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2010 **Miloš Hrachovec**

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Taylor Rules and Interest Rate Setting of the Czech National Bank

Author: Miloš Hrachovec
Supervisor: Roman Horváth Ph.D.
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Prohlášení

Prohlašuji, že jsem bakalářskou práci vypracoval samostatně a použil pouze uvedené prameny a literaturu. Souhlasím se zapůjčováním práce a s jejím zveřejňováním pro účely výzkumu a studia.

V Praze dne Miloš Hrachovec

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Abstract

This paper studies role of the so called Taylor rules in the complex procedure of interest rate setting. The Czech National Bank is described as the monetary authority in the Czech Republic, then optimal monetary policy and form of monetary policy rule is discussed, yielding conditions on the optimal rule. These conditions are then applied to the forward-looking reaction function of the Czech National Bank and the role of this reaction function within the Czech National Bank's monetary policy is addressed. Last section presents empirical estimates of a Taylor-like rule for the Czech National Bank and shows variability of possible utilization for the modified Taylor rule.

Key words: Taylor rules, Czech National Bank, monetary policy, inflation targeting, interest rate,

Abstrakt

Tato práce se zabývá rolí takzvaných Taylorových pravidel v rámci velmi obsáhlého procesu určování úrokových měr centrální bankou. Česká národní banka je nejprve definována jakožto instituce určující monetární politiku v České republice a poté jsou rozebrány výhody a nevýhody jednotlivých monetárních politik. Dále jsou projednány různé formy monetárních pravidel a definujeme podmínky optimality těchto pravidel. Následně jsou tyto podmínky zkoumány vzhledem k reakční funkci České národní banky a jejího procesu určování úrokových měr. V poslední části je ukázáno různé využití modifikovaných Taylorových pravidel pro empirický výzkum.

Klíčová slova: Taylorovy pravidla, Česká národní banka, monetární politika, cílování inflace, úroková míra

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Introduction

In the times of unstable financial markets and aftermath of an economic crisis, the role of central banks became increasingly important and visible. Optimal reaction to developments in real economy is the goal of each monetary authority, which tries to maintain the best possible conditions in the market.

This is only one of the reasons why central banking and monetary policy conduct is a lively research area with many developments in recent years. From different monetary policy regimes, through communication and transparency issues to sophisticated modeling and forecasting frameworks, central banking offers a broad variety of topics. This paper focuses on application of originally a simple instrument rule, known as the Taylor rule, into a complex procedure of central banks' instrument setting. From what was originally an ex-post analysis tool for interest rate developments, a widely used apparatus for future interest rate setting emerged, especially within the inflation targeting regime. For this purpose, multiple variations of the original rule were devised and implemented into complex policymaking procedures. On the particular case of the Czech National Bank, author wishes to show the role of the so-called Taylor rules in these procedures by identifying a Taylor-like rule in the interest rate reaction function. Furthermore, the paper focuses on optimality of the given reaction function rule using criteria described in Svensson (2001), Woodford (2000) or Woodford (2001).

The paper proceeds in following manner; initially, the Czech National Bank is defined as a monetary authority in the open market economy of the Czech Republic. The central bank plays vital role in maintaining stable conditions in the Czech market and as such utilizes several policy instruments. Therefore the monetary policy instruments are introduced, stressing the importance of the two week repurchase (REPO) rate for developments in the economy. For better understanding of specific conditions in the Czech market, brief history of the Czech National Bank's monetary policy regimes follows, leading to the introduction of inflation targeting in the Czech economy as of December 1997.

In the second section, the original concept of the Taylor rule is introduced and its modifications are discussed. Benefits and drawbacks of different Taylor-like rules specifications are identified, based on various criteria. Link to monetary policy of the

Czech National Bank is determined via the Quarterly Projection Model and optimality is assessed.

Third section presents results of empirical research conducted in past years with estimation of the Taylor rules for the Czech National Bank and shows possibilities of practical utilization of the concept.

This work has some substantial deviations from the originally proposed thesis, which was proposed in June 2009 (to be found at the end of this paper). First section about "brief history of interest rate theory" was completely omitted as it would not have offered any important information regarding the topic of Taylor rules. Historical views and theories have no relevance towards modern approach to interest rate setting and the only outcome would be insignificant long text. In the last section another change was made, as no comparison between the Czech National Bank and other monetary authorities is described. This is simply because the author decided to focus on the case of the Czech Republic only.

1. The Czech National Bank

Transparent and credible monetary authority is of vital importance in every developed country. In open economy conditions of the Czech Republic, such role is delegated to the Czech National Bank.

Existence of the Czech National Bank (CNB further on) is embedded in the constitution of the Czech Republic since its adoption in December 1992 (valid since 1st January 1993). The constitution defines that CNB is the central bank of the State (as a successor of the Czechoslovak National Bank) and its main objective "shall be to maintain price stability", however, this is due to an amendment by Act No.448/2001 Coll. Beforehand the objective was to maintain stability of currency. Further details on the CNB are defined in the Act on Czech National Bank (Act No.6/1993 Coll.), where more objectives of the CNB are specified. These include support of Government's economic policies leading to sustainable economic growth (without prejudice to its main objective) and obligation to act according to the principle of an open market economy. So as to pursue its primary objective, the CNB shall (among others): set monetary policy, issue banknotes and coins, manage circulation of currency, supervise the activities of entities operating on the financial markets and contribute to the stability of financial system as a whole. The most important part for this paper is Article 2(2a) – the CNB shall set monetary policy.

The monetary policy and the instruments for implementing this policy shall be set by Bank Board of the Czech National Bank (Bank Board further on), the supreme governing body of the CNB. The Bank Board consists of seven members: the Governor, two Vice- Governors and four other members of the Bank Board, who are appointed and relieved by the President of the Czech Republic. Despite the role of the President in selection of the Bank Board's members, independence of the CNB is also secured by the Act on CNB, Article 9(1) – "when providing for the primary objective of the Czech National Bank and when carrying out other activities, neither the Czech National Bank nor the Bank Board shall seek or take instructions from the President of the Republic, from Parliament, from the Government, from administrative authorities or from any other body." (Act No.6/1993, Article 9(1)) The CNB also may not provide any financial support to the Czech Republic, its bodies, regional authorities, bodies governed by public law or legal entities under the control of the state. Thus ensuring also financial independence and lowering the risk of political pressures upon the CNB. The independence is one of the keystones for credibility of the CNB.

1.1 The Czech National Bank's Monetary Policy Instruments

The CNB has several instruments at hand, but the most important and most widely used to influence the economy is the two-week repo rate. Current setting of all the instruments is in the table below, more detailed description follows:

Table 1 -CNB's Monetary policy instruments (http://www.cnb.cz/en/monetary_policy/instruments/), updated by author

Instrument	Rate	Valid since
Two-week repo operations – 2W repo rate	0.75%	May 2010
Deposit facility – discount rate	0.25%	August 2009
Marginal lending facility – Lombard rate	2.00%	December 2009
Reserve requirement – banks	2.00%	October 1999
Reserve requirement – building societies	2.00%	October 1999

This section heavily draws on the official websites of the CNB, more precisely on the monetary policy instruments section.

1.1.1 Open Market Operations

Main goal of the open market operations (OMO further on) is to influence the interest rate level in the economy. Three categories of OMOs are to be distinguished:

1) The main monetary policy instrument

The main monetary policy instrument is conducted in form of repo tenders. In these operations, the CNB collects excess liquidity from banks in exchange for agreed collateral (in form of eligible securities). The parties agree to reverse the operation after a certain amount of time, when the CNB repays the principle plus interest in return for the collateral securities. Duration of these operations is usually two weeks; the two-week repo rate (2W repo rate) is therefore the main instrument of the monetary policy under the conduct of the CNB. The tenders are organized in a form of variable rate tenders, where the "… declared repo rate serves as the maximum limit rate at which banks' bids can be satisfied in the tender. The bids are ranked using the American auction procedure, i.e. those with the lowest interest rate are satisfied as having priority and those with successively higher rates are accepted until the total predicted liquidity surplus for the day is exhausted."[1] Due to the liquidity excess in the Czech banking sector, these repo operations are employed solely for the purpose of absorbing liquidity from the market.

2) The supplementary monetary instrument

Takes form of a three-month repo tender, conducted again via the American auction procedure (as described above). Money market rate is used for this procedure, as the CNB does not aspire to send signals through the supplementary monetary instrument. Last time this instrument was used was in January 2001.

3) Fine-tuning instruments

These instruments include securities operations and exchange rate operations, and serve to mitigate the unfavorable developments of interest rates levels due to unexpected volatility of liquidity in the market. These instruments are only rarely used.

1.1.2 Automatic Facilities

Automatic facilities serve the purpose of providing or depositing liquidity overnight. Since the deposit/loan is a standing facility, the interest rates applied form a band for all short-term interest rates in the money market, including the 2W repo rate. Two automatic facilities are to be distinguished:

1) The deposit facility

It is a non-collateralized facility, which allows banks to make deposits of their surplus liquidity with the CNB. These deposits then bear the discount interest rate, which provides the floor for the short-term interest rate band.

2) The marginal lending facility

Contrary to the deposit facility, the marginal lending facility allows banks to acquire additional liquidity from the CNB. These loans are subject to a Lombard interest rate, which provides the ceiling for the short-term money market interest rate band. Due to the persisting excess of liquidity on the Czech money market, banks use this option only

[1] Taken from: http://www.cnb.cz/en/monetary_policy/instruments/

exceptionally. Also, the CNB may at any time decide to limit or suspend the provision of Lombard loans.

1.1.3 Minimum Reserves

The minimum reserves requirement is best described by the CNB: “Every bank, building society and foreign bank branch that has a banking license in the Czech Republic or intends to operate in the Czech Republic on the basis of the "Single License" is required to hold a pre-specified volume of liquid funds - known as minimum reserves - on its account with the CNB.”[2] Since October 1999, the minimum reserves are set to 2% (the ratio was gradually lowered and now is equal to European Central Bank’s) of the base used for calculation of the reserves. From July 2001, this base is defined as “volume of bank’s primary liabilities (chiefly deposits from non-banks) with maturity up to 2 years.”[3] Also as of July 2001 the minimum reserves are remunerated with the two-week repo rate (beforehand, no interest was paid on these deposits). The minimum reserves constitute a rather insignificant policy instrument, however, they serve an important role in ensuring a stable functioning of the interbank payment system.

1.2 Monetary Policy Regimes

Common target of the central banks throughout different countries is price level stability and different monetary policy regimes are merely the means of achieving this goal. For any monetary policy to be successful in reality, the given policy rule has to fulfill following criteria: simplicity, transparency, sufficient communication and verification channels (Orphanides, 2007, p.3). Three most popular regimes are stated below, including both the advantages and disadvantages of the given monetary policy regime. Main difference between the approaches to maintenance of price level is whether the monetary policy targets directly the price level, or rather selects an indirect target with a strong influence onto the price level.

1.2.1 Exchange rate targeting

Under the regime of exchange rate targeting, the central bank attempts to maintain stability of the exchange rate by the means of changes in interest rates and direct

[2] http://www.cnb.cz/en/monetary_policy/instruments/
[3] http://www.cnb.cz/en/monetary_policy/instruments/

interventions in the foreign exchange market. Exchange rate targeting has several variants itself. Bubula and Őtker-Robe (2002) divide the Exchange rate regimes into 3 main categories[4]:

1. Hard Pegs Regimes – most strict being the Currency Board arrangement
2. Intermediate Regimes – soft pegs and tightly managed floats
3. Floating Regimes – independently floating exchange rate being the least strict

Only the first two categories fit the definition of exchange rate targeting. Diagram with further division of the above mentioned categories is to be found in Appendix at the end of the thesis.

These exchange rate regimes usually fix the exchange rate to a basket of anchoring foreign currencies (or a single currency), usually those of stable developed countries with low inflation and a high share of mutual trade. This way the central bank tries to "import" low inflation from foreign countries and stabilize the price level at home. In the worst case, country may even abandon its own currency and have no separate legal tender (formal "dollarization"), which is also the case for currency union such as Eurozone. Another example of a hard peg is the case of Currency Board, when a country only issues domestic currency against an increase in foreign currency reserves. This means that domestic currency must be fully backed by foreign assets and foreign currency is exchanged at a fixed rate. Intermediate regimes include conventional fixed pegs, horizontal bands, crawling pegs and crawling bands. These regimes can be divided in many ways: according to the number of currencies used as an anchor, degree of adjustment possible, backward- or forward-looking adjustments. Important is, that unlike for the hard peg regimes, certain very limited possibility to influence the exchange rate remains in the hands of the monetary authority.

Main advantage of the exchange rate targeting regime is the "import" of lower inflation from the anchoring country. Another positive side of the regime is its transparency and comprehensibility of the nominal anchor to general public and therefore easier formulation of expectations by the public. Fixed exchange rate may also help to intensify economic integration of countries, as was the case of the European Exchange Rate Mechanism (ERM) which preceded the introduction of single currency in the European Union.

[4] For further details on the exchange rate regimes see Bubula and Őtker-Robe (2002), p.15

On the contrary, country under the exchange rate targeting regime sacrifices part of its monetary policy independence as the domestic interest rates have to be set “according to” the interest rate setting of the anchoring country. In the case of domestic supply or demand shocks, the reaction of monetary policy by adjusting the interest rates is limited. On the other hand the shocks from the anchoring country are transmitted to domestic economy through the correlation of interest rate setting. Another liability is the exposure of fixed exchange rate to speculative attacks on the market, which can further destabilize the domestic economy.

Despite the above mentioned disadvantages of the exchange rate targeting regime, it is very useful for small open economies, where the domestic price level is to a large extent influenced by the exchange rate. With the proceeding globalization and liberalization of the financial markets, countries abandon the exchange rate targeting regimes and switch to different regimes as described below. Possible exceptions are the Hard Pegs Regimes, which are used in case of extremely unstable or newly emerged economies to stabilize the developing economy and help to gain credibility.

1.2.2 Monetary Targeting (Money Growth Targeting)

This regime of central bank’s policy is based on the quantity theory of money and the general idea that in the long run, increase in price level is determined by (increase in) money supply. The monetary policy under such regime focuses on targeting a sustainable growth of a selected monetary aggregate and thus maintaining a stable rate of inflation. Diversity of the regime is then given by the variety of monetary aggregates, type of bands for the targeted variable and the way of conducting the policy by monetary authority.

As stated above, general idea of monetary targeting comes from the quantity theory of money, namely from the equation of exchange:

$$M.V = P.Q$$

where M is the amount of money circulating in the economy in given time period (for purpose of the policy the selected monetary aggregate), V is the transaction velocity of money and reflects demand for money, P is the price level in given period and Q is the real output in given period. For easier use and interpretation a growth rate variant of the equation of exchange is desirable:

$$\Delta m + \Delta v = \Delta p + \Delta q$$

where m, v, p and q are logarithms of the monetary aggregate, velocity of money, price level and real output respectively. Selecting only the targeted variable to remain on the left side of the equation, noting that $\Delta p = \pi$ we can then interpret the following simple rule:

$$\Delta m = \pi^* + \Delta q^* - \Delta v^*$$

Growth of the selected monetary aggregate should be selected with respect to the targeted inflation rate, change in economy's potential real output and change in the transaction velocity of money, as given by the equation above.

Svensson (1999, p.4) distinguishes two different regimes of monetary targeting – "strict" money growth targeting (which is purely theoretical and was never pursued by any monetary authority) and "pragmatic" money growth targeting (which was successfully pursued by the German Bundesbank).

In "strict" monetary targeting regime the money-growth target is set according to inflation target and no other variable than money-growth enters the optimized loss function. However successful in achieving the targeted average inflation over a long time period the regime may be, difficulties arise in the medium term. A clash between stabilizing money-growth and stabilizing inflation stems from the monetary aggregate not being an intermediate variable. This means that change in central bank's instrument (interest rate) does not influence the target variable (inflation) exclusively through the change in targeted variable (money-growth). In other words, the transmission mechanism has more channels of influencing inflation than solely affecting monetary aggregate first and monetary aggregate affecting inflation as a next step. Therefore the trade-off between increased inflation variability and increased money-growth variability exists. When contention between the two above mentioned targets emerges, strict monetary targeting prefers achieving the monetary-growth target. This results in high inflation variability and makes the strict monetary targeting inferior choice.

The "pragmatic" monetary targeting, as conducted for many years by the German Bundesbank, faces the same problem in the medium term as the "strict" regime. Where the strict monetary targeting favors money-growth target, the pragmatic approach abandons this target and focuses on fulfilling its inflation target (called "unavoidable inflation", "price norm" or "medium-term price assumption" (Svensson, 1999, p.7)). For the Bundesbank, its monetary target was not met half the time in the period of 1974-1999

(Mishkin (2001), p.8), but the inflation was kept low and well on the target. These facts comply with conclusions of both Mishkin (2001) and Svensson (1999) implying that the pragmatic monetary targeting exhibits larger similarities to flexible inflation targeting than to strict monetary targeting. Biggest difference then constitutes communication strategy of the central bank. The Bundesbank's communication with outsiders was conducted according to the monetary targeting approach (frequent explanations of the missed monetary targets, emphasis on long-term price levels in case of missed targets), but the actions were in reality disregarding the monetary target and focusing primarily on inflation. Svensson (1999, p.9) therefore describes pragmatic monetary targeting as "inflation targeting in actions, monetary targeting in words".

Major advantage of monetary targeting is the independence of monetary policy conducted under such regime. Central bank is therefore able to react to current developments in domestic economy and adjust its instruments according to specific needs of the given situation. Small number of variables entering the equation could be seen as an advantage, as the central bank does not need to conduct detailed research of the economy.

On the other hand, monetary authority faces many difficulties under the monetary targeting. Probably the most important drawback is the weak relationship between monetary aggregates and the target variable (inflation), which is further reduced by financial innovations and globalization of the markets. Moreover, the volatile connection of monetary aggregates and goal variables also hinders the role of monetary targeting as a communication tool of the central bank. Communication is one of the key factors determining success or failure of the conducted money-growth targeting. Examples of Switzerland and Germany show that monetary targeting can be successful, when the long-run strategy of inflation control is clearly communicated (Mishkin (2001), p.8-9). Even if communication is sufficient, monetary targets are harder to understand for the public. High degree of credibility is then necessary for the central bank to succeed. Such a condition is hard to fulfill especially in developing countries, where the monetary authority does not have a long history of credible results.

Altogether, monetary targeting is suitable especially for countries with long tradition of credible, transparent and successful monetary authority. Declining link between monetary aggregates and inflation, and increasing flexibility of the regime has brought the above described "pragmatic" money-growth targeting very close to inflation targeting. Svensson (1999, p.10) describes choice between these two regimes as a choice between "non-transparency and transparency", thus favoring inflation targeting.

1.2.3 Inflation Targeting

Inflation targeting is the youngest of the monetary policy regimes. After problems contended during the 1970's and 1980's with monetary targeting, many developed countries switched to inflation targeting with New Zealand being the first to adopt the regime in 1990. As the name suggests, monetary authority under this regime aims on maintaining stable price level or inflation (represented usually by a selected price index such as CPI). Reasons for selecting inflation (or price level) as the targeted variable originate from the following, generally accepted, ideas.

Existence of long-run trade-off between unemployment and inflation was denied. Lower unemployment rate (and/or higher output) can be produced by expansionary monetary policy only in the short-run (generating higher inflation). In the long-run, both decline in unemployment and growth in output are subject to capacity constraints of the economy, while the possible increase in inflation is not, as it is embedded in price expectations. Therefore attempts to take advantage of the above mentioned trade-off can generate rising inflation without output gains in the long-run. (Mishkin and Posen, 1997, p.11)

The time-inconsistency of monetary policy phenomenon leads to the same conclusion as the previous argument. In such situation the monetary authority with stronger interest in output growth than in inflation level tries to exercise more expansionary policy than expected by the price- and wage- setters. However, firms and workers can adjust their expectations about the actions of the central bank and transform their expectation of higher inflation into higher prices and wages (thus really causing increase in price level). As a result, central bank supporting primarily output targets might deviate towards a high inflation without increase in output.[5]

The inflation targeting regime lies on three key pillars[6]:

1. Publicly announced, explicit quantitative target for inflation (numerical inflation target)

[5] More reasons for the use of inflation targeting in Mishkin and Posen (1997), Mishkin and Schmidt-Hebbel (2006) or Svensson (1998)
[6] In Svensson (1998) and Svensson (2001); Mishkin (2001) structures the generally identical ideas into "five key elements".

2. Decision making process, which employs an internal inflation forecast as intermediate target, but also accounts for other significant variables such as output or output-gap (QPM in the case of the CNB, to be discussed further on)
3. Excessively high degree of transparency and accountability of the central bank. The central bank is accountable to public for attaining its inflation goals and is responsible for communicating its strategies and explaining its policy.

Similarly to monetary targeting regimes, different types of inflation targeting can be distinguished. Degree of concern about real economy variables is one of the dividing criteria. However, Svensson (1998, p.13) specifies that "real-world inflation targeting … corresponds to "flexible" rather than "strict" inflation targeting." In other words, all regimes in practice focus on more variables besides price level. These can include output, output variance, unemployment, exchange rate, real wages and many more.

Regarding the procedure of forecasting, conditional and unconditional inflation targeting regimes are to be specified. It is important to note, that both types have their advantages and drawbacks[7]. Conditional inflation forecast simulates developments of economy and inflation under a rather unrealistic assumption that the monetary authority will leave its instrument settings (interest rate) unchanged for the given time period, no matter the actual economic evolvement. The unconditional forecast takes into account central bank's reaction function and incorporates it into the predicted development of the economy. In spite of the name "unconditional", the forecast is dependent on many factors, such as external developments or agents' behavior. First argument in favor of conditional forecast is the relative simplicity, as there is no need for identifying central bank's reaction function (one of the hardest parts in unconditional forecast). On the other hand, the assumption about complete passivity of central bank conflicts with public agents' expectations. Passivity may be interpreted by the agents as a change in central bank's preferences or its apprehension of the economy and the agents would modify their reactions to the new perception of central bank's priorities. This change in agents' behavior would then need to be assessed in the forecasting model, making the original forecast obsolete and incorrect. Using the conditional forecast allows the central bank to estimate the direction of changes to be made, but not a numerical value, which is possible using the unconditional forecast. However, what may seem as a clear advantage of unconditional forecast may as well turn against it. By providing a clear quantitative suggestion about

[7] In more detail discussed in Coats *et al.*, 2003, Chapter 2

appropriate reaction, the forecast pressures bank board to accept such explicit instruction. Members of the board then have to provide very strong arguments for their disagreement with the suggested measures. Communicating these two types of forecasts also yields specific threats. With conditional forecasts, the assumption of un-altered interest rates tends to be neglected by the agents and perceived as unconditional. Credibility by the monetary authority then could be questioned when compared to factually unconditional forecasts of other institutions. Publication of unconditional forecasts is problematic from different angle. Forecasts of the central bank may be incorrectly viewed as a promise of future development with regard to both monetary policy and development of other economic variables. Agents may then modify their actions in attempt to take advantage of knowledge of the future values of e.g. exchange rate, altering the situation on the market and forcing the monetary authority to react in different manner then specified in the forecast. Taking into account all the information above, decision between conditional and unconditional forecast is rather a difficult one.

Inflation targeting has many advantages, from independence of the monetary authority in conducting the policy, strong anchor of the inflation expectations in the form of the officially announced target to increased transparency of such policy and strong credibility of the central bank. Medium-term focus of the inflation target is another advantage in comparison with monetary targeting, where effects of the policy suffer from longer lags. In experience, Mishkin (2001) and Mishkin and Schmidt-Hebbel (2006) illustrate, that inflation targeting regimes were successful in:

a) controlling inflation (lowering both inflation level and volatility)
b) mitigating the consequences of inflationary shocks (such as exchange rate pass-through, oil price shocks or developments of international interest rates)
c) improving communication of the central bank with the public
d) increasing transparency and accountability of the central bank (leading to strong independence of the monetary authority)

As mentioned above, inflation is usually for simplicity approximated by a selected price index. Regularly, the central bank cannot influence every item included in such price index and therefore cannot fully control development of the price level. Another drawback of the inflation targeting regime stems from the importance of credibility and transparency. Implementing inflation targeting in a country with high inflation level and large volatility of inflation is perilous, as danger of missing the inflation target is rather high. Central bank would suffer from a loss of credibility (which is especially dangerous in emerging markets). Therefore a period of disinflationary measures (associated with different monetary policy regime) is recommended before adoption of inflation targeting regime. (Mishkin, 2001, p.28)

1.3 Czech National Bank's Monetary Policy Regimes

Since its establishment in 1993, the CNB has gone through two main periods regarding its policy regime. To better understand current situation, I will shortly describe the developments of CNB's monetary policy regimes. Following text is divided into two parts: 1993-1998 and 1998-recently. The division is selected to distinguish periods before and after inflation targeting regime was implemented. This section draws heavily on Coats et al. (2003), Chapter 1

1.3.1 Pre-Inflation Targeting (1993-1998)

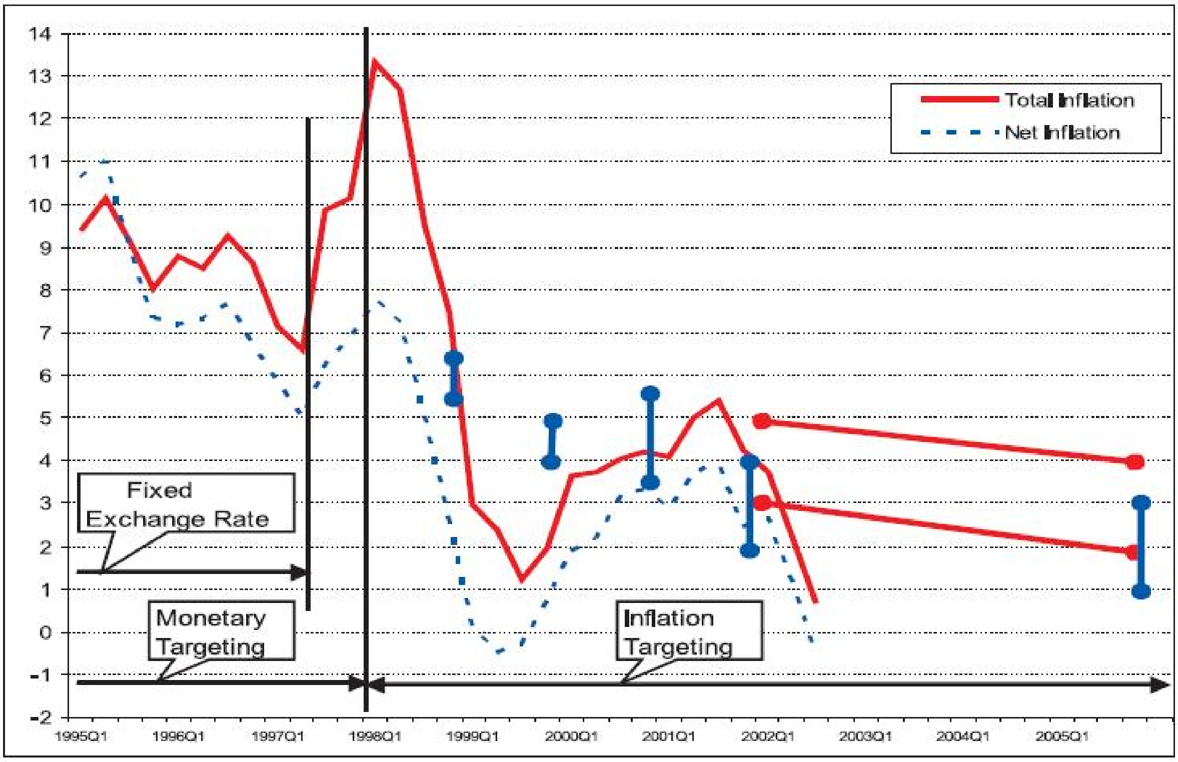
In the early years of economic transformation, liberalization of capital flows, privatization and price deregulation, combined regime of exchange rate targeting and monetary targeting seemed as the only sustainable choice. Indeed it has proven efficient; at least in the beginning of the period (inflation fell from level around 20% in 1993 to 10% in first quarter of 1994). Exchange rate of the Czech koruna was pegged to a basket of currencies, where the two dominant components were the Deutschmark and US dollar. Goal of the CNB was to initially maintain the exchange rate within a narrow band of +/- 0,5% (the band was eventually widened). With the exchange rate anchor providing sufficient protection against imported inflation, the CNB was able to use targeting of M2 monetary aggregate in reaction to domestic developments. The progressing privatization and increasing foreign capital inflows caused demand and money supply acceleration. The CNB failed to fulfill its monetary targets during the 1994-1996 period, owing largely to the growing excess demand. Supply side of the economy was hindered by slow progress of corporate restructuring and postponed privatization in the banking sector. Therefore the supply side could not sustain similarly rapid rates of increase as the demand, putting the economy under strong inflationary pressures. At this point, the CNB was facing two problems: high foreign capital inflows attracted by high domestic interest rates (suggests lowering of interest rates) and increasing domestic demand-driven inflationary pressures (suggests increase in interest rates). Part of the difficulties was resolved by widening of the exchange rate's fluctuation band to +/- 7,5% in February 1996. Factual abandonment of the hard peg regime significantly increased the exchange rate risk for foreign investors and the foreign investment pressures began to ease. Combined with tightening of the monetary policy by the CNB (increase in interest rates together with declining inflation had brought real interest rates to a substantial rise) and series of government's austerity packages throughout 1997, slow-down in demand side of the economy was inevitable. GDP growth fell below potential, inflationary pressures were relieved and inflation fell below 7% by the first quarter of 1997, owing both to exchange rate appreciation and monetary tightening.

May 1997 saw the end of gradual disinflation in the Czech economy. Following the Asian exchange rate crisis (although there was no strong link between the Czech Republic and Asia), Czech koruna got under pressure. Relatively strong appreciation of the currency in past years seemed too large to sustain, lack of progress regarding competitiveness of the Czech economy and increasing current account deficit also contributed to distrust about external value of the koruna. Result of all the above mentioned conditions was a sharp depreciation of the koruna by about 10% relative to the basket in May 1997. In response, the CNB adjusted its instrument dramatically in the upward direction as the depreciation led to short-term increase in inflation, and regime of pegged exchange rate was substituted by managed floating. Substantial rise in interest rates combined with the austerity packages resulted into even greater decline in already diminishing GDP-growth, excess supply gap developed and the economy entered into a recession. At this stage, the previous widening of the exchange rate band caused uncertainty of expectations, because no other nominal anchor was announced. Expectations were dependent on the current developments and the depreciation entered the inflation expectations very quickly, raising the prices of traded goods. Furthermore, increase in regulated prices (in 1997 and beginning of 1998) together with augmentation of indirect taxes contributed significantly to the rise in price indexes and inflation expectations. In situation of increasing inflation and inflation expectations, the CNB needed a new explicit target to successfully fight immediate rise in price level and to anchor inflation expectations.

1.3.2 Inflation Targeting (1998-recently)

New monetary policy of inflation targeting was implemented in December 1997, following experiences of many countries which had to abandon exchange rate targets before adoption of inflation targeting (e.g. Great Britain, Sweden or Finland). Two targets were announced in 1997, medium-term range for net inflation of 3.5-5.5% in December 2000 and to better anchor immediate expectations, short-term range of 5.5-6.5% as of December 1998 was added. Several factors began to influence the price level at the same time. Higher interest rates compared to Germany causing an exchange rate appreciation in 1998, recession in domestic economy with widening excess supply gap (GDP level hit its trough in second quarter of 1992) and decrease in oil prices all put substantial downward pressures on inflation. The price level declined considerably and all longer-term targets were undershot by a large margin. Such favorable outcome regarding immediate inflation enabled the CNB to focus on medium-term goals. These are specified in *CNB Monetary Strategy*, document launched in April 1999, defining the target as 1-3% band on the net CPI inflation by the end of 2005. Developments of inflation targets and the actual inflation developments are in figure 1.

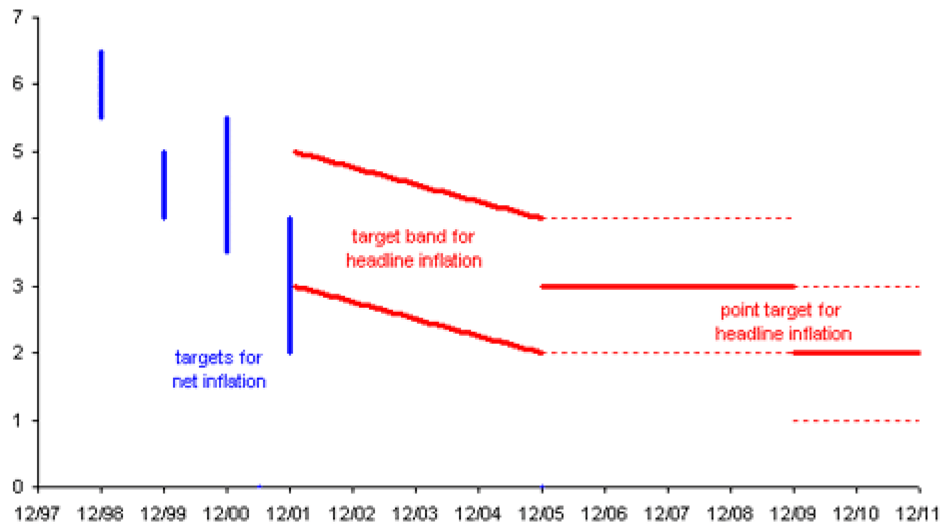
Figure 1- Targets for Total and Net Inflation, 1995-2005, taken from Coats et. Al (2003)



The document also defined so called "caveats" or "escape clauses" – additional factors that are not to be incorporated in the target commitment and therefore do not constitute an immediate need for adjustment of the conducted monetary policy.[8] For communication with public, these exceptions are an important element in explaining central bank's reactions or passivity.

Further step toward a full-fledged inflation targeting regime was made in April 2001. New target was set in terms of a CPI increase rate, instead of the previously used net inflation (defined as the CPI without regulated prices) change. Also the newly announced target was specified in a form of continuously decreasing interest rate band, starting at 3-5% in January 2002 and ending at 2-4% in December 2005. In March 2004, target of 3% with +/-1% confidence band was announced for period starting in January 2006 and in March 2007 last target was announced for the CPI increase in January 2010 to be 2%, again with +/-1% confidence band. Development of inflation targets until recently is best illustrated in figure 2.

Figure 2 - Inlflation targets of the CNB (http://www.cnb.cz/en/monetary_policy/inflation_targeting.html)



To ensure that targets will be met under the inflation targeting regime, especially in the medium-term, development of a reliable forecasting and policy analysis system was of a crucial importance. The CNB's Forecasting and Policy Analysis System (FPAS) is a very

[8] The „caveats" include: large deviation of world prices of raw materials, energy-producing materials and other commodities from the forecast; large deviations of the koruna's exchange rate that are not connected with domestic economic fundamentals and monetary policy; large changes in agricultural conditions and resulting increase on agricultural prices; natural disasters and other extraordinary events with cost and demand effects on prices. Two more were added in April 2001 (Coats et al., 2003)

complex system of models, forecasts, meetings and negotiations, leading to a Bank Board's decision about the instrument setting.

Implementation of current decision making procedure was a rather lengthy process and was undergone gradually. In the early stage of inflation targeting, the projections and evaluations were evaluated on a monthly basis. Projections of all the key data were assessed through time-series analysis, and emphasis was put on judgment of CNB's experts. Nowadays the projection is done on a quarterly basis, which better suits the length of the process and publication of national accounts data. Development of the forecasting process called for improved communication between individual divisions of the CNB, as Forecasting Team was established to execute the forecasting procedure. The Forecasting Team encompasses members of five divisions of the CNB (Monetary Policy, Economic Modelling, External Environment, Monetary Analysis and Real Economy Divisions) and the entire process takes about five weeks before the forecast is presented to the Board.[9] Presented forecast and recommendation about the monetary policy settings are derived as combination of near term forecast and model-based medium term forecast (as of 2001). Near term forecasts are still dependent on expert's judgment of their respective fields, for the medium term forecasts a Quarterly Projection Model (QPM further on) has been devised. For purposes of this paper, the QPM and its link to Taylor rules is of crucial importance and I shall focus on this topic in next section. However, even the original QPM (used since 2002) was already subject to modifications and an improved prognostic model called QPM+ was used for the period of standard inflation targeting with horizontal target since 2005 (Šmídková (Ed.), 2008, p.11). Further development of the core model led to an introduction of a general equilibrium model called "g3" in 2008.

[9] More details on the process and rough forecast schedule in Coats et al., 2003, Chapter 2

2. Taylor Rules

Taylor rules are best described as "simple monetary policy rules that prescribe how a central bank should adjust its interest rate instrument in a systematic manner in response to developments in inflation and macroeconomic activity." (Orphanides, 2007, p.1) The name "Taylor rules" refers to an article called "Discretion Versus Policy Rules in Practice" published in 1993 by John B. Taylor as part of the Carnegie-Rochester Conference Series on Public Policy. In the article, Taylor focused on how econometric policy evaluation could be used in actual conduct of monetary policy, setting a new trend for research. Main focus of the article was to identify major qualitative differences between discretionary monetary policies and rule-based monetary policies. However, one straightforward monetary policy rule was presented and became known as the "classic" Taylor rule (Taylor, 1993, p.202):

$$r = p + 0.5y + 0.5(p - 2) + 2$$

where r is the federal funds rate, p is the rate of inflation over the previous four quarters and y is the percent deviation of real GDP from a target. In this sense Taylor defined that the federal funds rate should rise when inflation is above its target of two percent and when the real output is above its target (y was defined as: $y = 100(Y - Y^*)/Y^*$; Y is real GDP; Y^* is trend real GDP, 2.2 percent for the period used by Taylor.) Coefficients of 0.5 each were chosen rather randomly. Practicality of the above mentioned rule was examined by Taylor on set of American data from the 1987-1992 period and a surprisingly good fit of the ex-post policy rule was found[10]. However, this does not mean that such simple rule should be mechanically followed by the policymakers. Already in the same article, Taylor argues that "A policy rule can be implemented and operated more informally by policymakers who recognize the general instrument responses that underlie the policy rule, but who also recognize that operating the rule requires judgment and cannot be done by computer."(Taylor, 1993, p.198) This leaves sufficient space for including discretion and experts' knowledge into the monetary policy and decisions about instrument settings. Similarly, Svensson (1998, p.5) interprets monetary policy rules as a "prescribed guide for monetary policy conduct" or action. Svensson (1998, p.18) furthermore stresses, that

[10] Resulting graph comparing the policy rule and actual federal funds rate in Appendix, or see Taylor, 1993, p.204

practical monetary policy has to incorporate judgment and never rely solely on results of a model, especially regarding the forecasting procedure.

2.1 Advantages and Perils of Taylor Rules

Over the years, Taylor's original hypothetical rule has been subject to many modifications. The original rule was defined as a "purely contemporaneous instrument rule", a rule that makes the current rate of central bank's instrument variable a linear function of the current inflation rate and current output gap only. Different specifications can modify Taylor rule into many different forms, such as:

i. Forward-looking or backward-looking rule:

$r_t = (1-\rho)\left[\overline{r} + \alpha\left(\pi_{t+i} - \pi^*_{t+i}\right) + \beta x_t\right] + \rho r_{t-1} + \varepsilon_t$ (Horváth, 2008),

where for backward-looking rule $i = 0$; for forward-looking rule $i > 0$

ii. History dependent rule, which captures central bank's interest rate smoothing (e.g. Horváth, 2008 – in above mentioned equation represented by the term ρr_{t-1}) or:

$i = (1-\theta_i)\left(r^* + \pi^*\right) + \theta_i i_{-1} + \theta_\pi\left(\pi - \pi^*\right) + \theta_q\left(q - q^*\right) + \theta_{\Delta q}\left(\Delta q - \Delta q^*\right)$ (Orphanides, 2007),

where the term $\theta_i i_{-1}$ represents inertial behavior in setting interest rates

iii. Rule which employs different variables (e.g. unemployment gap):

$f = r^* + \pi^* + \beta\left(\pi - \pi^*\right) + \gamma\left(u^* - u\right)$ (Orphanides, 2002)

where the term $\gamma\left(u^* - u\right)$ represents unemployment gap (instead of GDP gap) – but still provides a measure of macroeconomic activity through Okun's law

or combination of these three modifications.

Svensson (1998, p.5-13) distinguishes two types of monetary policy rules:

a) Instrument rules
b) Targeting rules (forecast targeting)

Instrument rule is characterized as a monetary policy rule, which defines the instrument as a specific function of predetermined or/and forward-looking variables. Furthermore, if the instrument is only dependent on predetermined variables, the rule is called explicit instrument rule. Contrary to it is the implicit instrument rule, which relates the instrument to forward-looking variables only. The original Taylor rule can then be classified as a simple (has only few arguments) explicit instrument rule. Advantages of simple instrument rules according to Svensson (2001, p.5) are:

i. Simple instrument rules are well understood by outsiders and easy to verify
ii. Different modifications of the Taylor rule have achieved acceptable results under various model specifications and only exceptionally resulted in poor outcomes.

On the other hand, Svensson (2001, p.5) finds even more disadvantages to instrument rules:

i. Instrument rules do not yield optimal outcomes for several reasons – responds to only small part of information available to monetary authority, does not allow for judgment in policy conduct, leaves only limited space for history dependence.
ii. No central bank has committed itself to mechanically follow an instrument rule
iii. Empirical estimates of Taylor-type rules only explain two thirds of instrument-rate changes

The instrument rules are therefore in practice used more often as comparisons or base-lines for the actual policy evaluation.

Targeting rules refer to a more complex procedure, where "an economic model is used to generate conditional forecast paths for the target variables from the present onward associated with alternative feasible policies" (Woodford, 2000, p.100). Then, according to either minimization of a loss function or best fit with the targeted variable (inflation level), a forecast path is chosen by the central bank. The central bank then follows actions required by the selected scenario (in terms of instrument rate setting). Advantages of these rules are again specified in Svensson (2001, p.8-9):

i. Even though the procedure is more complex, with announced forecasts of the target variables, the outsiders can verify whether the targeting rule is followed
ii. The targeting rule (if specified correctly[11]) can lead to an optimal outcome
iii. Allows for judgment to be incorporated in the forecasts used in the targeting rule

Possible disadvantage of such rule stems from the dependence on exact dynamic trade-off between targeted variables, which is difficult to measure.

Critique of Taylor rules from a more micro-economical point of view is offered in Benhabib et al. (1999) and Benhabib et al. (2002), showing that the active (responds to

[11] See Svensson(2001) for details regarding the mathematics

inflation growth with more than one-to-one increase of interest rate) interest rate policy can lead to indeterminacy and even chaotic outcomes. Due to zero-bound on interest rates, liquidity trap (a steady state where nominal interest rate is close to zero and inflation is possibly negative) could arise as an equilibrium outcome of Taylor-type rule.

To conclude this section, characteristic of optimal Taylor-type rule is proposed, taking into account above mentioned arguments. Optimal monetary policy Taylor-type rule is described as a targeting rule which is active, forward-looking, history dependent[12] (incorporates interest rate smoothing) and allows for judgment to enter the instrument-setting process. However, caution and attention to above mentioned threats and disadvantages is necessary.

2.2 Taylor Rules and the Quarterly Projection Model

This section heavily draws on Coats et al. (2003), Chapter 4.

As mentioned in section 1.3.2, the Quarterly Projection Model is a very complex forecasting tool of the CNB, designed to capture the core flows of the macro economy. Within the CNB, the QPM fulfills three major functions: it is useful as a research apparatus in learning about the economy and evaluating policy options, other two roles are associated with the forecasting procedure. The model serves as an organizational framework for forecasting and describes the necessary steps to be taken (conditional on all the other assumptions and short-term scenarios) to meet the inflation target. Second role of the model within forecasts regards uncertainty. The QPM is used to produce and study alternative scenarios, assessing possible risks to the original forecast. Without the model, such a procedure would be extremely time demanding. It is important to note, that short-term forecasts and predictions are mainly duties of CNB's experts, and therefore the model is designed so as to perform well over the medium-term. Since the QPM was the first model developed for needs of the CNB, it was logical to start with a smaller model as far as scope is considered. The most important was to capture the key dynamics in macro economy – connections between output, inflation, interest rates, exchange rates and employment.

[12] Optimality of history-dependence and interest rate smoothing is demonstrated in Woodford (2003) and Woodford (2000) respectively.

For this purpose, a "gaps" model was developed in cooperation with the IMF. The name comes from the specification of the model, where dynamics of disequilibrium paths (i.e. deviations from equilibrium values) are analyzed, especially developments of these in the medium term. No supply side enters the model for the sake of simplicity, making the QPM a relatively simple model compared to e.g. a large-scale model used by Federal Reserve System. With more data and experience over the years, the CNB adjusted its forecasting tools and gradually headed towards adopting a general equilibrium model. This new general equilibrium model ("g3", mentioned above) became the core model of the CNB's Forecasting and Policy Analysis System in July 2008. Since only limited data sample is available for the use of the g3 model and no empirical analysis is possible, I will focus on the use of Taylor rules in the original QPM as described in Coats et al. (2003). Considering that all models discussed in section 3 work with data from the period when QPM was used, this choice is logical.

2.2.1 General Idea Behind the Model

Before concentrating directly on the QPM, one question is to be answered: What are the main channels for the interest rate to influence inflation and real economy? Provided that the Czech Republic is a small and open economy functioning under a flexible-exchange-rate regime, first of the channels is the exchange rate channel. Second channel is then represented by the Phillips curve.

1. Exchange rate channel (Coats et al., 2003)

The exchange rate channel combines Uncovered Interest Parity condition (UIP) and arbitrage condition on prices of traded goods. The latter condition can be written as follows: $\pi^T = \pi^W - \dot{s}$

where π^T is the rate of increase of traded goods prices in domestic currency, π^W is the rate of inflation in the foreign currency and $\dot{s}$ is the rate of change of the exchange rate between Czech koruna and the foreign currency. This condition formulates that real change of prices should be the same in all countries. The equation shows that under a condition that all goods are traded (π^T then equals overall domestic inflation), exchange rate will depreciate at a rate given by difference of the domestic and foreign inflation rates: $\dot{s} = \pi^W - \pi^T$

Positive value of $\dot{s}$ means appreciation of koruna.

The UIP condition builds on a theoretical foundation that in equilibrium, with fully mobile short-term capital, the risk-adjusted rates of return will be equal in all economies, no matter what currency is used. This condition can be expressed (neglecting risk premium) as follows:

$$i = i^{*} - \dot{s}$$

where i is the domestic nominal interest rate, i^{*} is the foreign nominal interest rate and $\dot{s}$ is again the rate of appreciation of the exchange rate between Czech koruna and the foreign currency. If the central bank decides to increase interest rates (all else equal), the higher rate will draw short term foreign capital, thus putting strong upward pressures on appreciation of the exchange rate.

Summarizing the above mentioned: Increase in the CNB's instrument will exert pressures on appreciation of the Czech koruna (UIP), appreciated koruna then affects the inflation of traded goods in a downward direction (traded goods condition) and since the Czech Republic is very open economy, lower inflation in traded goods will pull the overall inflation lower as well. The exchange rate channel is hereby shown.

2. The Phillips curve channel (Coats et al., 2003)

Under standard economic assumptions, increase in interest rates would lead to a decrease in aggregate demand, as saving would generate more additional income in future and adding capital would become cheaper. Therefore the response of excess demand ($ygap$) would be negatively correlated to a positive difference between the real interest rate and its equilibrium value ($rgap$):

$$ygap = -\beta \cdot rgap$$

In the conditions of an open economy such as the one of the Czech Republic, the exchange rate is also an important factor. Appreciated exchange rate will have two effects in the same direction: decreased demand for domestic goods in foreign markets (with appreciated koruna, these become more expensive) and also decreased demand for domestic goods in the domestic market as imports get cheaper and might substitute for domestic goods. This effect of deviation of the exchange rate from its equilibrium level ($zgap$) can be captured as:

$$ygap = -\beta_1 \cdot rgap - \beta_2 \cdot zgap$$

To link the effects on aggregate demand to inflation, Phillips curve in its simplest form can be used:

$$\pi = \pi^e + \lambda \cdot ygap$$

Substituting for $ygap$ we obtain:

$$\pi = \pi^e - \lambda\left(\beta_1 rgap + \beta_2 zgap\right)$$

The last equation shows a direct influence of interest rate change on inflation through the term $rgap$ and indirectly through the term $zgap$ (result of the UIP condition). The real economy or Phillips curve channel is hereby shown.

The model is in fact only a broader and more detailed version of the equation set above, including expectations, lags, labor market, import prices and energy prices. Primary objective to anchor inflation expectations can be demonstrated on the last equation above – in real equilibrium where all gaps are equal to zero, inflation is equal to its expected value.

2.2.2 Direct Link to Taylor Rules

The original QPM is a system of about 85 equations, linking the growth rates, levels and identities of the used variables. List of 14 core equations is to be found in the Appendix (taken from Coats et al. (2003), Chapter 4). All the equations are an important part of the entire model, but we are looking for a link between the QPM and Taylor rules. This connection is fully provided by equation (9) from the list:

$$rs_t = m_0 rs_{t-1} + \left(1-m_0\right)\left(rr_t^{eq} + E_t\pi 4_{t+4} + m_1\left(E_t\pi_{t+4} - \pi_t^{Tar}\right) + m_2 ygap_t\right) + \varepsilon_t^{rs}$$

where rs_t is the short-term (one quarter) interest rate at time t; rr_t^{eq} is the equilibrium real interest rate at time t; $E_t\pi 4_{t+4}$ is the CPI inflation forecast four quarters ahead at time t; π_t^{Tar} is the inflation target four quarters ahead at time t; $ygap_t$ is the output gap, defined as $ygap_t = \left(y_t - \overline{y}_t\right)\cdot 100$, y_t is a log of real GDP, $\overline{y}_t$ is a log of potential output and the scaling converts output gap to a percentage of potential GDP, at time t; ε_t^{rs} is a disturbance term, an independent, identically distributed random variable.

The equation above is a forward-looking reaction function of a Taylor type with inertial behavior, very similar to the one described in Horváth (2008). Comparing the two equations, we can see only a small difference:

$r_t = \left(1-\rho\right)\left[\overline{r} + \alpha\left(\pi_{t+i} - \pi_{t+i}^*\right) + \beta x_t\right] + \rho r_{t-1} + \varepsilon_t$ readjusting to the same form as the QPM:

$r_t = \rho r_{t-1} + \left(1-\rho\right)\left[\overline{r} + \alpha\left(\pi_{t+i} - \pi_{t+i}^*\right) + \beta x_t\right] + \varepsilon_t$ and then comparing to the latter equation:

$$rs_t = m_0 rs_{t-1} + (1-m_0)\left(rr_t^{eq} + E_t\pi 4_{t+4} + m_1\left(E_t\pi_{t+4} - \pi_t^{Tar}\right) + m_2 ygap_t\right) + \varepsilon_t^{rs}$$

ignoring the different labeling and more general form of the first equation (for $i=4$ the equations become even more similar), the only difference stems from nominal interest rate being used in the QPM and real interest rate being used in Horváth (2008).

Focusing on optimality (in terms described at the end of section 2.1) of the Taylor-type rule used in the QPM, we can show that the equation is:

a) Forward-looking – term $E_t\pi 4_{t+4}$ incorporates a four quarter ahead estimate (expectation) of inflation into the model
b) History dependent – term $m_0 rs_{t-1}$ represents inertial behavior (interest rate smoothing) of the model by introducing one quarter lag of the short-term interest rate to the model
c) Judgment augmented – sufficient space for judgment and experts' opinions is left by the coefficients m_0, m_1 and m_2 which are subject to calibration

From this point of view the reaction function of CNB fulfills three out of four from the above mentioned characteristics of an optimal monetary policy rule. Whether the rule is also active will be addressed shortly.

Important to mention is the process of calibration of the model as compared to estimation. In the procedure of estimation, coefficients are determined by the means of fitting the model to historical data, subjected to a criterion such as minimization of sum-of-squared errors. In case of the CNB and implementation of the QPM, estimation of the coefficients was not a feasible choice. For the Czech Republic, only a very limited data set was available at the given time, and the data was influenced by major restructuring of the economy and changes in political as well as monetary policy system. Therefore the data sample could not be taken as representative for future developments.

In case of the QPM, coefficients were determined by calibration. Calibration is a process of many steps, which combines estimation technique with logical thinking, experience from other similar economies and comparison with historical data to eliminate systematically biased predictions.

Seven years have passed since the implementation of the QPM and since July 2008 a general equilibrium model called g3 has taken the place of the central projection model. For the new model's reaction function, no empirical estimates are available due to the lack of data. Therefore I focus on the Taylor rules estimates regarding the use of QPM in the CNB's forecasting and prognostic apparatus.

3. Empirical Estimates of the Czech National Bank's Taylor Rules

In the past years, several articles estimating the forward-looking Taylor type rule the CNB were published. All of them were originally published as part of the CNB's Working Paper Series and use internal data from the CNB's database, which are not publicly available. Therefore I decided not to estimate the rule myself (also the methods such as use of multivariate Kalman filter or even simpler Hodrick-Prescott filter are beyond the bachelor thesis level), but rather sum up the already conducted research and perhaps link the results of Horváth (2007), Horváth (2008) and Podpiera (2008) to different conclusions, than the original articles focused on.

Original calibration of the reaction function, as described in Coats et al. (2003):

$$rs_t = m_0 rs_{t-1} + (1-m_0)\left(rr_t^{eq} + E_t\pi4_{t+4} + m_1\left(E_t\pi_{t+4} - \pi_t^{Tar}\right) + m_2 ygap_t\right) + \varepsilon_t^{rs}$$

was set as:

Table 2- calibration of the CNB's reaction function coefficients (Coats et al. 2003)

Parameter	Value
m_0	0,5
m_1	5
m_2	1

So the calibrated reaction function then can be expressed as:

$$rs_t = 0,5 rs_{t-1} + 0,5\left(rr_t^{eq} + E_t\pi4_{t+4} + 5\left(E_t\pi_{t+4} - \pi_t^{Tar}\right) + ygap_t\right) + \varepsilon_t^{rs}$$

$$rs_t = 0,5 rs_{t-1} + 0,5(rr_t^{eq} + E_t\pi4_{t+4}) + 2,5\left(E_t\pi_{t+4} - \pi_t^{Tar}\right) + 0,5 ygap_t + \varepsilon_t^{rs}$$

From the figure above we can conclude that the calibrated rule is also active (coefficient of 2,5 for the deviation of inflation from its target), fulfilling the fourth condition for optimality.

However, these theoretical results are quite different from the empirical estimates, no matter whether quarterly or monthly data are used, or whether 3 month PRIBOR or 2 week REPO rate is used as the response variable.

3.1 Two week REPO, quarterly data

The forward-looking Taylor rule reaction function using quarterly data and the 2W REPO rate as the response variable is estimated in Podpiera (2008). The article focuses on various estimation methods and bias of their parameters in the framework of censored interest rate changes (adjustments of the interest rate are discrete, as the CNB adjusts its rates by entire multiples of 25 basis points). As part of the study, a forward-looking rule is estimated in the following form:

$$i_t = \beta_0 i_{t-1} + (1-\beta_0)\left(r_t^{eq} + p_t^e + \beta_1\left(p_t^e - p_t^{tar}\right) + \beta_2 gap_t\right) + e_t$$

Where $\beta_0, \beta_1, \beta_2$ are the calibrated parameters (a parallel to m_0, m_1, m_2), r_t^{eq} is the real equilibrium interest rate, p_t^e is the inflation forecast four quarters ahead, p_t^{tar} is the inflation target for four quarters ahead, gap_t is the output gap and e_t is the error term. Data were taken from second quarter of 2003 to first quarter of 2006, yielding only twelve observations.

Estimation of the above described formula by the means of Ordinary Least Squares method resulted in following model:

$$i_t = 0{,}83 i_{t-1} + 0{,}17\left(r_t^{eq} + p_t^e\right) + 0{,}24\left(p_t^e - p_t^{tar}\right) + 0{,}09 gap_t + e_t$$

Empirical coefficients for the 2W REPO rate were therefore estimated as:

Table 3- estimate of coefficients for the 2W REPO rate (Podpiera, 2008)

Parameter	Value
β_0	0,83
β_1	1,41
β_2	0,53

Compared to the original calibration of the coefficients, the empirical estimation suggests, that the central bank employed a larger degree of interest rate smoothing (expressed by coefficient β_0) than originally proposed by the QPM. Reaction to missed inflation target (expressed by coefficient β_1) is on the other hand much smaller than originally calibrated.

3.2 Three month PRIBOR, monthly data

In Horváth (2007), similar forward-looking rule is estimated for a different dataset, biggest differences being the use of monthly data and 3 month PRIBOR as a response variable (3M PRIBOR was also used in the actual QPM). Primary focus of the article is on estimation of time-varying policy neutral interest rate using endogenous regressors, and application with regards to future development of inflation. As part of the article, forward-looking monetary policy rule is estimated and is defined as:

$$r_t = (1-\rho)\left[\overline{r_t} + \alpha\left(\pi_{t+i} - \pi^*_{t+i}\right) + \beta x_t\right] + \rho r_{t-1} + \varepsilon_t$$

where r_t is the 3-month PRIBOR rate (short-term interbank rate), $\overline{r_t}$ is the policy neutral interest rate, π_{t+i} is the central bank's inflation forecast for i periods ahead, π^*_{t+i} is the central bank's inflation target for i periods ahead, x_t represents the output gap and ε_t is the error term. Data set runs from January 2001 to September 2006 and the model is estimated using 69 observations. The only parameter allowed to vary over time is the policy neutral rate $\overline{r_t}$.

The above mentioned model is estimated in many variants[13], depending on the inclusion of bias correction terms, different inflation measures and different methods of GDP gap estimation. When significant, the regression coefficients were estimated with the following values:

Table 4- coefficients estimates for the 3M PRIBOR rate (Horváth, 2007)

Parameter	Value
ρ	0,41
α	0,28
β	0,63

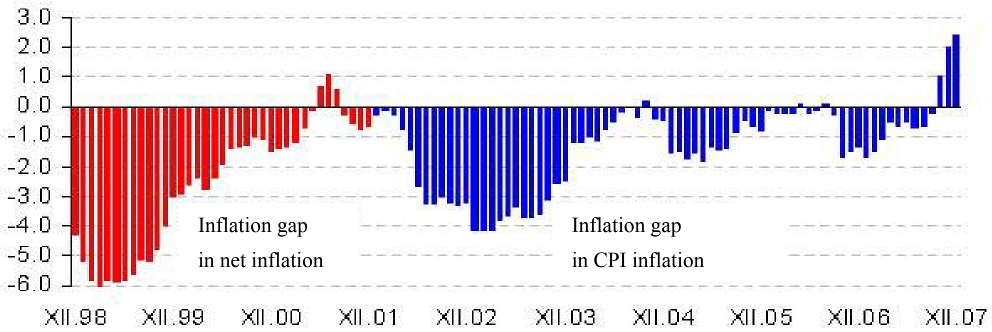
When the model was estimated as time invariant, the smoothing parameter ρ was estimated to be around $\rho_{inv.} = 0,9$. This result corresponds to previously shown estimate of $\beta_1 = 0,83$, which is also result of a time invariant model. On this example is shown, that time-invariant modeling of forward looking reaction function substantially overestimates the degree of interest rate smoothing.

[13] For all different specifications see Horváth (2007)

The time-variant model of interest rate is close to the original QPM calibration considering the interest rate smoothing parameter, but both time variant and invariant model specifications for both response variable have substantially smaller coefficients of the reaction to the missed inflation target (coefficients β_1, α respectively).

These two results can partially explain, why inflation in the Czech Republic was below target for most of the time in period from December 1998 to December 2007, illustrated in graph below.

Figure 3 – Inflation gap development, taken from Šmídková (Ed. 2008), Chapter 3



Skořepa in Chapter 3 of Šmídková (Ed. 2008, p.41) through purely statistical procedures shows, that undershooting of inflation targets can be blamed mostly on bias of the prognostic system. The smaller coefficients for inflation gap hinder the policy instrument from faster reaction and add to slower adjustment toward meeting the inflation target. However, we can see from the graph, that adjustments to the QPM gradually improved the performance and the inflation gap was closer to zero in the period of 2004-2006.

3.3 Asymmetry via Taylor rule estimate

Different use of a modified Taylor rule is implemented in Horváth (2008), where symmetry of monetary policy is questioned. There the original model is in following form:

$$i_t = (1-\rho)\left[\alpha + \beta_1 \pi_{above} + \beta_2 \pi_{below} + \gamma X_t\right] + \rho i_{t-1} + \varepsilon_t$$

where i_t is the response interest rate (3M PRIBOR), i_{t-1} is its one period lag, π_{below}, π_{above} together constitute inflation gap as described below, X_t stands for all other variables (such as GDP gap, exchange rate, foreign interest rate etc.) and ε_t is the error term.

π_{above} is defined as: $\pi_{above} = \pi^{f}_{t/t+4} - \pi^{*}_{t}$ if $\pi^{f}_{t/t+4} > \pi^{*}_{t}$, otherwise $\pi_{above} = 0$

π_{below} is defined as: $\pi_{below} = -\left(\pi^{f}_{t/t+4} - \pi^{*}_{t}\right)$ if $\pi^{f}_{t/t+4} < \pi^{*}_{t}$, otherwise $\pi_{below} = 0$

where $\pi^{f}_{t/t+4}$ is the inflation forecast in time t for four quarters ahead and π^{*}_{t} is the corresponding inflation target. Period of four quarters ahead was chosen to correspond with CNB's monetary policy horizon of 4-6 quarters.

To determine symmetry or asymmetry of the monetary policy rule, hypothesis of equality of coefficients β_1, β_2 is tested ($H_0 : \beta_1 = \beta_2$)

Estimation was conducted using quarterly data from period 1998 Q1 – 2007 Q3, yielding 39 observations in the sample. For simplicity, the hypothesis was tested using a simplified[14] model, reacting solely to the developments regarding inflation:

$$i_t = \alpha + \beta_1 \pi_{above} + \beta_2 \pi_{below} + v_t$$

This model was estimated for several different periods within the data sample with the most important results being[15]:

For the full data sample (1998Q1 – 2007Q3) the null hypothesis is rejected with coefficient $\beta_1 > \beta_2$, meaning that the monetary policy reacted stronger to inflation forecasts above the target, than to the forecasts below. However, without the first year of data, the null hypothesis could not be rejected for any period. Splitting the data in two parts, before the adoption of QPM and afterwards, Horváth (2008) concludes the following:

a) For the period of 1998-2002 (before QPM) the monetary policy was asymmetric and the monetary policy reaction was stronger to inflation forecasts above the target, then to those below the target.
b) For the period of 2003-2007 (with QPM) the monetary policy was symmetric, even though the coefficients were still larger for inflation forecast above the target. From this point of view, implementation of the QPM can be seen as one of the reasons for monetary policy to be symmetric.

This example shows that Taylor-like rules can be utilized in many different ways, not only as an ex-post analysis tool for interest rate level as it was originally devised.

[14] This does not mean, that all the other variables are ignored, they simply enter the equation indirectly within the inflation forecasts

[15] For all the results see Horváth (2008)

Conclusion

In this bachelor thesis, role of the so called Taylor rules in a sophisticated procedure of monetary authorities' instrument setting is addressed. On a particular example of the Czech National Bank author first described the role of a central bank in the economy as an authority whose goal is to maintain stability of price level through utilization of various policy instruments. Among these, the two-week repurchase rate (2W REPO) proved to be the most frequently used and also most influential regarding the developments in the real economy. Decision making process regarding setting of this specific interest rate then provides connection to the theory of Taylor rules – simple instrument rules for monetary policy conduct.

After reviewing the available literature on this topic, especially advantages and disadvantages of miscellaneous monetary policy regimes and various specifications of monetary policy rules, author came to following conclusions. Out of the three discussed monetary policy regimes, inflation targeting seems to be the best choice in the current economic situation of the Czech Republic. Its implementation by the Czech National Bank (following a period of disinflation under different monetary policy regimes) also corresponds to optimal procedure.

For the monetary policy rule, as represented by the forward-looking reaction function incorporated in a Quarterly Projection Model of the Czech National Bank, optimality conditions are also satisfied (or at least could be). These conditions (as described in multiple resources) consist of the history dependence of the interest rate reaction function, pritomnost of a forward-looking element in the reaction function and sufficient space for experts' knowledge and judgment in the forecasting and decision making process. Last condition defines the monetary policy as active – reacting with more than one-to-one change of interest rate to a change in inflation developments. Only the last condition seems to be broken as the empirical estimates in part three suggest. Based on data analysis for the Czech Republic (by Horváth and Podpiera), difference between the original calibration of the Czech National Bank's reaction function (described in Coats et al., 2003) and its empirical values was found. Coefficients for the inflation gap were estimated as smaller than one, therefore implying a non-active monetary policy. Among others, author sees this fact as one of the reasons for undershooting of inflation target in the Czech Republic for the period when the Quarterly Projection Model was used. Variability of Taylor rules' utilization is demonstrated in the last part, where symmetry of monetary policy conducted by the Czech National Bank was investigated.

All of the above mentioned ideas support authors believe that Taylor rules are not an obsolete concept without a use in practice. As was shown above, simple monetary policy rules can be used for both ex-post analysis, and after certain changes in specification also as a forecasting tool.

Space for further research in this area opens with implementation of a new forecasting model (called g3) by the Czech National Bank. When more data are available, empirical estimation of Taylor-like rule used in the new model will be an interesting exercise.

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http://www.cnb.cz/en/monetary_policy/instruments/

Appendix

Appendix 1 – CNB's inflation targets (http://www.cnb.cz/en/monetary_policy/inflation_targeting.html

Inflation targets

The CNB´s inflation targets set in terms of net inflation:

Year	Target level	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

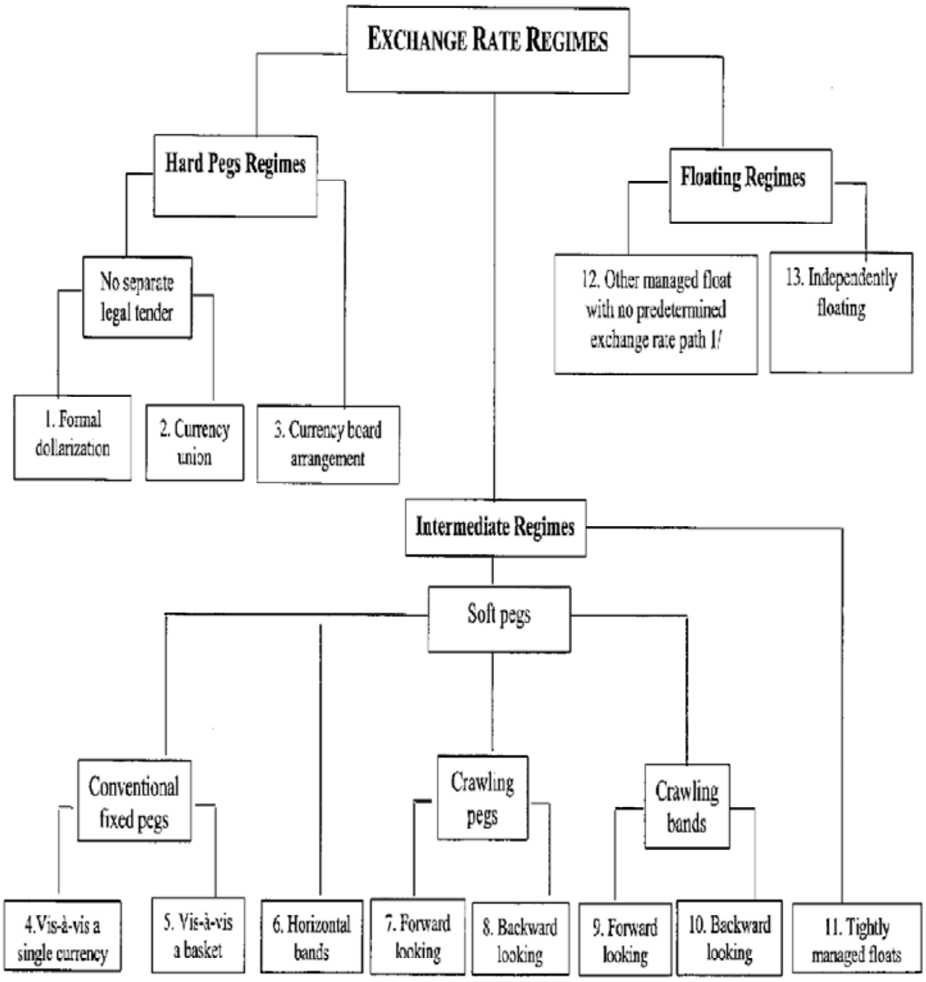
b) Target band set in terms of headline consumer price inflation for the January 2002 - December 2005 period:

	Month	Target level	Target month	Set in
Band starts	January 2002	3% - 5%	January 2002	April 2001
Band ends	December 2005	2% - 4%	December 2005	

c) The inflation target set in terms of headline inflation of 3% with effect from January 2006 to December 2009. The CNB strives to ensure that actual inflation does not differ from the target by more than one percentage point in either direction.
d) The inflation target set in terms of headline inflation of 2% with effect from January 2010 until the Czech Republic's entry to the euro area. As before, the CNB will strive to ensure that actual inflation does not differ from the target by more than one percentage point in either direction.

Appendix 2 – Classification of Exchange Rate Regimes (Bubula and Őtker-Robe, 2002, p.14)

Diagram 1. De Facto Classification of Exchange Rate Regimes



1/ Excludes tightly managed floats.

Appendix 3 – Comparison of the originál Taylor rule with actual Federal funds rate (Taylor, 1993, p.204)

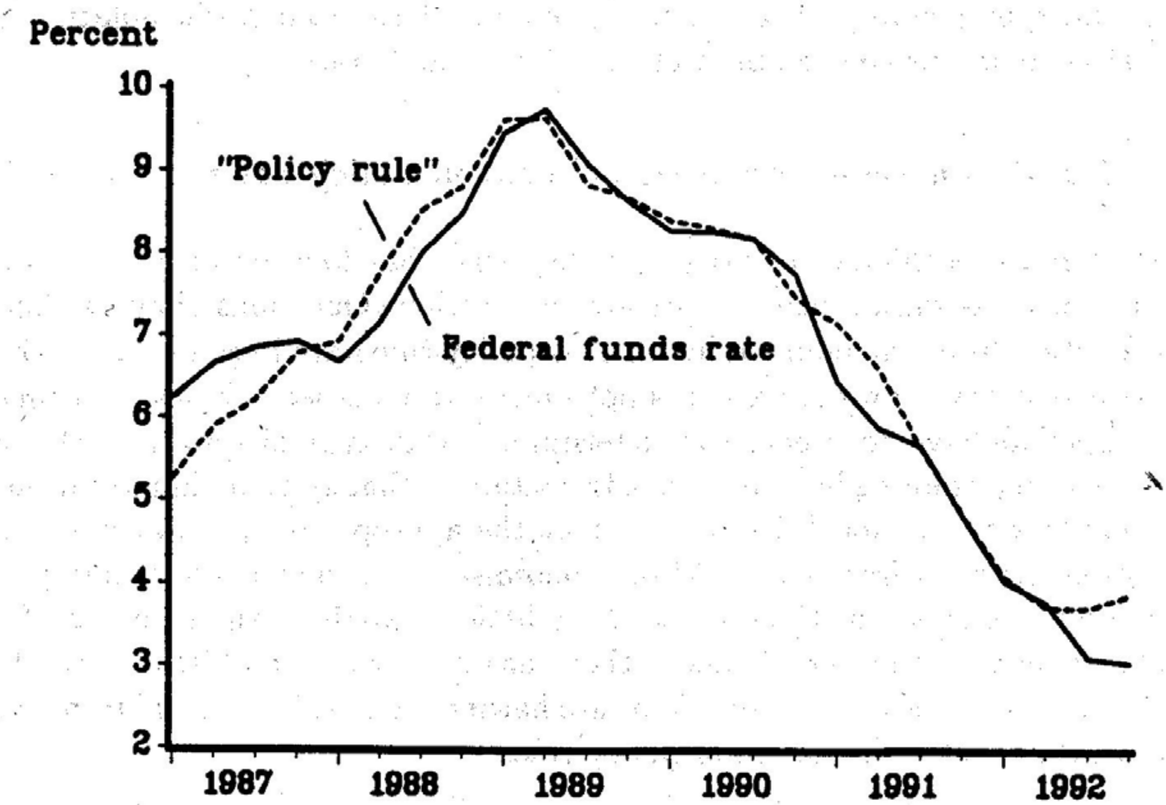


Figure 1. Federal funds rate and example policy rule.

Appendix 4 – 14 core equations from the CNB's Quarterly Projection Model, description in Coats et al. (2003), taken from Coats et al. (2003, p.70)

Table 1: The Main Equations of the Core Model

$$y_t = \bar{y}_t + ygap_t / 100 \quad (1)$$

$$u_t = \bar{u}_t - ugap_t \quad (2)$$

$$lz = ls + lcpi - gr\_lcpi \quad (3)$$

$$\pi core_t = a_0 \left[\pi 4_t^{MexE} + 100 * \Delta_4 lz_t^{eq}\right] + a_1 E0_t \pi 4_{t+1} + \left(1 - a_0 - a_1\right) \pi core_{t-1} + a_2 ygap_{t-1} + \varepsilon_t^{\pi} \quad (4)$$

$$ygap_t = d_0 ygap_{t-1} - d_1 rr12gap_{t-1} - d_2 rr4gap_{t-1} - d_3 gr\_rrgap_{t-1} - d_4 lzgap_{t-1} + d_5 gr\_ygap + \varepsilon_t^{ygap} \quad (5)$$

$$ugap_t = f_0 ugap_{t-1} + f_1 ygap_t + \varepsilon_t^{ugap} \quad (6)$$

$$ls_t = g_0 E_t ls_{t+1} + (1 - g_0)(ls_{t-1} - 2E0_t(\pi 1_{t+1} - gr\_\pi 1_{t+1})/400 + 2\Delta lz_t^{eq}) + (rs - gr\_rs - prem)/400 + \varepsilon_t^{ls} \quad (7)$$

$$prem_t = rr_t^{eq} + 100(lz_t^{eq} - lz_{t-4}^{eq}) - gr\_rr_t^{eq} + \varepsilon_t^{prem} \quad (8)$$

$$rs_t = m_0 rs_{t-1} + (1 - m_0)(rr_t^{eq} + E_t \pi 4_{t+4} + m_1(E_t \pi 4_{t+4} - \pi_t^{Tar}) + m_2 ygap_t) + \varepsilon_t^{rs} \quad (9)$$

$$rs4_t = j_0 + j_1 \cdot (\textstyle\sum_{i=0}^{3} E_t rs_{t+i}) / 4 + (1 - j_1) \cdot rs + \varepsilon_t^{rs4} \quad (10)$$

$$rs12_t = p_0 + p_1 \cdot (\textstyle\sum_{i=0}^{11} E_t rs_{t+i}) / 12 + (1 - p_1) \cdot rs + \varepsilon_t^{rs12} \quad (11)$$

$$\pi_t^{MexE} = k_1(gr\_\pi_t - 400(ls_t - ls_{t-1})) + (1 - k_1)\pi_{t-1}^{MexE} - k_2 \cdot 100\,(lpmexe_{t-1} - gr\_lcpi_{t-1} + ls_{t-1} + k_0) + \varepsilon_t^{\pi^{MexE}} \quad (12)$$

$$\pi_t^{ME} = h_1(\pi oil_t - 400(lsu_t - lsu_{t-1})) + (1 - h_1)\pi_{t-1}^{ME} - h_2 \cdot 100\,(lpme_{t-1} - lpoil_{t-1} + lsu_{t-1} + h_0) + \varepsilon_t^{\pi^{ME}} \quad (13)$$

$$\pi_t^{EN} = n_0 \left[\pi 4_t^{ME} + 100 * \Delta_4 lz_t^{eq}\right] + n_1 E0_t \pi 4_{t+1} + \left(1 - n_0 - n_1\right) \pi_{t-1}^{EN} + n_2 ygap_{t-1} + \varepsilon_t^{\pi^{EN}} \quad (14)$$