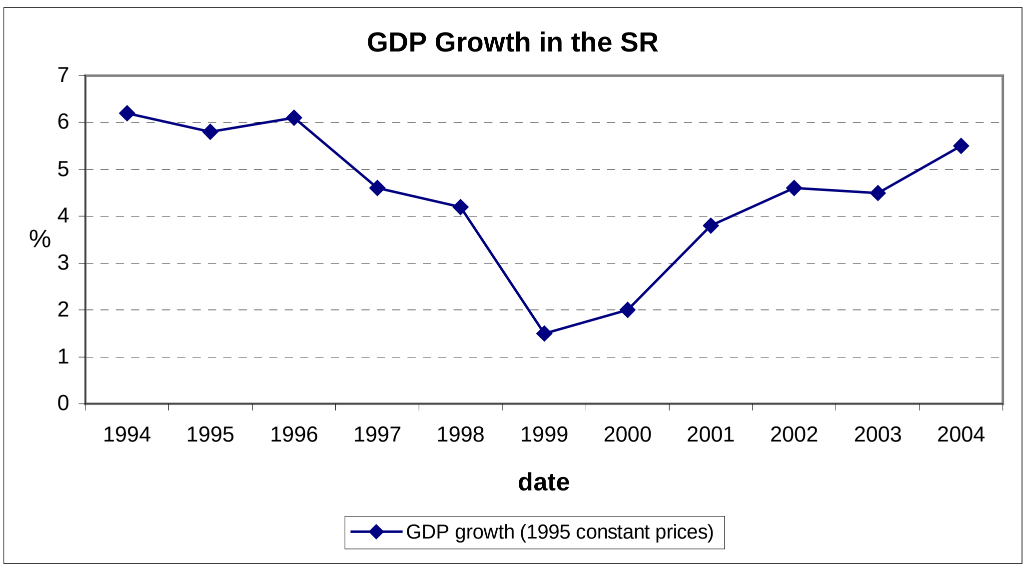
Source: the NBS web page.



Source: the NBS web page.



Source: Information Service at the Statistical Office of the SR.



Source: Information Service at the Statistical Office of the SR.