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Viktor Kotlán*

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 useful indicator of future inflation and/or future real economic activity. However, this paper argues that shortcomings of the single-equation approach may produce results that are biased, and that the predictive ability must be analyzed from within a model framework. We have elected to use a simple macroeconomic model of a small open economy and examine the predictive properties of the term spread from within its framework. The main contribution of this paper 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 as more emphasis is placed on inflation (real economic activity) stabilization in the central bank's reaction function. Third, we show that understanding the way expectations are formed is an important prerequisite for using the term spread as an indicator. Apart from these general findings, the predictive power of the term spread is examined in the context 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 inflation target six quarters in the future.

JEL Codes: E41, E52, F41
Keywords: Term spread, Monetary policy, Macroeconomic modeling

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Nontechnical Summary

Many central banks have recently changed their policy strategy to direct inflation targeting. This has led to a marked increase in the importance of macroeconomic forecasts for monetary policy. While there is no alternative through inflation targeting for a central bank's own structural model-based inflation forecast in the conduct of monetary policy, various indicators may serve as a useful supplementary policy guide. One of the most often discussed indicators is the term structure of interest rates. Using a simple single-equation approach, many studies have shown that the term structure of interest rates or its approximation – the term spread – may be a useful indicator of future inflation and/or future real economic activity.

This paper argues that the various shortcomings of the single-equation approach that is usually adopted may produce biased results. We identify at least three reasons. First, it is unclear whether a changing term spread at any moment in time indicates future changes in inflation or in real economic activity, or both, and what the future values of these variables should be. Second, even though monetary policy is conventionally believed to affect the term spread considerably, the single-equation approach does not explicitly take the role of monetary policy into account. Third, the reduced-form techniques applied are, by themselves, not well suited to evaluate the predictive content of the term spread or any other indicator.

To overcome these problems, we use a simple macroeconomic model of a small, open economy and examine the predictive properties of the term spread from within its framework. Specifically, our goal is to find out whether the proposed relationship is structural or monetary-policy dependent, and whether it is influenced by the way in which agents form expectations. We first introduce the model and then examine the role of monetary policy behavior and expectations formation on the predictive ability of the term spread using model simulations.

This paper's 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 as more emphasis is placed on inflation (real economic activity) stabilization in the central bank's reaction function. Third, we show that understanding the way expectations are formed is an important prerequisite for using the term spread as an indicator.

1. Introduction

The forward-looking character of monetary policy, that is due to "long and variable lags" in transmission, combined with uncertainty about future economic development, ideally requires that some kind of intermediate policy target or forecast be employed. Recently, however, many central banks have changed their policy strategy to direct inflation targeting, thus the weight placed on intermediate targets (e.g. money stock in monetary targeting) has lessened considerably. At the same time, this has led to a marked increase in the importance of macroeconomic forecasts for monetary policy.

While there is no alternative for a 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 supplementary policy guide. We think of indicators as variables from which it is possible to extract agents' expectations about future economic development, though they do not necessarily cause this future development. Apart from reflecting market expectations, indicators have other favorable properties that distinguish them from macroeconomic forecasts: they are usually available with greater frequency, and they are not subject to data revisions.

Various authors have shown that one of the most successful indicators is the term structure of interest rates. The whole term structure is usually approximated by a single variable, the *term spread*, calculated as the difference between long-term and short-term interest rates. What can the term spread tell us? There are basically two lines of research in this 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 a 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 a positive current term spread is associated with an increase in real economic activity in the future, and a negative term spread a decrease. A summary of the results of the studies above that take a multi-country approach can be found in Table A1 in the Appendix. In the context of the small open Czech economy, similar research has been conducted by Kotlán (1999a, 1999b), testing, respectively, the ability of the term spread to act as an indicator of future inflation and future real economic activity. In these studies, the term spread has been found to indicate inflation six quarters in the future, and real economic activity three quarters in the future.

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 argue that the results based on such an approach are subject to three types of criticism. First, it is unclear whether a changing term spread at any moment in time indicates future changes in inflation or in real economic activity, or both, and what the future values of these variables should be. Second, even though monetary policy is conventionally believed to affect the term spread considerably, the approaches mentioned do not explicitly take the role of monetary policy into account. Third, the reduced-form techniques applied are, by themselves, not well suited to evaluate the predictive content of the term spread 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 a positive *X* indicates future inflation above the target and a negative *X* indicates future inflation below the target. Since the bank's goal is to 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 fluctuated, inflation has stayed at the target level. Reduced-form econometric techniques might then lead to a false conclusion that there is no relation between indicator *X* and (lagged) inflation.[1]

These critiques can be avoided if the predictive power of the term spread is examined from the perspective of a macroeconomic framework. The idea of analyzing the term structure of interest rates 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, consisting of the rational-expectations-hypothesis (REH) based term structure equation and the central bank's reaction function, to improve the empirical results of testing the REH. More complex macroeconomic models, however, have been used in this context in only a few studies. Turnovsky (1989) examines interactions of various macroeconomic policies and the term structure using a simple macro model. In their seminal study, Fuhrer and Moore (1995) look at the observed correlation between the Fed Funds rate and real economic activity by following interest rate transmission along the yield curve. Eijjfinger et al. (2000) discuss the implications of the REH for inflation targeting. Finally, Estrella (1998), whose approach is closest to ours, analytically solves a simple macroeconomic model with an emphasis on directly linking the term spread with the indicated variable (inflation, real economic activity).

Although we take this body of research as our starting point, our aim and approach differ. In this paper we re-examine the relationship between the term spread and future inflation and/or future real economic activity from within a model framework. Our goal is to find out whether the proposed relationship is structural or monetary policy dependent, and whether it is influenced by the way in which agents form expectations. The approach we take differs in two respects. First, while all the studies mentioned in the paragraph above examine the term spread's predictive properties within a closed economy, we are the first to do so using a small open economy modeling framework. For this purpose we have chosen the Czech economy. Second, 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

[1] The same argument applies to the reason why it is often the case that regressing inflation data on lagged values of the central bank's interest rates leads to false 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 model.

monetary policy behavior and expectations formation on the predictive ability of the term spread using model simulations; and, Chapter 4 states our conclusions.

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 grounded in economic theory. Second, the model should be as simple as possible. Third, the equations should resemble the Czech data. We briefly discuss the main behavioral equations below. The whole model, including the calibrated coefficients, is summarized at the end of this chapter.

Aggregate demand

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

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

The left-hand side (LHS) variable y_t is the output gap. The data was obtained by subtracting from quarterly real GDP data the estimated potential output series using the Hodrick-Prescott (HP) filter.[2] The output gap enters the right-hand side (RHS) with a one-period lag.[3] The second term on the RHS R_{t-1} is one-period-lagged long-term real interest rate (1Y PRIBOR) deflated by expected CPI inflation (equation 7). We assume four-fifths of agents form inflation adaptively and one-fifth model-consistently or rationally (equation 10). The third term on the RHS y^*_{t-3} stands for three periods lagged foreign demand proxied by the German GDP gap (HP filter). The lag reflects our assumption that the duration of foreign trade contracts is relatively long. The fourth term on the RHS q_{t-1} is the one-period-lagged real exchange rate. Note that a rise in q stands for depreciation. The foreign trade structure and the availability of consistent historical data was the reason for working with the CZK/DEM exchange rate, deflated by CPI rates of inflation (equation 8). The last term on the RHS $shock^{IS}_t$ stands for demand shock.

While calibrating the coefficients, we started off with an OLS estimate using data for 3Q1994 – 1Q2001, and found the values broadly in line with economic intuition.[4] The influence of foreign demand α_{13} = 0.47 reflects the 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 lag of one quarter, a decline in real output one-fifth of a percentage-point below equilibrium (α_{12} = -0.22). The influence of the real exchange rate is about

[2] 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, a variant of the HP filter due to Laxton-Rose-Xiu (LRX) was used, making it possible to expertly adjust the end-point of the gap (-1.0 p.p. in 1Q2001 in this case).

[3] An 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 the simplicity principle.

[4] The coefficients were all significant at standard levels; adj. R^2 = 0.95; LM (4) = 4.36; S. E. = 0.01.

the same in magnitude (α_{14} = 0.20). The output gap persistency was estimated at 0.97. Such a value seemed too high compared to other studies, as did the implied long-term elasticities of both the foreign demand and the domestic policy variables. We thus calibrated the coefficient slightly lower and set α_{11} = 0.90.

Phillips curve

The "Phillips curve" equation links nominal and real variables, assuming short-term stickiness in prices and wages.

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

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 four quarters in the future (equation 10). This specification reflects a common belief that the lower the inflation, the less frequently contracts are re-negotiated. Consequently, there are higher 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 work with inflation expectations four quarters in the future. 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 equation 2) change in the nominal CZK/DEM exchange rate. These two terms are intended to capture foreign influence on 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.[5] The imposed linear homogeneity in the inflation terms reflects the assumption of a vertical long-term Phillips curve (no long-run trade-off between inflation and growth). The fourth term y_t is the output gap and reflects 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 "cost-push" supply shock.

While calibrating this equation we again started off with OLS estimation results.[6] The estimated coefficients were in line with our expectations and data typical of small open economies. Of the "inflation terms," foreign inflation (0.46), together with nominal exchange rate dynamics (0.22), had the strongest influence. Inflation expectations enter the equation with the expected sign, however, the coefficient was found insignificant on standard levels. We believe this result may be connected to our specification of the expectations formation process. Since we experiment with this process later on, and the value is in line with international evidence (e.g. Laxton and Scott, 2000), we decided to calibrate this coefficient on the level of the original estimate (0.32).[7] The estimates further showed that the cyclical position of the economy has a strong influence on the

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

[6] Adjusted R^2 = 0.42; DW = 2.18; S. E. = 0.03.

[7] Alternatively, a separate wage setting equation (with e.g. unit labor costs, imported inflation, the output gap and expected inflation) could be considered. This would, however, violate our simplicity principle.

determination of prices. Real output standing one percentage-point above potential output increases inflation by 0.61 p.p.

Uncovered Interest Rate Parity

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

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

where s^e_{t+1} is the currently expected nominal exchange rate one period in the future and s_t stands for current nominal exchange rate. The exchange rate is expressed in domestic units per unit of foreign currency, and, as was mentioned above, a rise in s_t reflects a depreciation. I_t and I_t^* stand for long-term (here one year) nominal domestic and foreign interest rates, respectively.[8] The term *disp* is used 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 a transition-economy-specific temporary shock, consider a foreign capital inflow-driven appreciation of the domestic currency that is due to privatization of domestic assets. The expected exchange rate can be modeled in various ways. As with inflation expectations, we simply have divided the agents in the financial market into two groups: one group of participants (weighted as α_{31}) forms model-consistent expectations, while the other group (weighted as $1-\alpha_{31}$) is strictly backward-looking[9]

$$s_t = \alpha_{31} E_t s_{t+1} + (1-\alpha_{31}) s_{t-1} - (I_t - I^*_t - disp_t)/4 + shock^{UIP}_t \qquad (3),$$

where E_t stands for model-consistent expectations. We begin by setting the fraction of agents forming exchange rate expectations in this way equal to that on the goods market, i.e. $\alpha_{31} = 0.2$, and later experiment with this coefficient.

The central bank's reaction function

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

$$i_t = \alpha_{41} i_{t-1} + (1-\alpha_{41})\left[i^{eq}_t + \alpha_{42}(E_t \Pi_{t+4} - \Pi^{tar}_{t+4}) + \alpha_{43} y \right] + shock^{RF}_t \qquad (4)$$

The LHS variable i_t is the short-term (3M) interest rate. The term in square brackets on the RHS includes the current output gap and the expected deviation of inflation from the corresponding

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

[9] Alternatively, one could model exchange rate expectations by adding expected equilibrium real appreciation adjusted by the expected inflation differential to the last observed exchange rate value. This specification, used in some other CNB's models, would reflect the common knowledge of Balassa-Samuelson driven real exchange rate trend-appreciation in converging economies.

inflation target (Π_{t+4}^{tar}) four quarters in the future. This deviation is sometimes referred to as the "inflation gap." It is important to note that the forward-looking central bank, in contrast to all other agents, forms inflation expectations as purely model-consistent ($E_t\Pi_{t+4}$). In addition to these two variables, the RHS term in brackets also includes the equilibrium short-term nominal interest rate (equation 11). The reaction function is further supplemented by a one-period-lagged short-term nominal interest rate to reflect the observed persistence in short-term rates. This "interest rate smoothing" may be explained by monetary policy uncertainties, central bankers' fear of "losing face," or simply by their efforts not to destabilize markets.[10] The last term in equation (4) stands for a reaction function or "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 α_{41} = 0.8, α_{42} = 2 a α_{43} = 0.9. This means we start off with a less aggressive "smoothing" coefficient and upper bound coefficient on the deviation of inflation from the target. This is to reflect a more aggressive policy usually observed in the first years after the switch to an 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 small open transition economies implicitly target the external balance and that this balance is, to a large extent, driven 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:

$$I_t = \alpha_{51}\, i_t + \left(1-\alpha_{51}\right)\left(i_t + E_t i_{t+1} + E_t i_{t+2} + E_t i_{t+3}\right)/\,4 + z_t\,, \qquad (5)$$

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

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

where $shock_t^{TS}$ is term premium shock, with persistency given by α_{52}. We begin by supposing α_{52} equals zero, i.e. no persistency. The term premium reflects agents' uncertainty about future interest rate behavior and can be broken down into uncertainty about the future reaction function of the central bank and future shocks affecting the economy. Since the agents that are unsure about the central bank's reaction function may prefer to set the current long-term nominal interest rate at the 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.

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

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). Other reasons for the empirical failures of the REH have been offered by Mankiw and Miron (1986) and McCallum (1994), who examine the influence of monetary policy on the validity of the REH in practice. The authors argue that the high "interest rate smoothing" that results in the high auto-correlation of short-term interest rates may be behind the considerable influence of current short-term interest rates on long-term interest rates (coefficient α_{51} above) that has been observed. Mankiw and Miron even conclude that the REH began to fail in 1914 when the Fed was established. We believe that it is precisely for the reasons mentioned — the influence of monetary policy on the REH — that testing the REH using a single-equation approach is insufficient. If this influence is to be taken into account, one needs to endogenously model the behavior of the monetary authority as well. This is the approach we take below. The baseline simulations are based on the results of Kotlán (1999c), who was not able to reject the validity of the REH based on comparing actual long-term interest rates with those implied by the current term spread in the Czech money market. We thus start off by setting α_{51} equal to zero, and later experiment with this coefficient.

Identities, expectations and exogenous variables

Equations 7 and 8 below are identities for the real long-term interest rate and real exchange rate, respectively. Equation 9 transforms quarter-to-quarter inflation into a year-to-year representation. Equation 10, describing the expectations formation process, has already been described above, as has equation 11, which determines the equilibrium short-term interest rate. Equation 12 is an identity for the term spread as the difference between long-term (1Y) and short-term (3M) nominal PRIBOR interest rates. As for foreign variables, instead of explicitly modeling their behavior and inter-relations, we assume that foreign inflation, output gap, and interest rates evolve independently of each other based upon an auto-regressive process. This is supplemented by a stochastic term with a zero mean value that serves as a shock to foreign variables. The auto-regressive coefficient is set ad hoc to 0.5 in equations 13 and 14, which, respectively, determine foreign inflation and output gap, and to 0.8 in equation 15, which determines foreign long-term interest rates.

The model and baseline coefficients

The final specification 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 *unexpected temporary* (one-quarter) one-percentage-point shocks: demand, supply (cost push), foreign inflation, exchange rate, and reaction function shock simulations were undertaken. The responses (deviations from equilibrium) over the course of 16 quarters are plotted in Figures A1 through A5 in the Appendix. They have been compared to those of Svensson's (2000) small open economy model and were found to be broadly consistent.

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

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

$$s_t = \alpha_{31} E_t s_{t+1} + (1 - \alpha_{31}) s_{t-1} - (I_t - I^*_t - disp_t)/4 + shock^{UIP}_t \quad (3)$$

$$i_t = \alpha_{41} i_{t-1} + (1 - \alpha_{41}) \left[i^{eq}_t + \alpha_{42} (E_t \Pi_{t+4} - \Pi^{tar}_{t+4}) + \alpha_{43} y \right] + shock^{RF}_t \quad (4)$$

$$I_t = \alpha_{51} i_t + (1 - \alpha_{51}) \left(i_t + E_t i_{t+1} + E_t i_{t+2} + E_t i_{t+3} \right)/4 + z_t \quad (5)$$

$$z_t = \alpha_{52} z_{t-1} + shock^{TS}_t \quad (6)$$

$$R_t = I_t - \Pi^e_{t+4} \quad (7)$$

$$q_t = q_{t-1} + s_t - s_{t-1} - \pi_t/4 + \pi^*_t/4 \quad (8)$$

$$\Pi_t = \left(\pi_t + \pi_{t-1} + \pi_{t-2} + \pi_{t-3} \right)/4 \quad (9)$$

$$\Pi^e_{t+4} = \beta_{11} \Pi_{t-1} + (1 - \beta_{11}) E_t \Pi_{t+4} \quad (10)$$

$$i^{eq}_t = r^{eq}_t + \Pi^{tar}_{t+4} \quad (11)$$

$$spread_t = I_t - i_t \quad (12)$$

$$\pi^*_t = \gamma_{13} \pi^*_{t-1} + shock^{\pi*}_t \quad (13)$$

$$y^*_t = \gamma_{14} y^*_{t-1} + shock^{y*}_t \quad (14)$$

$$I^*_t = \gamma_{15} I^*_{t-1} + shock^{i*}_t \quad (15)$$

Coefficient	**Value (S.E. if estimated)**	**Interpretation**	**Equation**
α_{11}	0.90	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	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	Auto-regressive foreign inflation	*(13)* Foreign inflation
γ_{14}	0.5	Auto-regressive foreign output gap	*(14)* Foreign output gap
γ_{15}	0.8	Auto-regressive foreign long-term IR	*(15)* Foreign long-term interest rates

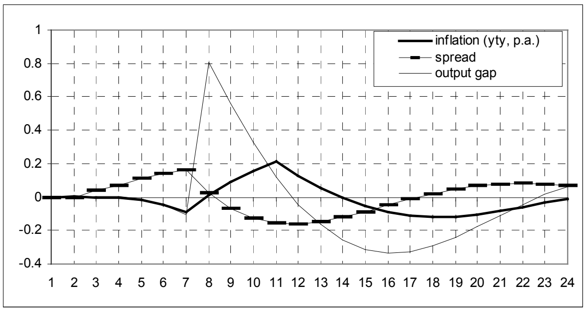
3. The term spread as an indicator

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 predictive abilities of the term spread are dependent on the central bank's behavior. Second, in section 3.2 we examine the influence of the way agents form expectations. In both cases we do so by simulating model-consistent reactions of chosen variables to macroeconomic shocks. In contrast to the simulations depicted in the Appendix, in this chapter the shocks to which the model is subjected are all *expected* shocks.[11] This is to reflect the idea that forward-looking agents react to expected future economic events in advance. We investigate the responses of inflation, real economic activity, and the term spread in reaction to future expected temporary one-percentage-point demand and supply shocks. The shock is always introduced into the model eight quarters after the start of the simulation. The graphical results of the following two sections are further examined in the last section of this chapter.

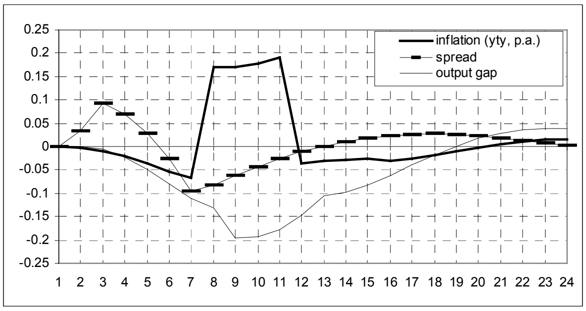
Figure 1 below shows the results of a baseline simulation, i.e. a simulation where all the coefficients are kept as calibrated in the previous chapter. These responses form a "benchmark" to which all later simulations will be compared.

Figure 1: Benchmark simulation

Demand shock



Supply shock



Let us first briefly discuss the response of the economy to an expected demand shock depicted in the left-hand panel of Figure 1. Before the shock actually occurs, a moderate fall in both inflation and the output gap may be observed. This is due to restrictive monetary conditions driven by the expected monetary policy reaction to a positive demand shock (rise of long-term interest rate) and a rise in inflation expectations (real exchange rate appreciation). The output gap increases dramatically in the eighth quarter, although the above-mentioned high persistency of real economic activity causes the spike in the output gap to be slightly below one percentage-point. Together with demand pressures, year-to-year inflation gradually rises (quarter-to-quarter inflation rises immediately). The shock is smoothly eliminated through the central bank's reaction and, after some "overshooting" (driven by the dynamics of the nominal exchange rate and the falling real interest rate), both inflation and output converge back to equilibrium. Market expectations of the central bank's reaction (long-term rates) and the reaction itself (short-term

[11] 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).

rates) drive the development of the term spread. The expected demand shock first pushes the term spread up and then, after the reaction occurs and future loosening is expected, the term spread falls. Concentrating on the predictive properties, it is apparent that the term spread indicates future real economic activity about three quarters in advance. Similarly, the position of the term spread indicates future inflation, with a lead-time of five to six quarters.

The right-hand panel of Figure 1 shows the response of the chosen variables to a supply shock. Since year-to-year inflation is examined, the original one percentage-point shock in quarter-to-quarter inflation is spread out over a longer period. Expected pre-emptive monetary policy in a small open economy is once again strongly assisted by an appreciation of the real exchange rate driven by the (expected) inflation differential. This leads to a fall in real output with disinflationary consequences, and the necessary interest rate hike is thus much smaller than in a closed economy. Still, the movement of the term spread is similar to that in the demand shock case because the agents' perceived reaction function puts strong emphasis on inflation stabilization. The term spread's ability as an indicator of future inflation is unchanged, but it is no longer able to indicate future real economic activity. This, though, is a sensible outcome, since supply shocks have, by nature, different impacts on output and price dynamics.[12]

3.1 The term spread and monetary policy behavior

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

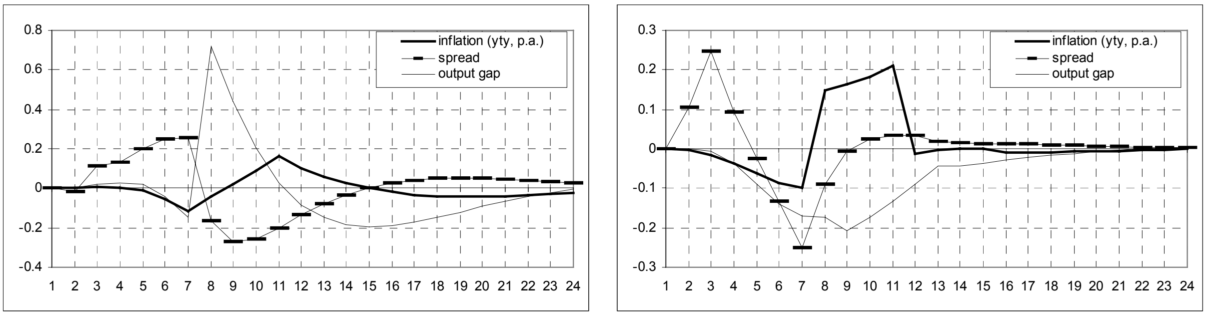
Smaller interest rate smoothing

The motivation for altering the degree to which a central bank smoothes interest rates may vary. Let us look at a specific transition economy factor for smoothing: extreme vulnerability to capital flows. Countries in transition often exhibit a high interest rate differential compared to the rest of the world, which often leads to a high volume of speculative capital inflow. Because of this, policymakers in transition countries usually set interest rates with respect to some "limit" level of the interest rate differential, after which massive capital outflow is believed to occur, causing abrupt nominal exchange rate depreciation. If policymakers are unsure of this "limit" level, they will be very cautious in setting interest rates. But once domestic interest rates get 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 a more flexible monetary policy, in other words less interest rate smoothing. We reflect this in our model by lowering the coefficient α_{41} in the reaction function from 0.8 to 0.4. Simulation responses are depicted in Figure 2.

[12] 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 reaction function. This remains a challenge for further research.

Figure 2: Smaller interest rate smoothing

Demand shock | Supply shock



The simulation shows that a more flexible monetary policy results in smaller volatility of inflation (both shocks) and real output (demand shock) around their equilibrium values in comparison to the baseline case in Figure 1. Monetary policy is less bound by the previous levels of interest rates and may be faster and more emphatic in eliminating the consequences of the shocks. The short-term nominal interest rate is logically more volatile, which is then translated to the term spread movement. Overall, there seems to be no qualitative difference in the predictive abilities of the term spread. The spread is still a good indicator of inflation about six quarters in the future.

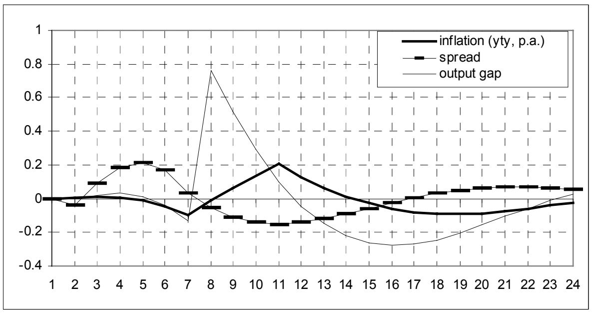
A much more important modification of the central bank's behavior may concern the weight placed on inflation gap and output gap stabilization in the reaction function. Let us illustrate the motivation by a simple example. Suppose there are two central banks with different reaction functions. Let us assume that central bank A sets interest rates only with respect to future development of the inflation gap, whereas central bank B takes into consideration only the output gap. Suppose also that countries A and B are both expected to be hit by an identical supply shock in the future (for instance, a tax increase). What will happen to the yield curves in the two countries after the agents find out about the expected adverse 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 raise interest rates in the future in order to prevent a future rise in inflation. The agents of country B, however, will probably expect the central bank to cut rates in the future in order to prevent any (real exchange rate-appreciation-driven) negative impact of the supply shock on real economic activity. This will lead to a downward sloping yield curve and thus a negative term spread. As this example of an adverse supply shock illustrates, the predictive power of the term spread may be monetary policy dependent – different reaction functions lead to different predictive abilities of the term spread. Let us now examine this proposition in our model framework.

Greater weight on the inflation gap

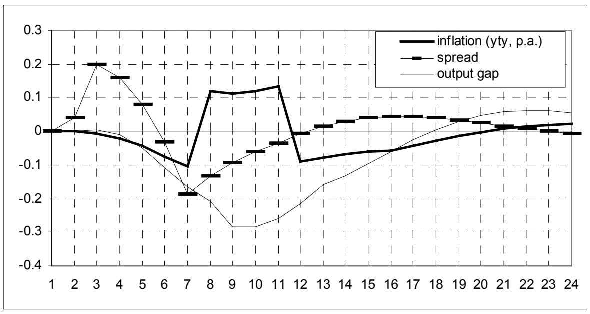
We start off by simulating a case in which the reaction function only includes the inflation gap. We change the model reaction function by setting the coefficient on the output gap equal to zero, and at the same time increase the coefficient on the inflation gap in order to make the results more vigorous. We run the simulations with $\alpha_{42} = 5$ and $\alpha_{43} = 0$. The results are shown in Figure 3.

Figure 3: Greater weight on the inflation gap

Demand shock



Supply shock



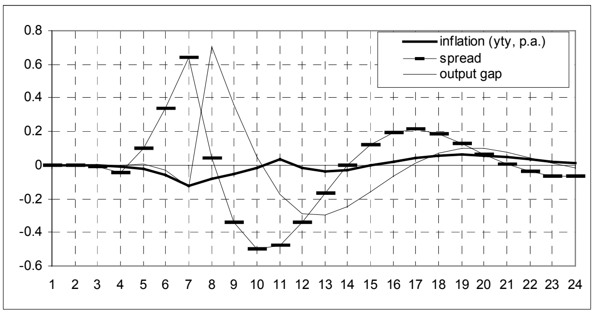
The demand shock responses of both the inflation and output gaps are very similar to the benchmark case in Figure 1. This is because the output gap that serves as an initial propagation variable for demand shock enters inflation through the Phillips curve equation. Consequently, even a central bank that puts zero weight on the output gap in its reaction function, is concerned about real output to the extent that it affects inflation. Furthermore, even in the baseline case, the weight put on price-level stabilization is greater compared to that put on output stabilization. In the case of the supply shock shown in the right panel of Figure 3, however, the results are very different from those in Figure 1. The supply-shock-induced fall in the output gap is now not a "problem" for the central bank. In fact, it is even welcome because it helps to contain inflationary pressures. Agents are aware of this and expect more aggressive restriction, which translates into higher long-term rates and a higher term spread. Increased policy flexibility is connected to greater volatility of the term spread. However, the predictive ability of the term spread seems to remain unaffected: the term spread is still a good indicator of future inflation.

Greater weight on the output gap

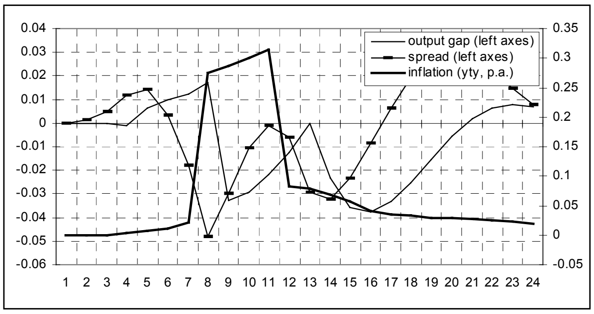
We now examine the predictive ability of the term spread in a setting in which interest rates are set only with regard to the output gap. Again, for the purpose of illustration, we decided to model a case where not only is the weight placed on the inflation gap decreased to zero, but the weight placed on output is increased compared to the baseline case.[13] We set $\alpha_{42} = 0$ and $\alpha_{43} = 5$. The simulation results are shown in Figure 4.

Figure 4: Greater weight on the output gap

Demand shock



Supply shock



[13] This also assures determinacy of the model.

Examining Figure 4, it is clear that in the case of monetary policy driven solely by the output gap, the term spread becomes a good indicator of future real economic activity. It is important that this holds true under both types of shocks (supply shock depicted using dual scaling). Further, it is apparent that the lead horizon has shortened: while the demand shock responses in the benchmark case (Figure 1) pointed to a lead horizon of three quarters, in the case examined here the term spread indicates future real output only two 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 "earlier," before the shock. In line with our illustration above (country A and B), the term spread's predictive ability for future inflation disappears completely.

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 an important determinant of the relation between the term spread and future inflation or economic activity. Before examining the above results in more detail in the following section, 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

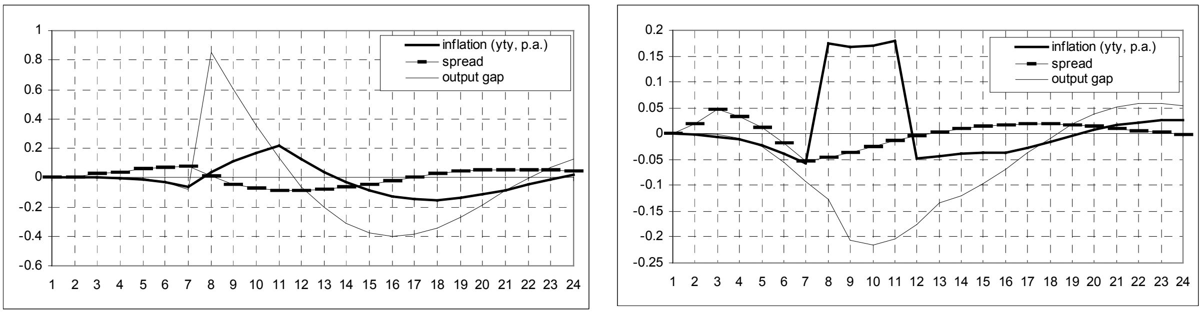
When specifying the model in Chapter 2, we discussed possible reasons for empirical failure of the REH. Our baseline specification, however, was based on the findings of Kotlán (1999c) that the REH holds in the Czech inter-bank market. In this section, we relax the assumption that all agents behave according to the REH.

There is still another reason for doing so apart from the problems of empirical evaluation of the REH mentioned in Chapter 2. The employed model assumes there is only one asymmetry between the central bank and the rest of the agents. This asymmetry rests in the difference between the formation of inflation expectations for the two types of agents (equation 4 vs. equation 10). The assumption that only a portion of the agents set interest rates according to the REH may be viewed as introducing yet another asymmetry. This one represents the uncertainty agents face while trying to pin down the central bank's reaction function. The impact of this uncertainty on the predictive properties of the term spread is partly discussed by Roley and Sellon (1996), and Favero (2001). The latter paper, using a GE macroeconomic model, shows that it may be this uncertainty about monetary policy behavior that often leads to empirical rejection of the REH.

We approach the problem by supposing that the fraction of agents who are unsure about the central bank's reaction function set long-term interest rates in a rather naive way by identifying them with current short-term interest rates. Specifically, we suppose that half of all agents behave in this way, and we thus set the coefficient α_{51} in the term structure 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

Demand shock Supply shock



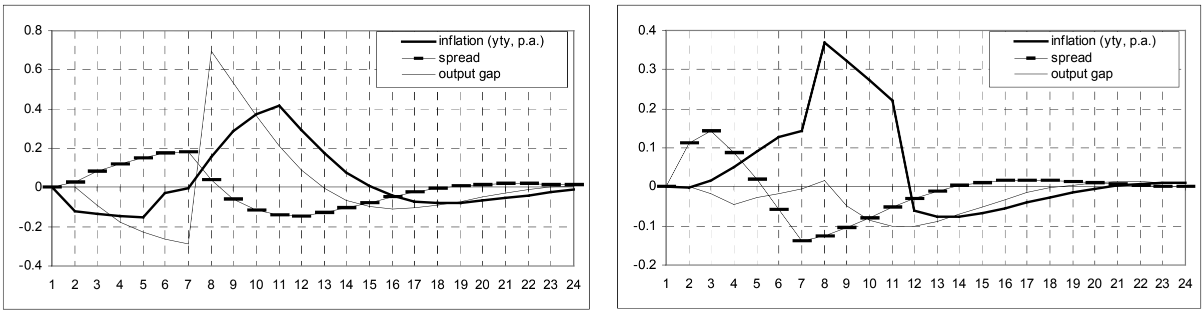
Examination of the responses and their comparison with the benchmark results of Figure 1 leads to the following conclusion. Although the responses of inflation and real economic activity are similar, the elasticity of their relationships with the term spread changes significantly. The predictive ability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

Expectations about future exchange rate and inflation

While the previous paragraphs examined what happens to the predictive properties of the term spread if the number of agents who form expectations rationally goes down, this section takes up the opposite situation. We examine the impact of "expectations rationality" on the term spread's predictive ability. Namely, we let all the agents forming expectations on the future exchange rate (equation 3) and inflation (equation 10) behave fully rationally (model-consistently), and set α_{31} = 1 and β_{11} = 0 (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 rational expectations

Demand shock Supply shock



The basic feature of the responses in Figure 6 as compared to our benchmark case in Figure 1 is the faster convergence of all variables towards their long-term equilibrium levels in the period after the shock actually takes place. In the same time under a purely forward-looking economy, both demand and supply shocks lead to a deeper initial fall in real economic activity. After inspecting the responses of other variables not shown in Figure 6, we conclude this happens because of the quick initial appreciation of the real exchange rate driven by a rationally expected rise in inflation. Overall, the term spread remains a good indicator of future inflation.

3.3 Summary of the results and discussion

The results of the simulations are summarized in Table 1 below. The first column characterizes the type of simulation performed and thus also the question we sought to address. The second column shows the value of the 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 the optimal lead horizon in parentheses. In the case that the results for both types of shocks are positive, we further examine the outcome by performing a series of OLS regressions using the data values obtained in the simulations performed. We let inflation and real economic activity be explained by the term spread with an appropriate lag. 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, displaying R^2 in parenthesis.

Table 1: Summary of the results

Model	**Modified coefficients**	**Spread indicates inflation (lead in quarters)**		**Spread indicates output (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) 0.88 (0.79)	0.88 (0.17)	no	
Smaller smoothing	$\alpha_{41} = 0.4$	yes (5-6) 0.23 (0.33)	0.39 (0.07)	no	
Higher weight on inflation gap	$\alpha_{42} = 5$ $\alpha_{43} = 0$	yes (5-6) 0.71 (0.81)	0.66 (0.63)	yes	
Higher weight on output gap	$\alpha_{42} = 0$ $\alpha_{43} = 5$	no		yes (2) 0.68 (0.69)	0.76 (0.43)
REH partly ignored	$\alpha_{51} = 0.5$	yes (6) 1.82 (0.82)	2.26 (0.42)	no	
Rational expectations (eq. 3 and 10)	$\alpha_{31} = 1$ $\beta_{11} = 0$	yes (6-7) 1.35 (0.59)	1.53 (0.52)	no	

The *baseline simulation* results reported in the first row show that the term spread has a substantial predictive power for future inflation. The coefficients lead to the conclusion that a one percentage-point difference between the long-term (1Y) and short-term (3M) interest rates indicates that inflation 5 to 6 quarters in the future is expected to be about 0.9 percentage-points above the inflation target. As the baseline model coefficients should best mimic the Czech economy, this finding is important.

After reviewing the results of the baseline simulations, let us now inspect the findings with regard to the role of monetary policy behavior. 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 of the term spread (lower fit of the regressions). This result 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. In the case of a *greater weight on the inflation gap* in the reaction function, the term spread remains a good indicator of future inflation. The quantitative changes are very small and the results seem even more robust when the fit of the regressions is examined. The results are completely reversed when the reaction function is specified with a *greater weight on the output gap*. Inspecting the results in the fourth row, we conclude that while the predictive properties in terms of future inflation have disappeared, the term spread is now a good indicator of future real economic activity. Quantitatively, the plausible outcome is that the term spread of one percentage-point in this case indicates future output to be about 0.7 percentage-points above its equilibrium value. These results differ from those of Estrella (1998), who concludes that if the reaction function includes just the output gap, the term spread indicates future real output (four quarters ahead) and inflation (eight quarters ahead). Estrella further shows that when only the inflation gap is considered for setting the policy rate, the predictive ability of the term spread vanishes. The experiments we performed suggest the differences can be explained by the role of the exchange rate transmission channel in a small open economy. Consider two examples. First, in the case of greater weight on the output gap we find no link with future inflation. This 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 lead horizons in our simulations 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 ability of the term spread remains 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 that is farther above the target than in the baseline case. The fact that agents do not set long-term interest rates based on expected central bank 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. A smaller spread is then connected to similar values of inflation and real output as in the baseline case. The last row summarizes the results for the case of *rational exchange rate and inflation expectations*. The term spread remains a good indicator of future inflation, albeit the quantitative relation changes slightly.

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 behavior and on how agents' expectations are formed. It is therefore necessary to use a model of the economy with endogenous monetary policy and expectation formation in order to find out what variables the term spread indicates and with what lead.

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

3. 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 six quarters in the future.

Even though we tend to think the results presented in this paper present a certain amount of progress in the understanding of the predictive properties of the term spread, we are aware of its limitations. First, further research will be focused on performing stochastic simulations with reaction function derived from the central bank's loss function. Second, developing a truly structural model of the Czech transition economy certainly remains among the biggest challenges.

The results suggest that the term spread is a good indicator. However, this does not say much as to what importance should be assigned to the term spread in the conduct of monetary policy. On the one hand, it is tempting to say the "predictions" of the term spread may form a valuable input into monetary policy decision making. After all, many central banks pay considerable attention to its development. On the other hand, the warnings of Lucas (1976) or Goodhart (1981) fully apply. Since the relation between the term spread and future inflation or output is based upon agents' expectations, and monetary policy action alters those expectations, using the term spread as a direct input into setting policy does not seem to be a wise decision. The central bank always needs to bear in mind that the information based upon agents' expectations is only a supplement and that inflation targeting cannot be successfully implemented without a forward-looking structural model. Indicators may, however, help assess the degree to which the policy is understood and believed. As credibility is one of the main preconditions for a successful inflation targeting strategy, this is a very important function.

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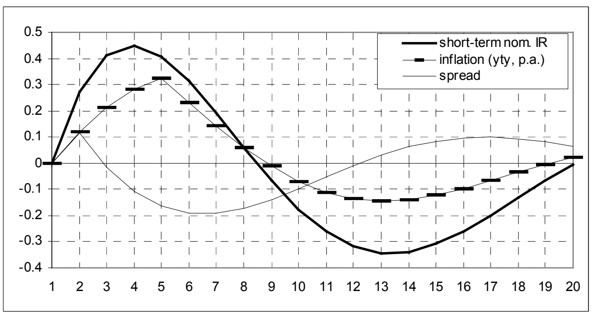
Appendix

Table A1: Overview of recent research findings

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

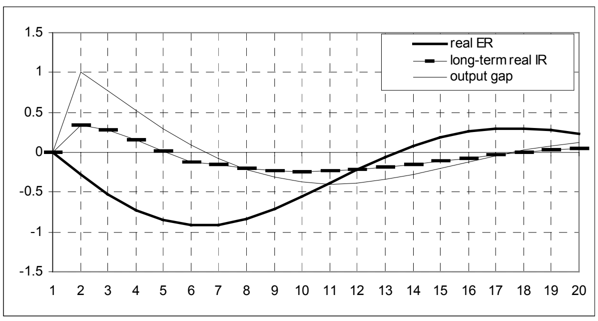
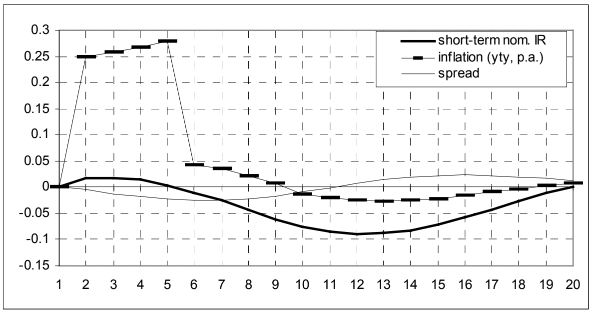


Figure A2: Supply (cost-push) shock

Nominal variables



Real variables

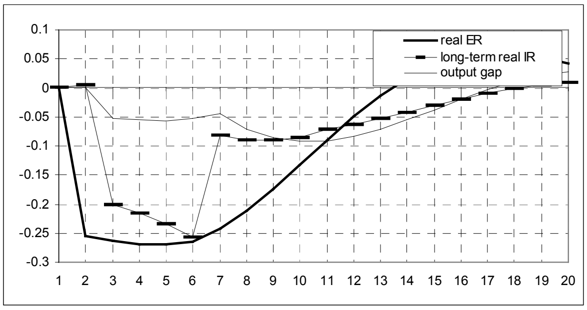
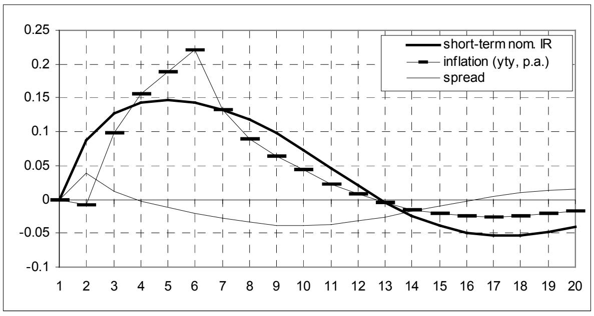


Figure A3: Foreign inflation shock

Nominal variables



Real variables

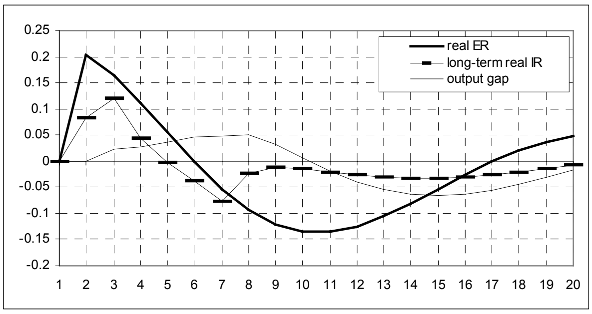
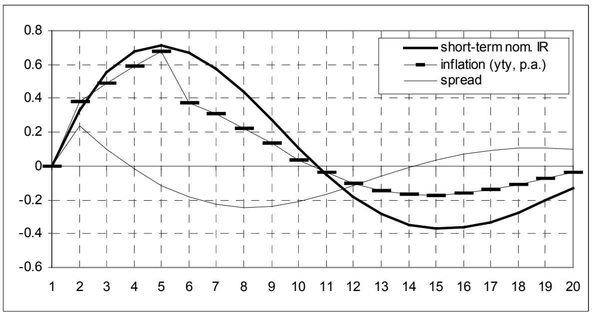


Figure A4: Exchange rate shock (nominal depreciation)

Nominal variables



Real variables

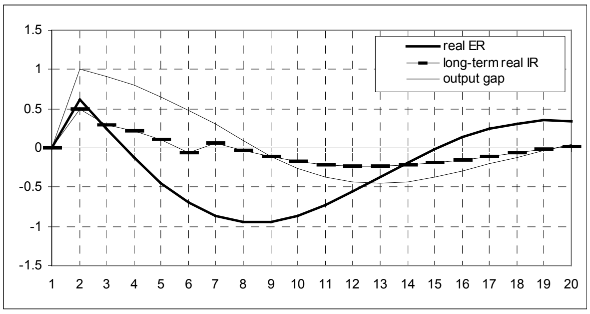
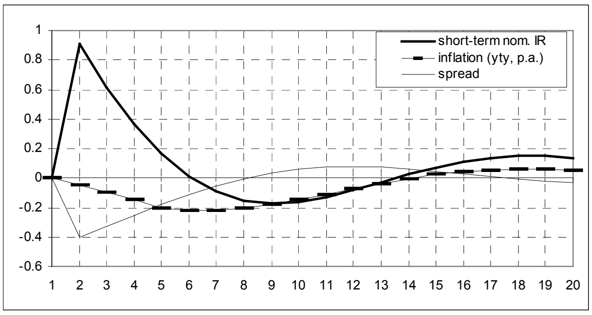
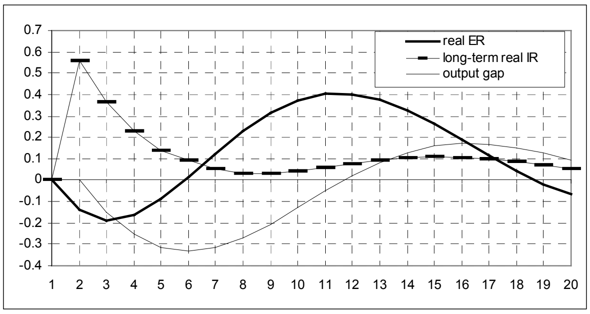


Figure A5: Reaction function (monetary) shock

Nominal variables



Real variables



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