Monetary policy and the term structure of interest rates in a small open economy - a model framework approach

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Comments welcome

Abstract

Using a simple single-equation approach, many studies have shown that the term structure of interest rates or its approximation - the term spread is a potentially useful indicator of future inflation and/or future real economic activity. We argue that these results may be biased due to the insufficiencies of the single-equation approach and that the predictive ability must be analyzed from within a model framework. Simple general equilibrium macroeconomic model of a small open economy is introduced and the indicative properties of the term structure are discussed from within its framework.

Our main contribution to the literature is threefold. First, we show that the predictive ability of the term spread is not structural but monetary policy dependent. Second, we argue that the term spread's predictive ability with regard to future inflation (real economic activity) increases with increasing weight on inflation (real economic activity) stabilization in central bank's reaction function. Third, we show that undestanding the way expectations are formed is an important prerequisite for using the term structure as an indicator for monetary policy.

Apart from these general findings, the predictive power of the term spread is examined in the case of the Czech economy. It is shown that the term spread between one year and three month PRIBOR interest rates of one percentage point indicates that agents expect inflation to be almost one percentage point above the target six quarters ahead.

JEL Codes: E41, E52, F41

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1. Introduction

The forward-looking character of monetary policy, that is due to "long and variable lags" in transmission, combined with uncertainty of future economic development requires that some kind of intermediate policy target or forecast be employed. Recently, however, many central banks changed their policy strategy to direct inflation targeting and the weight put on intermediate targets (e.g. money stock in monetary targeting) thus went down substantially. At the same time, this led to a marked increase in the importance of macroeconomic forecasts for monetary policy. Inflation targeting is a strategy essentially based on (inflation) forecasts, a fact reflected by its complementary label "inflation forecast targeting".

While there is no alternative for central bank's own (structural model-based) inflation forecast in the conduct of monetary policy through inflation targeting, various indicators may serve as a useful cross-check and a supplementary policy guide. We think of indicators as variables from which it is possible to extract agents' expectations about future economic development even though they do not necessarily cause this future development. Apart from reflecting market expectations, indicators bear other favorable properties that distinguish them from macroeconomic forecasts: they are usually available with higher frequency and they are not subject to data revisions.

Various authors have shown that one of the most useful monetary policy indicators is the term structure of interest rates. The whole term structure is usually approximated by a single variable called *term spread*, calculated as a difference between long-term and short-term interest rates. What does the term spread tell us? There are basically two separate lines of research in the area. The first tests the predictive power of the term spread for future inflation. Mishkin (1990a, 1990b, 1991), Fama (1990), Jorion-Mishkin (1991), Ragan (1995), Estrella-Mishkin (1997), Day-Lange (1997), Breedon-Chadha (1997) or Kozicki (1998) argue that positive current term spread is associated with positive future inflation or its dynamics, and vice-versa. The second line of research is aimed at examining the predictive power of the term spread for future real economic activity. Hu (1993), Plosser and Rouwenhorst (1994), Cozier and Tkacz (1994), Bernard and Gerlach (1996), Estrella and Mishkin (1996), Haubrich and Dombrosky (1996), Bonser-Neal and Morley (1997), Kozicki (1997), Smets and Tsatsaronis (1997), Estrella (1997), Attna-Mensaha and Tkacz (1998) or Berk and Van Bergeijk (2000) show that positive current term spread is associated with future rise in real economic activity, and vice-versa. The results of those of the mentioned studies that take a multi-country approach are reported in table A1 in the Appendix. Similar research has also been conducted in the context of the small open Czech economy by Kotlán (1999a, 1999b) who tests the indicative property of the term spread for future inflation and future real economic activity respectively. The term spread has been found to forecast future inflation with a lead of 6 quarters and future real economic activity 3 quarters ahead.

The empirical methodology of the above mentioned studies is usually based on standard reduced form regressions or VARs without much discussion of the underlying theory. We want to argue that the results based on such an approach are subject to three types of criticism. First, it is unclear whether rising (falling) term spread in any moment in time indicates future rise (fall) in inflation or in real economic activity or in both and what the future levels of these variables should be. Second, even though monetary policy is conventionally believed to affect the term spread to a great extent, the mentioned approaches do not take its role explicitly into account. This point is further discussed in the following chapter in connection with the rational expectations hypothesis (REH). Third, the reduced form techniques applied are by themselves not well fit to evaluate the indicative content of the term structure or any other indicator. The idea behind this crucial argument was put forward by Woodford (1994) and further refined by Bernanke and Woodford (1997). Let us provide a simple informal exposition of the argument. Suppose a central bank whose only objective is to keep inflation at the level given by its inflation target uses a certain variable called X as the only indicator of future inflationary pressures. Suppose positive X indicates future inflation above the target and negative X indicates future inflation below the target. Since the bank's goal is too keep inflation on target, it will – based on what the indicator suggests – take such measures so as to reach the target in the future. In the end, if X is used for setting monetary policy and if the policy is successful, what shall we see in the data? We will most likely see that while X has moved around, inflation has stayed at the target level. Reduced form econometric techniques might then lead to a conclusion that there is no relation between indicator X and (lagged) inflation.[2]

[2] The same argument applies to the reason why it is often the case that regressing inflation data on lagged values of central bank's interest rates leads to a conclusion that the central bank does not affect inflation. This is one of the reasons why it is crucial that inflation forecasts used for monetary policy are based on a structural

These criticisms can be avoided if the predictive power of the term spread is examined from a perspective of a general equilibrium macroeconomic framework.[3] The idea of looking at the term structure of interest rate from within a broader range of macroeconomic relations is not new. Mankiw and Miron (1986), McCallum (1994), Rudebusch (1995) and Roley and Sellon (1996) use simple two-equation systems composed of the REH-based term structure equation and central bank's reaction function in order to improve on the empirical results of testing the REH. Complex general equilibrium macroeconomic models have, however, been used in this context only in several studies. Turnovsky (1989) examines interactions of various macroeconomic policies and the term structure using a simple macro model. Fuhrer and Moore (1995) in their seminal study look at the observed correlation between the Fed Funds rate and real economic activity through following interest rate transmission along the yield curve. Eijjfinger et al. (2000) discuss implications of the REH for inflation targeting. Finally, Estrella (1998) whose approach is closest to ours, analytically solves a simple macroeconomic model with emphasis on directly linking the term spread with the predicted variable (inflation, real economic activity). Although we follow up on this body of research, our aim and approach differ.

In this paper we re-examine the relationship(s) between the term spread and future inflation and/or future real economic activity. Our goal is to find out whether the proposed relationship is structural or policy dependent and whether it is influenced by the way in which agents form expectations. The approach we take differs in three respects. First, while all the studies mentioned in the previous paragraph examine the term structure indicative properties within a closed economy, we are the first to do so using a small open economy modeling framework. For this purpose we choose the Czech economy. Second, and again contrary to the mentioned studies, our key model equations are estimated and the results should thus closely track the real data. Third, we examine the relationship using model simulations, not analytical solutions. The rest of the paper is organized as follows. The model is introduced in chapter 2. Chapter 3 examines the role of monetary policy goals and expectations formation on the predictive ability

model.

[3]It could be argued that in order to completely avoid the criticisms, the policy related model coefficients should all be calibrated based on micro foundations. However, as will be discussed in the following chapter, reduced form estimation might be an option in cases when state-of-the-art theory contrasts the real world data.

of the term spread using model simulations. Finally, chapter 4 concludes.

2. The model

For our purposes we chose to build a quarterly monetary business cycle model. While building the model, three general principles were applied. First, behavioral equations should be firmly grounded in economic theory. Second, the model should be as simple as possible. And last but not least, the equations should closely resemble the Czech economy. Where these principles come into conflict, the latest one is chosen as a guiding one and comments on possible alternative specifications are provided.

IS curve

The first equation specfies aggregate demand determination. All variables are deviations from long-term equilibrium trend:

$$y_t = \alpha_{11} y_{t-1} + \alpha_{12} R_{t-1} + \alpha_{13} y^*_{t-3} + \alpha_{14} q_{t-1} + shock^{IS}_t \tag{1}$$

The left-hand side (LHS) variable y_t is the output gap. The data were obtained by subtracting quarterly real GDP data from estimated potential output series using Hodrick-Prescott (HP) filter.[4] The output gap enters the right hand side (RHS) of equation (1) with a one period lag. Optimizing-agent-based forward-looking specification complemented by explicitly modeled habit formation – in order to reflect high output persistency – as in Fuhrer (2000) or McCalum (2001) was judged inferior to the final specification based on the above mentioned principles, namely data consistency and simplicity principle.[5] The second term on the RHS R_{t-1} is one period lagged real long-term interest rate. Here, we use 1Y PRIBOR (Prague Interbank Offered Rate) deflated by expected CPI inflation. As the data on inflation expectations in the Czech economy are only available since May 1999, we approximate the expectation formation process.

[4] In the case of the domestic output gap, we had a strong view as to the current output gap value. To account for this view, variant of HP filter due to Laxton-Rose-Xiu (LRX) was used that makes it possible to expertly adjust the end-point of the gap (-1,0 p.p. in 1Q2001 in this case).

[5] Further, the optimizing approaches apply to consumption, which usually forms a smaller part of the total GDP in small open economies that in large closed economies.

Concretely, we suppose that one fifth of agents form expectations rationally (actual CPI inflation 4 quarters ahead, i.e. "perfect foresight") and four fifths adaptively (actual CPI inflation lagged one quarter, i.e. the last observation). We suppose the same expectations formation process in the baseline model simulations in chapter 3 and thus set $\beta_{11} = 0{,}8$ in equation (10) below. In simulations, long-term real interest rate is determined by the real version of the term structure equation (equations 5 and 7 below). The third term on the RHS y^*_{t-3} stands for three periods lagged foreign demand. The lag reflects our belief on the relatively long duration of foreign trade contracts. Foreign demand is proxied by German GDP gap. The forth term on the RHS q_{t-1} is one period lagged real exchange rate representing relative price between domestic and foreign goods that influences net exports. Note that a rise in q stands for depreciation of the exchange rate. Since most of the Czech foreign trade takes place with Germany and other EU countries, CZK/DEM (equivalent in dynamics to CZK/EUR since 1999) exchange rate deflated by CPI rates of inflation is used. It was mentioned that all variables are deviations from trend. In terms of the real exchange rate we think of the observed long-term appreciation (about 5 % year to year) as reflecting real convergence and Balassa-Samuelson driven relative price structure adjustment. The last term on the RHS $shock^{IS}_t$ is a demand shock.

The coefficients were estimated by OLS using data for 3Q1994 - 1Q2001.[6] Their values correspond to economic intuition. The influence of the lagged output gap $\alpha_{11} = 0{,}97$ confirms very high persistency of real economic activity and the influence of the foreign demand $\alpha_{13} = 0{,}47$ reflects high income elasticity of Czech exports as well as the fact that exports form a substantial part of Czech GDP. The level of long-term real interest rates 1 p.p. above equilibrium causes, with a one quarter lag, fall of real output one fifth of a percentage point below equilibrium ($\alpha_{12} = 0{,}22$), the influence of the real exchange rate is about the same in magnitude (α_{14}= -0,20).

[6] The coefficients were all significant at standard levels; adjusted R2 equaled 0,95; LM (4) test was at 4,36 and S. E. of regression was 0,01.

Phillips curve

The second equation - a "Phillips curve" - links nominal and real variables supposing short-term stickiness in prices and wages. Our specification is in line with Calvo's (1983) model of staggered prices setting, hence the introduction of forward-looking inflation expectations on the RHS of equation (2):

$$\pi_t = \alpha_{21}\Pi^e_{t+4} + \alpha_{22}\pi^*_{t-1} + (1 - \alpha_{21} - \alpha_{22})(s_t - s_{t-1})\,4 + \alpha_{23}y_t + shock^{PC}_t \qquad (2)$$

The term on the LHS π_t stands for quarter to quarter annualized CPI inflation. The first term on the RHS Π^e_{t+4} represents current inflation expectations of year to year inflation 4 quarters ahead (equation 9 below). This specification reflects a common belief that the higher the inflation, the more frequently contracts get re-negotiated. Consequently, there are lower nominal rigidities in the economy. While this may not be the case of other small open transition economies, in the Czech economy we suppose an average contract duration of one year, and hence we work with 4 quarter ahead inflation expectations. In estimations, expected inflation is determined as described above, equation (10) is used for simulations. The second term on the RHS π^*_{t-1} stands for one period lagged foreign quarter to quarter annualized inflation, proxied by German PPI. The third term $(s_t - s_{t-1})$ represents quarter to quarter (annualized in eq. 2) change in nominal CZK/DEM exchange rate. These two terms are intended to capture the foreign influence on the domestic price development. The choice of German PPI rests on the idea that this price index reflects the influence of both intermediate goods prices and raw material prices on the domestic price formation process.[7] The imposed linear homogeneity in the inflation terms of equation (2) reflects the assumption of vertical long-term Phillips curve: there is no long run trade-off between inflation and growth. The fourth term y_t is the output gap and reflects the price pressures arising from excess demand. We believe that the current output gap captures the influence of past excess demand (due to high output persistency) but also makes it possible to grasp the role of forward-looking agents on price determination. The last term on the RHS $shock^{PC}_t$ is a "cost-push" supply shock.

[7] Imported inflation could, of course, be modeled using alternative specifications. For instance, it would be possible to trace the separate influences of import prices, raw material prices and complement the current setting by the CZK/USD exchange rate reflecting the trade in raw materials.

The coefficients estimated by OLS are in line with our expectations and small open economies stylized facts.[8] From the "inflation terms", foreign inflation (0,46) together with the nominal exchange rate dynamics (0,22) have the strongest influence. Inflation expectations enter the equation with expected sign, however, the coefficient is insignificant on standard levels. We believe this result may be connected to our specification of the expectation formation process. Since we experiment with this process later on, we decided to calibrate this coefficient on the level of the original estimate (0,32). This corresponds to international evidence, see for example Bank of England (1999) or Laxton and Scott (2000). The estimates further showed that cyclical position of the economy has strong influence on the determination of prices. Real output standing one percentage point above its potential increases inflation by 0,61 p.p.

Uncovered Interest Rate Parity

The arbitrage-based UIP specification posits that the expected change in domestic exchange rate is equal to the current differential between domestic and foreign interest rates reduced by a risk premium:

$$s^e_{t+1} - s_t = \left(I_t - I^*_t - disp_t\right)/4,$$

where s^e_{t+1} is expected nominal exchange rate one period ahead, s_t stands for current nominal exchange rate. Exchange rate is expressed in domestic units per unit of foreign currency and as was mentioned above, rise in s_t reflects a depreciation. I_t and I^*_t stand for long-term (here one year) nominal domestic and foreign interest rate respectively.[9] The term $disp$ is to capture all the disparities between actual exchange rate development and that implied by risk-free UIP. These disparities can be attributed both to the risk premium and to temporary shocks. As an example of transition-economy-specific temporary shock consider a foreign capital inflow driven appreciation of domestic currency that is due to privatization of domestic assets. Expected exchange rate can be modeled in various ways. In the equation below we think of the agents in the financial market to be divided into two groups. One group of participants with weight

[8] Adjusted R2 equaled 0,42; DW test was at 2,18 and S. E. of the regression was found to be just 0,03.

[9] For a discussion of proper interest rate maturity to enter UIP equation see Derviz (1999). Note that the interest rate differential is divided by four to reflect quarter to quarter specification.

α_{31} forms "model consistent" expectations while the other group with weight $(1 - \alpha_{31})$ forms expectations by adding expected equilibrium real appreciation (Δq_t^{eq}) adjusted by expected inflation differential ($\pi_{t+1}^e - \pi_{t+1}^{e*}$) to the last observed exchange rate value.[10] This is to reflect the common knowledge of real exchange rate trend appreciation in converging economies mentioned already in the discussion of the aggregate demand equation. In line with past data we set $\Delta q_t^{eq} = 5$ %. Formally:

$$s_{t+1}^e = \alpha_{31} E_t s_{t+1} + (1 - \alpha_{31}) \left[s_{t-1} + \left(\Delta q_t^{eq} + \pi_{t+1}^e - \pi_{t+1}^{e*} \right) /4 \right]$$

This specification not only tracks the data closer but also partially solves too high a volatility of exchange rate usually observed in models with pure UIP specification. We set the fraction of agents forming exchange rate expectations in a "model-consistent" manner equal to that on the goods market, i.e. $\alpha_{31} = 0{,}2$.[11] We later experiment with this coefficient. Combining the two equations and supplementing the result with a shock term ($shock_t^{UIP}$), we obtain:

$$\begin{aligned} s_t &= \alpha_{31} E_t s_{t+1} + (1 - \alpha_{31}) \left[s_{t-1} + \left(\Delta q_t^{eq} + \pi_{t+1}^e - \pi_{t+1}^{e*} \right) /4 \right] \\ &\quad - \left(I_t - I_t^* - disp_t \right) /4 + shock_t^{UIP} \end{aligned} \quad (3)$$

[10] Even though the real exchange rate is CPI based (see eq. 1), we proxy foreign inflation in equations (3) and (9) below by German PPI. We believe this simplification does not have a great impact on the results. Alternatively we could explicitly model the connection between German PPI and CPI (or Czech CPI and PPI) but this would go against our simplicity principle.

[11] One the one hand, it could be argued that agents on the financial market are more forward-looking than agents on the goods market. On the other hand, though, it has been argued that the best exchange rate prediction is a naive random walk model. Further, we believe most agents will put a strong weight on the known equilibrium long-term appreciation.

Central bank reaction function

The reaction function is to capture the agents' perceived pattern of central bank behavior. We do not attempt to explicitly derive reaction function through loss function optimization and instead suppose a standard forward-looking equation as in Clarida, Gali and Gertler (1997) or Woodford (2000):

$$i_t = \alpha_{41} i_{t-1} + (1 - \alpha_{41}) \left[r_t^{eq} + \Pi_{t+4}^{tar} + \alpha_{42} \left(\Pi_{t+4}^{e} - \Pi_{t+4}^{tar} \right) + \alpha_{43} y \right] + shock_t^{RF} \tag{4}$$

The LHS variable i_t is 3M PRIBOR interest rate that closely tracks the actual Czech national bank's instrument 2W repo rate. The RHS includes deviation of four quarters ahead expected inflation from the corresponding inflation target (Π_{t+4}^{tar}) and an output gap term. The first two terms in brackets stand to represent equilibrium nominal short-term interest rate as a sum of equilibrium real short-term interest rate (r_t^{eq}) and a corresponding inflation target. Equation (4) is supplemented by one period lagged short-term nominal interest rate to reflect the observed persistence in short rates. This so called "interest rate smoothing" may be explained by monetary policy uncertainties, central bankers' fear from "loosing face" or simply by an effort not to destabilize the markets.[12] The last term in equation (4) stands for a reaction function or a "monetary" shock.

The coefficients were calibrated using the ranges estimated by Clarida, Gali and Gertler (1997). The authors examining reaction functions of Germany, Japan, USA, UK, France and Italy came up with the range of 0,9 - 0,95 for α_{41}, 0,9 - 2,04 for α_{42} and 0,19 - 0,88 for α_{43}. We experiment with the values of these coefficients in chapter 3 but the baseline simulations are based on $\alpha_{41} = 0{,}8$; $\alpha_{42} = 2$ a $\alpha_{43} = 0{,}9$. This means we start off with less aggressive "smoothing" coefficient and upper bound coefficient on deviation of inflation from target. This is to reflect a more aggressive policy usually observed in the first years after the switch to inflation targeting strategy that is due both to credibility problems and the fact that many central banks use inflation targeting for disinflation purposes. At the same time we increase the weight assigned to output stabilization. This should reflect the fact that many central banks of

[12] Lansing (2001) interestingly argues that the observed persistency in short-term interest rates is given by central bank's inability to identify changes in trend growth of potential output.

small open transition economies implicitly target 'sustainable' external balance and that this balance is driven to a large extent by excessive demand pressures.

Long-term interest rate determination - rational expectations hypothesis

The last behavioral equation determines the long-term nominal interest rate based on the REH and is understandably a key relationship in our model. The REH can be formally expressed as:

$$I_t = \alpha_{51} i_t + (1 - \alpha_{51}) \frac{1}{4} (i_t + E_t i_{t+1} + E_t i_{t+2} + E_t i_{t+3}) + z_t, \tag{5}$$

where α_{51} represents the share of agents that form their expectations about future short-term interest rates in a rather adaptive way. If α_{51} equals zero, the equation collapses into expectations hypothesis. The last term z_t is a term premium. We suppose it evolves according to an autoregressive process of the form:

$$z_t = \alpha_{52} z_{t-1} + shock_t^{TS}, \tag{6}$$

where $shock_t^{TS}$ is a term premium shock with persistency given by α_{52}. We start off by supposing α_{52} equals zero, i.e. no persistency. The term premium reflects agents' uncertainty on future interest rate behavior and could be decomposed into uncertainty about future central bank reaction function and future shocks hitting the economy. Since the agents that are unsure about the CB's reaction function may prefer to set current long-term nominal interest rate at current short-term interest rate level, the first type of uncertainty can also be modeled by increasing α_{51}. This is done in the following chapter.

Although empirical tests of the REH have long been quite popular, the results remain mixed. This may be partly due to mis-specifications of some of the tests, as pointed out by Bekaert, Hodrick and Marshall (1997). Theretical reasons or the empirical failure of the REH are put forth by Mankiw and Miron (1986) and McCallum (1994). The authors examine the influence of monetary policy on the validity of the REH in practice. They argue that the high "interest rate smoothing" that results in high autocorrelation of short-term interest rates, may stand behind the observed high influence of current short-term interest rates on long-term interest rates (coefficient α_{52} above). The first study even concludes that the REH started to fail in 1914 when the Fed was established. We believe that exactly for the mentioned reasons – the influence of monetary policy on the REH – it is insufficient to test the REH using a single-equation approach. If this influence is to be taken into account, one needs to endogenously model the behavior of monetary authority as well. This is the approach we take below. The baseline simulations are based on the results of Kotlán (1999c), who confirms the validity of the REH in the Czech money market by comparing actual long-term interest rates with those *implied* by the *current* term spread. We thus start off by setting α_{51}equal to zero.

Exogenous variables

Instead of explicitly modeling the behavior and the inter-relations of exogenous variables, we simply suppose that foreign inflation, output gap and interest rates evolve independently of each other based upon an autoregressive process. This is supplemented by a stochastic term with zero mean value that serves as a shock to foreign variables at the same time. The autoregressive coefficient is set to 0,5 in equation (13) and (14) determining foreign inflation and output gap respectively, and to 0,8 in equation (15) determining foreign long-term interest rates.

The final specifications of the model equations including the values of the coefficients as discussed above that will be used for our baseline simulations in the following chapter are reported below. The model characteristics have been checked using a series of simulations. Specifically we ran simulations of five standard *unexpected temporary* (1 quarter) one percentage point shocks: demand, supply (cost push), foreign inflation, exchange rate and reaction function shocks simulations were undertaken. The responses (deviations from equilibrium) over 16 quarters are plotted in figures A1 - A5 in the Appendix. They have been compared to the ones of Svensson's (2000) small open economy model and found broadly consistent.

Summary of the model and baseline coeficients

$$y_t = \alpha_{11} y_{t-1} + \alpha_{12} R_{t-1} + \alpha_{13} y^*_{t-3} + \alpha_{14} q_{t-1} + shock_t^{IS} \tag{1}$$

$$\pi_t = \alpha_{21} \Pi^e_{t+4} + \alpha_{22} \pi^*_{t-1} + (1 - \alpha_{21} - \alpha_{22})(s_t - s_{t-1})\, 4 + \alpha_{23} y_t + shock_t^{PC} \tag{2}$$

$$s_t = \alpha_{31} E_t s_{t+1} + (1 - \alpha_{31}) \left[s_{t-1} + \left(\Delta q_t^{eq} + \pi^e_{t+1} - \pi^{e^*}_{t+1} \right)/4 \right]$$
$$- (I_t - I^*_t - disp_t)/4 + shock_t^{UIP} \tag{3}$$

$$i_t = \alpha_{41} i_{t-1} + (1 - \alpha_{41}) \left[r_t^{eq} + \Pi^{tar}_{t+4} + \alpha_{42} \left(\Pi^e_{t+4} - \Pi^{tar}_{t+4} \right) + \alpha_{43} y \right] + shock_t^{RF} \tag{4}$$

$$I_t = \alpha_{51} i_t + (1 - \alpha_{51}) \frac{1}{4} (i_t + E_t i_{t+1} + E_t i_{t+2} + E_t i_{t+3}) + z_t \tag{5}$$

$$z_t = \alpha_{52} z_{t-1} + shock_t^{TS} \tag{6}$$

$$R_t = I_t - \Pi^e_{t+4} \tag{7}$$

$$q_t = s_t - \pi_t - \pi^*_t \tag{8}$$

$$\Pi^e_{t+4} = \frac{1}{4} \left(\pi^e_{t+1} + \pi^e_{t+2} + \pi^e_{t+3} + \pi^e_{t+4} \right) \tag{9}$$

$$\pi^e_{t+1} = \beta_{11} \pi_{t-1} + (1 - \beta_{11}) E_t \pi_{t+1} \tag{10}$$

$$i_t^{eq} = r_t^{eq} + \Pi^{tar}_{t+4} \tag{11}$$

$$spread = I_t - i_t \tag{12}$$

$$\pi^*_t = \gamma_{14} \pi^*_{t-1} + shock_t^{\pi^*} \tag{13}$$

$$y^*_t = \gamma_{15} y^*_{t-1} + shock_t^{y^*} \tag{14}$$

$$I^*_t = \gamma_{16} I^*_{t-1} + shock_t^{I^*} \tag{15}$$

Coefficient	Value (S.E. if estimated)	Interpretation	Equation
α_{11}	0,97 (0,05)	Output gap persistency	(1) IS curve
α_{12}	-0,22 (0,08)	Long-term real interest rate	
α_{13}	0,47 (0,26)	Foreign output gap	
α_{14}	0,20 (0,05)	Real exchange rate	
α_{21}	0,32 (0,31)	Inflation expectations	(2) Phillips curve
α_{22}	0,46 (0,32)	Foreign inflation	
$(1-\alpha_{21}-\alpha_{22})$	0,22	Nominal exchange rate dynamics	
α_{23}	0,61 (0,28)	Output gap	
α_{31}	0,2	Fraction of model consistent exp.	(3) UIP
α_{41}	0,8	Interest rate smoothing	(4) CB's reaction function
α_{42}	2	Inflation gap	
α_{43}	0,9	Output gap	
α_{51}	0	Fraction of non-REH agents	(5) Long IR determination (REH)
α_{52}	0	Term structure shock persistency	(6) Term structure shock eq.
β_{11}	0,8	Fraction of backward-looking agents	(10) Inflation expectations
γ_{13}	0,5	Autoregressive foreign inflation	(13) Foreign inflation
γ_{14}	0,5	Autoregressive foreign output gap	(14) Foreign output gap
γ_{15}	0,8	Autoregressive foreign long-term IR	(15) Foreign long-term interest rates

3. The term spread as an indicator

After discussing the motivation in the first chapter and introducing the model in the previous chapter, we now approach the very questions posited in the introduction. First, in section 3.1 we explore whether the indicative abilities of the term spread defined in equation (12) above are dependent on monetary policy preferences approximated by the central bank's reaction function.[13] Second, in section 3.2 we examine the influence of the way agents form their expectations. In both cases we do so by simulating model consistent reactions of chosen variables to macroeconomic shocks. In contrast to the simulations shown in the Appendix, the shocks we subject the model to in this chapter are all *expected* shocks.[14] This is to reflect the idea that forward-looking agents react to expected future economic events in advance. We investigate the

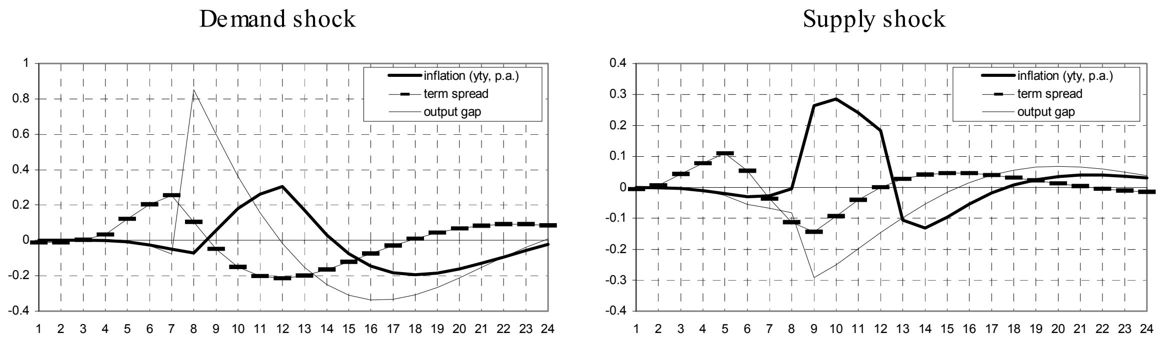
[13] The term "approximated" reflects the fact that deriving reaction function from central bank's loss function (that depicts preferences) is, under given model relationships, likely to lead to inclusion of terms that might not appear in the loss function itself.

[14] Although certain type of shocks (e.g. oil price shocks) are mostly unexpected, various other events shifting the system potentially out of equilibrium are expected in advance (e.g. future rise in taxes).

responses of inflation, real economic activity and the term spread in reaction to future expected temporary one percentage point demand and supply (cost-push) shocks. We always shock the model eight quarters after the simulation starts. The graphical results of the following two sections are further scrutinized in the last section of this chapter.

Figure 1 below shows the results of a baseline simulation, i.e. a simulation where all the coefficients stay as estimated or calibrated in the previous chapter. These responses form a "benchmark" to which all later simulations will be compared.

Figure 1: Benchmark simulation



Let us first briefly discuss the response of the economy to an expected demand shock depicted in the left hand panel of figure 1. After the initial small fall in output, that is due to restrictive influence of expectations driven real exchange rate appreciation, the output gap strongly jumps up in the eight quarter. The above mentioned high persistency of real economic activity causes the spike in output gap to be little below one percentage point. Positive output gap and expectations of future rise in year to year inflation lead the agents to expect future monetary policy tightening. The long-term interest rate thus rises faster than the short term rate which leads to positive term spread. The deviation of both long term real interest rate and real exchange rate from their equilibrium values in a "tightening direction" causes output gap and inflation to gradually return to equilibrium. After some "overshooting" in both inflation and output gap that is driven by the dynamics of nominal exchange rate and falling real interest rate, the economy converges back to equilibrium. Concentrating on the indicative properties of the term spread, it is apparent the term spread indicates future real economic activity about 3 quarters ahead. Similarly, the position of the term spread indicates future inflation with a lead of 5 to 6 quarters.

The right hand panel of figure 1 shows response of the chosen variables to a supply shock. Since year to year inflation is examined, the original one percentage shock in quarter to quarter inflation is spread out over a longer period. Expected pre-emptive monetary policy is once again strongly assisted by an appreciation of the real exchange rate driven by the (expected) inflation differential. Since inflation is further pressed down by a negative output gap, the necessary interest rate hike is much smaller. Still, the trajectory of the term spread is very similar to the demand shock case because the agents' perceived reaction function puts strong emphasis on inflation stabilization. As for the indicative power of the term spread, it is unchanged with regards to future inflation, but the term spread is no longer able to predict future real economic activity. This is a sensible finding though, since supply shocks do, by their nature, have different impacts on output and price dynamics.[15]

3.1 The term spread and monetary policy preferences

We now turn to examine the role of monetary policy preferences on the relation between the term spread and future inflation and real economic activity. Modifying coefficients in the reaction function (4) allows us to perform different experiments. We start off by examining the role of interest rate smoothing.

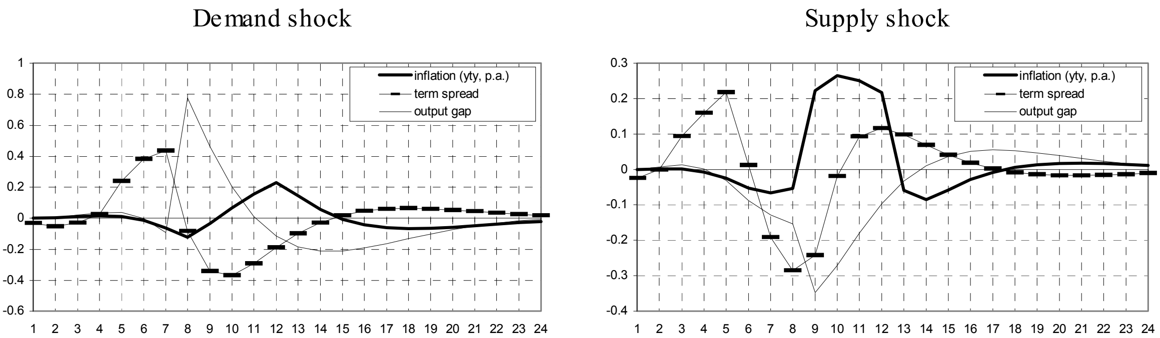
Interest rate smoothing

The motivation for altering the degree to which central bank smoothes interest rates may vary. Let us take on a specific transition economy factor for smoothing: extreme vulnerability to capital flows. Countries in transition often exhibit high interest rate differentials to the rest of the world, which – together with financial account liberalization – cause high volume of speculative capital inflow. Further, policymakers in these countries often set interest rates

[15] Further refinement could be made with regard to the so called "escape clauses" or "caveats" that some inflation targeting central banks use in the case of temporary supply shocks. The aim of such measures is to ex ante communicate that the bank will not aim to fulfill its inflation target. This should ensure that unnecessary output losses are avoided while the bank's credibility is not affected by missing the inflation target. Taking this complication into account would require specification of an asymmetric (agents' perceived) reaction function. This remains a challenge for further research.

with respect to some "marginal" or "limit" level of interest rate differential after which massive capital outflow is believed to occur, causing shock exchange rate depreciation. If policymakers are unsure of this "limit" level, they will be very cautious in setting their interest rates. But once domestic interest rates are close to foreign interest rates, the differential is too small to attract speculative capital and the caution in setting interest rates may decrease. This will mean more flexible monetary policy, in other words less interest rate smoothing. We reflect this in our model by lowering the coefficient α_{41} in reaction function (4) from 0,8 to 0,5. The responses are shown in figure 2.

Figure 2: Smaller interest rate smoothing



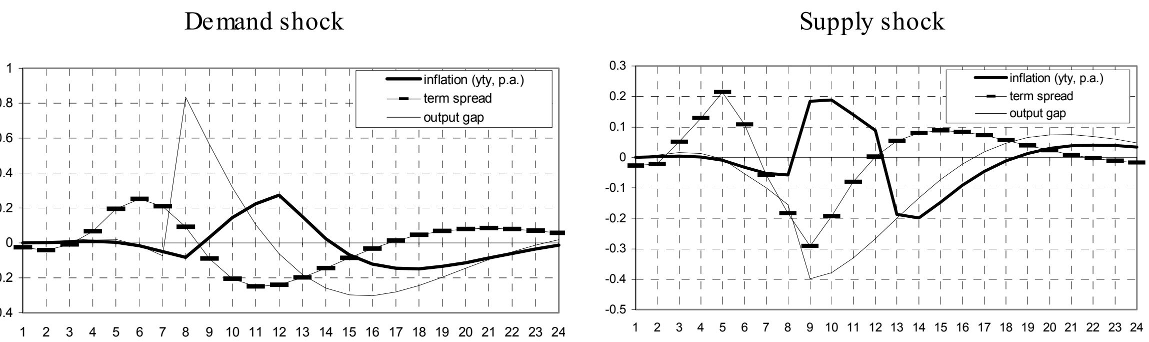
The simulation results show that more flexible monetary policy results in smaller volatility of inflation and real output (in the demand shock panel) around their equilibrium values in comparison to the baseline case in figure 1. Monetary policy is less bound by former levels of interest rates and may be faster and more emphatic in eliminating the consequences of the shocks. Short-term nominal interest rate is logically more volatile. There seems to be no great difference in the indicative abilities of the term spread: spread still predicts future inflation about 6 quarters ahead.

Strict inflation targeting

The motivation for examining the predictive power of the term spread under two alternative extreme cases – strict inflation targeting here and strict output targeting later on – can be illustrated by a simple example. Suppose there are two countries (A and B) both expected to be hit by an identical supply shock. Further suppose that central bank's A only goal is stable prices and central bank's B only goal is stable output. What happens with the yield curve in the two countries after the agents find out about the expected shock? It is likely that country A will see an upward sloping yield curve, i.e. a positive term spread. The reason is that agents will expect the bank to rise future interest rates in order to prevent future rise in inflation. On the contrary, country B's agents will probably expect the central bank to cut rates in the future in order to prevent negative impact of the supply shock on real economic activity. This will lead to downward sloping yield curve and thus negative term spread. As this example illustrates, the predictive power of the term spread may be policy dependent - the change of the slope of the yield curve in reaction to expected shocks depends on central bank's preferences. Let us now examine this proposition more formally.

We start off by strict inflation targeting. We define this strategy using our model by setting the coefficient on the output gap in the reaction function equal to zero and in the same time increasing the coefficient on inflation (deviation from target) in order to make the results more vigorous. We set $\alpha_{42} = 5$ and $\alpha_{43} = 0$. The results are depicted in figure 3.

Figure 3: Strict inflation targeting



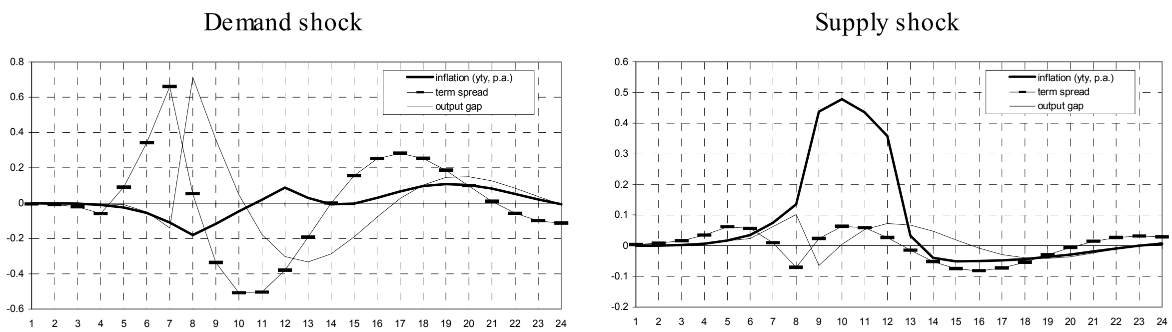
Demand shock responses of both inflation and output gap are very similar to the benchmark case in figure 1. This is because the output gap that serves as an initial propagation variable for demand shock enters inflation through the Phillips curve equation (2) and so even strict inflation targeting central bank cares about the output gap to the extent it affects inflation (see footnote 13 for a related point). Furthermore, even in the baseline case, the weight put on price level stabilization is much higher compared to that put on output gap stabilization.

In the case of a supply shock shown in the right panel of figure 3, the results are, however, very different from those in figure 1. The supply shock induced fall in output gap is now not a "problem" for the central bank, it is even welcome since it helps to contain the inflation pressures. Agents are well aware of this and expect more aggressive restriction, which is manifested in higher long-term nominal interest rate and thus higher term spread. Because of the absence of a "trade-off" between inflation and real economic activity in the minds of policymakers, the path of inflation is logically smoother in this case than in the benchmark case. The predictive ability of the term spread seems to remain unaffected: spread is a good indicator of future inflation.

Strict output targeting

We now turn to the other extreme case and examine the predictive power of the term spread under strict output targeting. Again we decided to model a case, where not only is the weight put on inflation decreased to zero, but the weight put on output is increased compared to the baseline case. We set $\alpha_{42} = 0$ and $\alpha_{43} = 5$. Figure 4 shows the results.

Figure 4: Strict output targeting



Examining figure 4, it is clear that under strict output targeting the term spread is a good indicator of future real economic activity. It is important that this holds true under both types of shocks. Further, it is apparent that the lead horizon has shortened: while the demand shock responses in our benchmark case indicated a 3 quarters ahead predictive horizon, during strict output targeting the spread predicts future real output 2 quarters ahead. This is due to the specification of the reaction function where there is no lag between changes in output and policy reaction and the agents thus expect the restriction to come much "closer" before the shock. As for the predictive ability of the term spread for future inflation, it completely disappears in the case of strict output targeting. This is in line with our illustration (country A and B) above.

3.2 The term spread and the formation of expectations

Since the predictive ability of the term spread is based on agents' expectations of future economic development, the way agents form expectations is possibly a key determinant of the relation between the term spread and future inflation or economic activity. This section examines this proposition. We first focus on the way agents set long-term interest rates based on expected short-term rates and then on the way inflation and exchange rate expectations are formed.

Long-term interest rates and the rational expectations hypothesis

When specifying the model in chapter 2, we discussed possible reasons for the empirical failure of the REH. Our baseline specification was based on the findings of Kotlán (1999c) that the REH holds in the Czech interbank market. In this section, we relax the assumption that all agents set long-term interest rates according to the REH.

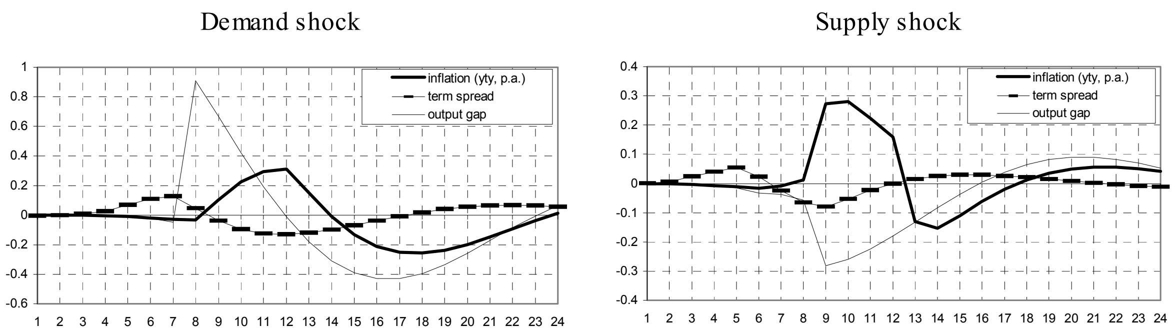
There is, however, another reason for doing so apart from the problems of empirical evaluation of the REH mentioned in chapter 2. Let us provide a short informal exposition. The model set up in chapter 2 assumes that agents on the financial market and the central bank have the same information and think in the same way. In reality it is, nevertheless, likely that there exist numerous information asymmetries between the bank and the agents. Since agents are often unsure about the way the central bank will react to given forecast or data, one of the asymmetries concerns the monetary policy preferences or central bank's reaction function.[16] The

[16] For a discussion of this asymmetry in connection to transparency and credibility issues, see Faust and Svensson (1998).

impact of this uncertainty on the indicative properties of the term spread is partly discussed by Roley and Sellon (1996) and Favero (2001). The authors of the former paper work with a naive single-equation model of the economy and examine the impact of unexpected central bank's behavior on the yield curve. The latter paper shows, using a GE macroeconomic model, that it may be this uncertainty about monetary policy preferences that often leads to empirical rejection of the REH.

We approach the problem by supposing that the fraction of agents who are unsure about central bank's reaction function set long-term interest rates in a naive way by identifying them with current short-term interest rates. Specifically, we suppose that half of all the agents behave in this way and we thus set the coefficient α_{51} in equation (5) to 0,5. Figure 5 depicts the responses of the observed variables to demand and supply shock simulations.

Figure 5: Expectations hypothesis partly ignored



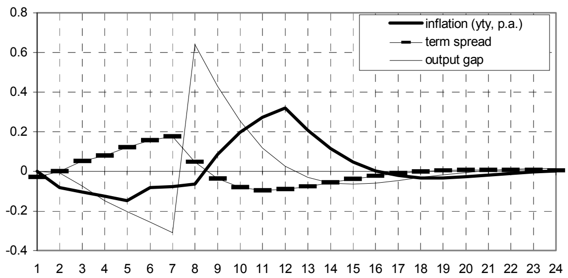
Examination of the responses and their comparison with the benchmark results of figure 1 leads to the following conclusion: while the responses of inflation and real economic activity are similar, the elasticity of their relationships with the term spread changes significantly. The predictive ability of the term spread does not fail but there is a marked quantitative change further explored below in 3.3.

Expectations about future exchange rate and inflation

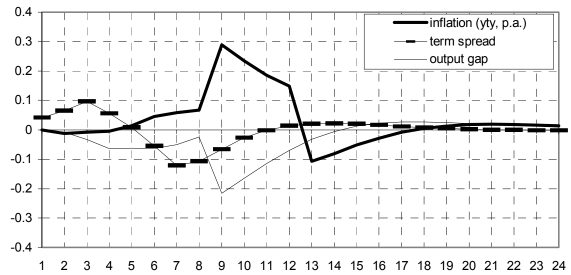
While the previous paragraphs examined what happens to the indicative properties of the term spread if the number of agents who form expectations rationally or "model consistently" goes down, this section takes up an opposite question. We examine the impact of increased "expectations rationality" on the term spread's predictive power. Namely, we increase the fraction of forward-looking agents in the UIP equation (3) and decrease the fraction of backward-looking agents in the inflation expectations equation (10). We choose not to model a completely rational expectations case since this seems rather unrealistic and instead set α_{31}= 0,9 and β_{11}= 0,1 (in line with the baseline case we reset α_{51} back to zero). Simulation results are summarized in figure 6.

Figure 6: The case of almost rational expectations

Demand shock



Supply shock



The basic feature of responses in figure 6 as compared to our benchmark case in figure 1 is faster convergence of the variables towards their long-term equilibrium levels. Further, we can see that the forward-looking nature of the economy enables the central bank to pursue a less aggressive monetary policy. Another finding is that with a more "forward-looking economy", both demand and supply shocks lead to deeper initial fall of real economic activity. After inspecting the responses of other variables not shown in figure 6, we conclude this is so because of a quick initial appreciation of the exchange rate driven by forward-looking agents. If the change in expectations formation process occurs only on the goods market (inflation), the response of the output gap mimics closely that shown in figure 1. Overall, the term spread is still a good predictor of future inflation.

3.3 Summary of the results and discussion

The results of this chapter are summarized in table 1 below. The first column characterizes the type of simulation performed and thus also the question we tried to address. The second column shows the value of modified model coefficients used in the given simulation. The third column presents our results with regard to future inflation and the fourth with regard to future real economic activity. The results are presented in a simple yes/no form (i.e. indicate/doesn't indicate future inflation or output) with optimal lead horizon in parenthesis. Apart from this, we further scrutinize the results by performing series of OLS regressions using the data values obtained in the performed simulations: we let inflation and real economic activity be explained by the term spread. For the sake of brevity, we only report the coefficient on the term spread (always significant on standard levels) and the fit of the regression using R2.

Table 1: Summary of the results

Model	**Modified coefficients**	**Spread predicts inflation (lead in quarters)**		**Spread predicts ouptut (lead in quarters)**	
		Demand shock coefficient (R^2)	Supply shock coefficient (R^2)	Demand shock coefficient (R^2)	Supply shock coefficient (R^2)
Baseline	original	yes (5-6)		no (3)	
		0,99 (0,85)	1,48 (0,58)	1,79 (0,63)	*0,59 (0,02)*
Smaller smoothing	$\alpha_{41} = 0,5$	yes (5-6)		no (3)	
		0,3 (0,49)	0,58 (0,37)	0,81 (0,48)	*0,25 (-0,01)*
Strict inflation targeting	$\alpha_{42} = 5$	yes (5-6)		no (3)	
	$\alpha_{43} = 0$	0,74 (0,84)	0,72 (0,68)	1,56 (0,65)	*0,5 (-0,01)*
Strict output targeting	$\alpha_{42} = 0$	no		yes (2)	
	$\alpha_{43} = 5$	*-0,01 (-0,01)*	*1,38 (0,02)*	0,69 (0,72)	0,67 (0,53)
REH partly ignored	$\alpha_{51} = 0,5$	yes (6)		no (3)	
	$\alpha_{51} = 0,8$	2,04 (0,85)	2,74 (0,61)	3,55 (0,64)	*1,79 (0,19)*
More "rational" expectations	$\alpha_{31} = 0,9$	yes (6-7)		no	
	$\beta_{11} = 0,1$	1,31 (0,64)	1,48 (0,48)	*1,55 (0,3)*	*0,66 (0,15)*

The *baseline simulation* results are reported in the first row. The indicative power of the term spread for future inflation is substantial. In an attempt to come up with a single coefficient linking the current value of the term spread to future inflation, we estimated a simultaneous SUR regression using the data from both the demand and the supply shock simulations. The result suggests that a term spread of one percentage point (p.p.) indicates future inflation 0,94 p.p. above the inflation target in 6 quarters. The fourth column shows the results with respect to future real economic activity. Although the coefficients have the expected signs, the low fit of the regressions confirms the results of section 3.1: the term spread is not a good indicator of future real economic activity in the Czech economy. Since the model with the original coefficients should track the real data of the Czech economy most closely, we would expect the results to be in line with those of Kotlán (1999a) and Kotlán (1999b) that examined the predictive power of the term spread using a simple single-equation approach. The outcomes support the finding of the former study but oppose the findings of the latter one. We believe this can be explained by the criticisms put forth in the introduction, especially the point made by Woodford (1994) and Bernanke and Woodford (1997) seems relevant here.

After reviewing the results of the baseline simulations, let us now inspect the findings with regard to the role of monetary policy preferences for the predictive ability of the term spread. The outcomes are summarized in rows 2 - 4 of table 1. Smaller *interest rate smoothing*, i.e. more activist monetary policy, leads to a weakening of the predictive ability. Lower fit of both regressions and smaller SUR coefficient (0,3) is not surprising. If the agents are aware of the fact that monetary policy will react to changes in economic conditions more flexibly, the term spread becomes more volatile. Since higher policy flexibility at the same time leads to lower volatility of inflation and output, the relation between these variables and the term spread becomes weaker. *Strict inflation targeting* on the other hand leads to an increase in the robustness of the relation between the term spread and future inflation. This is apparent not only by looking at the fit of the supply shock regression and converging coefficients for both types of shocks, but also from the results of SUR regression coefficient (0,74) that is close to both individual regression coefficients. In strict inflation targeting, the term spread predicts future inflation but not future real economic activity. The results are completely reversed in the case of *strict output targeting*. Inspecting the results in the fourth row, we can see that while the indicative properties in terms of future inflation disappeared, the term spread now indicates future real economic activity very successfully. Regression coefficients for both demand and supply shock are very close, a fact manifested in SUR regression coefficient of 0,69. The fit of the regressions also increases markedly. In strict output targeting regime, term spread of one percentage point indicates future real output 0,69 p.p. above potential.

The above results differ substantially from those of Estrella (1998) who concludes that under strict output targeting the term spread predicts future real output (4 quarters ahead) and inflation (8 quarters ahead) and that strict inflation targeting leads to complete erosion of the indicative properties the term spread. We believe the differences can be explained to a great extent by the role of the exchange rate transmission channel in a small open economy. Consider two examples. First, the fact that in the strict output targeting case we find no link with future inflation can be blamed on exchange rate appreciation that pushes inflation back to the target quickly (see demand shock responses depicted in figure 4). Second, the shorter predictive horizons indicated by our results can again be attributed to the working of the exchange rate transmission channel that greatly speeds up monetary policy effects in a small open economy.

Another series of simulations was performed in section 3.2 with the aim of examining the influence of the way expectations are formed. The results are summarized in the last two rows of table 1. Even though the predictive power of the term spread stays high, the relation is quantitatively different. Namely, if the fraction of agents not setting long-term interest rates in accordance with the *rational expectations hypothesis* increases, the same value of the term spread indicates future inflation higher above the target than in the baseline case. The fact that agents do not set long-term interest rates based on expected central bank's action, makes the central bank behave more aggressively: higher short-term rates are necessary to influence long-term rates and the term spread thus falls. Smaller spread is then connected to the same values of inflation and real output. Formally, this is confirmed by higher SUR regression coefficient of 1,95. The result implies that if a central bank intends to use the term spread as an indicator of future inflation, it first needs to know just how good a description of the agents' behavior the rational expectations hypothesis is. Without this understanding, it is impossible to judge how high inflation is expected to be in the future. The last row summarizes the results for the case of *almost rational exchange rate and inflation expectations*. The term spread stays a good indicator of future inflation: SUR regression coefficient of 1,05 is quite similar to the baseline case and the fit of the regressions is reasonable.

4. Conclusions

The main findings of this paper can be summarized as follows:

1. The predictive ability of the term spread with regard to future inflation and real economic activity is not structural but depends on monetary policy preferences and on the behavior of agents in a given economy. It is therefore necessary to use a structural model of the economy with endogenous monetary policy to find out what variables and with what lead the term spread predicts.

2. The term spread's predictive ability with regard to future inflation increases with increasing weight on inflation stabilization in central bank's reaction function. Similarly, the term spread's predictive ability with regard to future real economic activity increases with increasing weight on real economic activity stabilization in central bank's reaction function.

3. In order to use the term spread as an indicator for monetary policy, it is important to know the degree to which agents on average behave according to the expectations theory when setting long-term interest rates and to know the way agents form their inflation and exchange rate expectations.

4. In the Czech economy, the term spread between one year and three month PRIBOR interest rates of one percentage point indicates that agents expect inflation to be almost one percentage point above the target 6 quarters ahead.

Overall, the results show that the term spread may be a useful indicator for conducting monetary policy. This explains why the term structure of interest rates is closely watched by many central banks. Goodhart (1993) and Piazzesi (2001) even argue that the term spread directly enters reaction function of some central banks. Other authors, however, warn that monetary policy decisions should not be too closely tied to any variable strongly influenced by expectations. This argument is, of course, based on the well known Lucas (1976) critique or its variant labeled as Goodhart's (1981) law. If the relationship between future inflation and its indicator is driven by agents' expectations, and if monetary policy reacts to the indicator with the aim to influence future inflation, then it is likely, that this reaction will change agents' expectations. This will in turn diminish the usefulness of the indicator. Is it really true that if a central bank starts to use a certain relationship for policy purposes, the relationship become unstable and it is not possible to use it for policy anymore? We believe this is only true in cases when the relationship is not based on a structural model but rather comes out of ex post regressions (i.e. an approach criticized in the introduction) or in cases when the indicator is the only policy guide available to a central bank. However, if monetary policy decisions are based on a structural macroeconomic forecast, the term spread is a very useful indicator for monetary policy.

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Appendix

Table A1

Author(s)	Predicts future real output		Predicts future (change in) inflation	
	Yes	**No**	**yes**	**no**
Mishkin (1991)			France, Germany, UK	Canada, Switzerland
Hu (1993)	France, Italy, Canada, Germany, USA	Japan, UK		
Plosser and Rouwenhorst (1994)	Germany, USA	UK		
Bernard and Gerlach (1996)	Canada, Germany, USA	Japan		
Bonser-Neal and Morley (1997)	France, Canada, Germany, USA (Australia, Holland, UK)	Italy, Japan, Sweden, Switzerland		
Estrella and Mishkin (1997)	Germany, USA	Italy	Italy, Germany, USA	France, UK
Kozicki (1997)	Australia, Italy, Canada, Germany, USA	Sweden, Switzerland, UK		
Kozicki (1998)			Australia, Japan, Canada, USA (Germany, Sweden, Switzerland)	Italy, France, Holland, UK

Figure A1: Aggregate demand shock

Nominal variables | Real variables

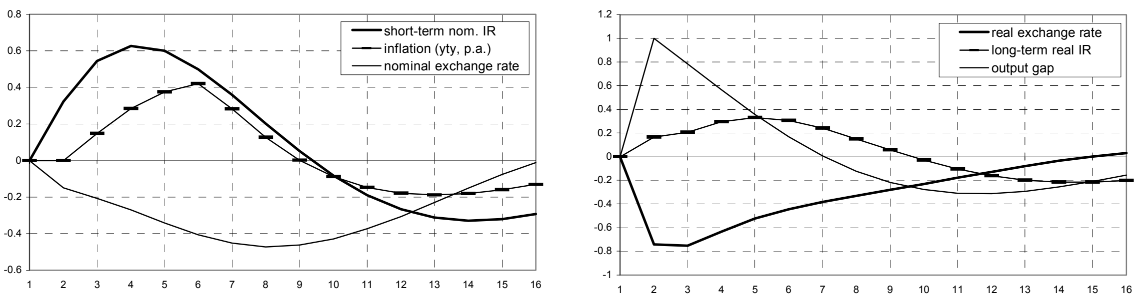
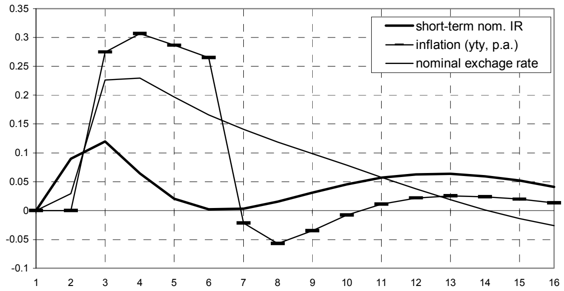


Figure A2: Supply (cost-push) shock

Nominal variables



Real variables

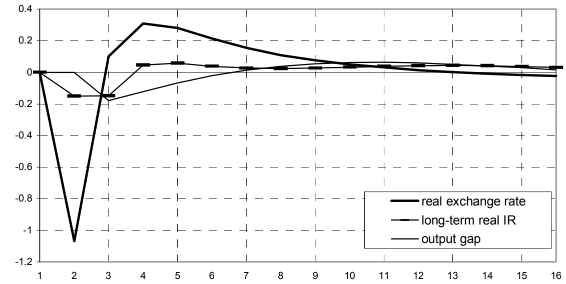
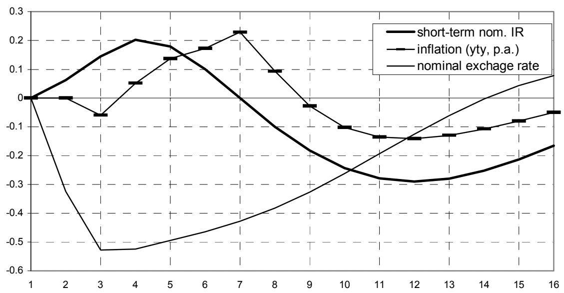


Figure A3: Foreign inflation shock

Nominal variables



Real variables

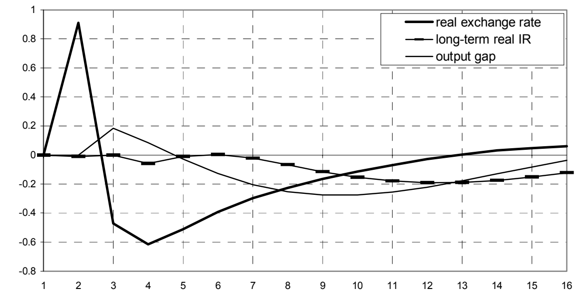
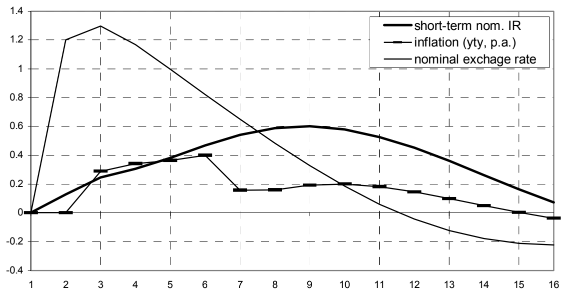


Figure A4: Exchange rate shock (nominal depreciation)

Nominal variables



Real variables

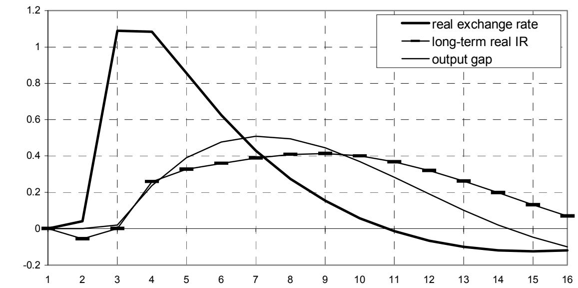


Figure A5: Reaction function (monetary) shock