The Term Structure of Interest Rates and Future Inflation

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Published: Eastern European Economics, Vol. 37, No. 5, September-October 1999, pp. 36-51

Expected inflation is a major decision factor of various economic agents. Since expected inflation is not directly observable, economists have been seeking ways of extracting market's inflation expectations from observable variables.[1] One of the most reliable sources of inflation expectations is the term structure of interest rates.

The popularity of using the term structure of interest rates for forecasting future development of various economic variables stems from the fact that the term structure incorporates information on the future course of interest rates. The hypothesis that the current yield curve is capable of predicting the development of future inter-est rates rests on the well known expectations hypothesis and was empirically tested by Mishkin (1988), Dahlquist and Jonsson (1995) and Dziwura and Green (1996) among others. Kotlán (1999a) shows that the term structure of interest rates provides useful information on the development of future interest rates in the Czech inter-bank market. Recent studies of Plosser and Rouwenhorst (1994), Cozier and Tkacz (1994), Bernard and Gerlach (1996), Estrella and Mishkin (1996), Haubrich and Dombrosky (1996), Smets and Tsatsaronis (1997), Estrella (1997) and Attna-Mensah and Tkacz (1998) also successfully employ the term structure for forecasting the development of future economic activity.[2]

The aim of this article is to test the information content of the term structure of interest rates regarding future inflation development in the Czech economy. The rest of the paper is organized as follows. The first section presents the models that will be used for empirical tests in the third section. The second section details the data and the forth section discusses the results and concludes.

I. Methodology

There are two hypotheses relating the current term structure to future inflation. The first hypothesis starts off by decomposing term structure spread into expected real rate change, expected inflation change and term premium differential. If most of the variation in the term structure spread is caused by variation in expected inflation, the spread will help predict future change in inflation. The second hypothesis is based on the belief that the term structure approximated by spread between long and short rate is a good indicator of the stance of monetary policy. The actions of monetary authority influence short interest rates to a greater extend than long rates that are determined mainly by equilibrium real interest rates and market's expectations of future inflation and short term interest rates. Monetary tightening will thus lead to a reduction of the spread and predict a slowdown in economic activity and

[1] While it is also possible to conduct surveys of market player's inflation expectations, such surveys in adition to being time demanding and costly may not always provide reliable results; see Laster-Bennett-Geoum (1996) for discussion.

[2] For introduction to theory, references and relation between the term structure spread and real economic activity in the Czech economy see Kotlán (1999b).

inflation. In the remaining part of this section models for testing the two hypotheses are developed.

Term structure and future change in inflation

Following the methodology introduced by Mishkin (1990a) and further refined and tested by Fama (1990), Mishkin (1990b, 1991), Jorion-Mishkin (1991), Ragan (1995), Estrella-Mishkin (1997), Day-Lange (1997), Breedon-Chadha (1997) and Kozicki (1998) among others, we will investigate whether current spread between m-period and n-period interest rates includes information about change of inflation between periods m and n.

It stems from the Fisher equation (1) that nominal interest rate in time t with maturity in period m ($i_{t,m}$) may be decomposed into an ex ante real interest rate ($rr_{t,m}$) in time t maturing in m and expected inflation ($E_t p_{t,m}$) over the next m-periods in time t:

$$i_{t,m} = E_t p_{t,m} + rr_{t,m}. \qquad (1)$$

The actual inflation over the next m-periods equals expected inflation in the period plus the forecast error of inflation ($e_{t,m}$):

$$p_{t,m} = E_t p_{t,m} + e_{t,m} . \qquad (2)$$

By combining equations (1) and (2), we obtain:

$$p_{t,m} = i_{t,m} - rr_{t,m} + e_{t,m} . \qquad (3)$$

Since we are interested in the information about the future path of inflation that is embodied in the term structure we must subtract similar equation for n-periods ($m > n$) from equation (3) which then results in:

$$p_{t,m} - p_{t,n} = i_{t,m} - i_{t,n} - rr_{t,m} + rr_{t,n} + e_{t,m} - e_{t,n} . \qquad (4)$$

After rewriting this equation into a regression form that will be used for empirical testing we obtain:

$$p_{t,m} - p_{t,n} = a_{m,n} + b_{m,n} (i_{t,m} - i_{t,n}) + h_{t,m,n} , \qquad (5)$$

where:

$$a_{m,n} = \widehat{rr}_n - \widehat{rr}_m \qquad (5a)$$

$$h_{t,m,n} = e_{t,m} - e_{t,n} - (m_{t,m} - m_{t,n}) \qquad (5b)$$

$$m_{t,m} = rr_{t,m} - \widehat{rr}_m \qquad (5c)$$

$$m_{t,n} = rr_{t,n} - \widehat{rr}_n \quad (5d)$$

There are two assumptions necessary for ordinary least-squares technique to provide consistent estimates of coefficient $b_{m,n}$. The first assumption is that expectations are rational. The inflation forecast errors must not be predictable using all available information in time t, including interest rates $i_{t,m}$ a $i_{t,n}$. It follows that: $E_t e_{t,m} = E_t e_{t,n} = 0$ and the forecast errors $e_{t,m}$ and $e_{t,n}$ are then orthogonal to the right-hand side regressors of equation (5). The second assumption posits that the slope of the real term structure is constant over time. If this condition is satisfied, the $m_{t,m}$ - $m_{t,n}$ term from equation (5b) disappears and the error term $h_{t,m,n}$ in equation (5) is reduced to $e_{t,m}$ - $e_{t,n}$. If the slope of the real term structure is not constant over time, the slope of the nominal term structure still contains information about future inflation change but it is no longer an optimal predictor.[3]

The above mentioned leads to the following conclusions regarding $b_{m,n}$ coefficient estimates. If the hypothesis $b_{m,n} = 0$ is statistically rejected, the slope of the nominal term structure ($i_{t,m}$ - $i_{t,n}$) contains information about the change in future inflation rate between periods n and m, and in the same time the slope of the nominal and the real term structures do not move one-for-one in time.[4] If the hypothesis $b_{m,n} = 1$ is statistically rejected then the slope of the real term structure is not constant over time and the slope of the nominal term structure contains information about the real term structure.

Term structure and future level of inflation

While the model of the previous subsection was based on rigorous definition of the relations between nominal interest rates, real ex ante interest rates and expected inflation, the model of this subsection is somewhat more straightforward in nature. The transmission mechanism of monetary policy in today's world is greatly based on the interest rate channel. Manipulating with central bank's interest rates allows the monetary authority to influence both aggregate demand and inflation: a rise in the interest rate generally leads to a slowdown in aggregate demand and inflation and vice versa.[5]

The change in central bank's interest rate is, however, not translated into the term structure proportionally since monetary authority is usually able to exercise greater control over the „short end“ of the yield curve than over the „long end“. If we believe that a rise in short term interest rates points to lower future inflation, why bother with the term structure? The main reason is that the spread between long and short rate incorporates both current actions of

[3] Furthermore, as pointed out for instance by Mishkin (1990), if the slope of the nominal term structure is correlated with the slope of the real term structure, then $h_{t,m,n}$ is correlated with ($i_{t,m}$ - $i_{t,n}$). The obtained OLS estimate $b_{m,n}$ then has a probability limit different from one and the estimate of constant $a_{m,n}$ will also not be a consistent estimate of the mean slope of the real term structure.

[4] Kozicki (1998) shows that a statistical rejection of $b_{m,n} = 0$ does not necessarily provide evidence that the term structure contains significant information about the future change in inflation. He argues that the coefficient estimate of $b_{m,n}$ need not imply that the term structure helps predict inflation since it may be reflecting that the term structure spread is correlated with current inflation. Based on the same argument he also considers the conventionally reported adjusted R^2s as overestimating the actual fit of the equation and proposes an alternative measure of the coefficient of determination. His serious arguments, however, hold only when m is large enough relative to n and when inflation is highly persistent. We avoid these problems by working with relatively „narrow“ spreads.

[5] While this text-book-type of transmission need not always work in practice we will proceed on the assumption that it does.

monetary authority (short rate) and market's perception of this action (long rate). The way that market players perceive the central bank's action, may have a significant impact on the effect of the action itself. The long interest rates are determined by equilibrium real interest rates and market's expectations of future inflation and short term interest rates. Let us now discuss the implication of central bank's induced rise of short term interest rate for the term spread.[6] There are three possible scenarios of the term spread's reaction. First, the term spread increases if the long rate rises more than one-for-one following the rise of the short rate. The rising long rate suggests that the market expects either future inflation or future short rate to rise and thus perceives the current action of the monetary authority as unsatisfactory. Under the assumption that future short rates will rise as a reaction to inflation threat, rising spread indicates rising future inflation. Second, the term spread may fall after the rise in the short rate if the long rate falls, remains unchanged or rises less than the short rate. Following the same reasoning as above, decreasing term spread points to lower future inflation. The third possible outcome of the rise of the short rate is no change in the term spread. This would suggests that the market expects future inflation to remain at current levels.

The hypotheses that rising term spread suggests a future rise in inflation and decreasing term spread suggests falling future inflation may be written in the regression form:

$$p_{t+k} = g_1 + f_1(i_{t,m} - i_{t,n}) + e_{t,m,n}\,, \qquad (6)$$

where p_{t+k} denotes year-to-year inflation at time $t+k$ and all other variables are defined as before. In the regression equation (6) we would expect the f_1 coefficient to be significantly different from zero and positive. Since the lead horizon (k) for inflation is unknown in the Czech economy, equation (6) will be estimated with ad hoc specified 6, 12 and 18 months leads as well as with no lead ($k=0$).

In order to test the hypotheses that it is the difference between the long and the short rate that explains future level of inflation we will also test equation (6) controlling for the short term central bank's rate:

$$p_{t+k} = g_2 + f_2(i_{t,m} - i_{t,n}) + q_2 is_t + e_{t,m,n}\,, \qquad (7)$$

where is_t stands for the short term rate. Since the history of the Czech national bank's principal monetary policy tool - the two week repo rate - is short and there were only seldom changes to the rate prior to 1997 we will instead use a two week inter-bank interest rate that tracks the movements of the two week repo rate very closely and is available from April 1992. If the coefficient q_2 is significant, the fit of the regression improves and the significance of the f_2 coefficient vanishes, then the short rate is more useful for predicting inflation by itself than as a part of the term spread.

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[6] In the following we assume that the equilibrium real interest rate is constant in the long run and that the movements in the long interest rate are caused either by changing expectations of future inflation or future short term interest rates.

II. Data

The development of inflation in transitive economies is influenced by gradual relaxation of regulated prices and so we run the calculations both for the headline and the net inflation[7]. Inflation for 1, 3, 6, 9 and 12 months is calculated from CPI and CPIx (net inflation) series respectively, both seasonally adjusted by the ratio to moving average (multiplicative method) and annualized. For instance inflation denoted as $p_{t,6}$ for t set to January 1996 is calculated as July 1996 CPI divided by January 1996 CPI and annualized. Both CPI and CPIx series were provided by the Czech Statistical Office (CSO). We further use monthly averages of 2 week and 1, 3, 6, 9 and 12 month offer inter-bank interest rates (PRIBOR) provided by the Czech national bank (CNB).[8] All the data series except for 9 month interest rates (from August 1993) and net inflation (from January 1993) are available from April 1992 to July 1999.

III. Empirical results

Term structure and future change in inflation

Prior to further testing, the inflation change series and interest rate spreads were all checked for unit roots using the augmented Dickey-Fuller testing procedure and were found stationary in levels, that is integrated of order zero. This indicates feasibility of using OLS in levels. Equation (5) was estimated using the following *m, n* pairs of interest rates and corresponding inflation changes: 3,1; 6,3; 9,6; 12,6 and 12,9. The results are reported in *table 1.* Since the monthly interval of the data is shorter than the forecast horizon, the forecasts are overlapping. This is likely to cause serial correlation with MA (m-1) process.[9] The standard errors reported in *table 1* are thus estimated using Newey-West correction procedure that accounts for possible autocorrelation and heteroscedasticity in residuals.

The estimation results reported in *table 1* are somewhat disappointing. First, the $b_{m,n}$ coefficients are insignificant in most cases and in some cases even of a wrong sign. The exception are forecast horizon over 6 months (that is pairs 12,6 and 12,9) for net inflation change forecast where the coefficients are close to one and significant. Second, the adjusted R^2s are very low, indicating poor fit of the regressions. A bit higher adjusted coefficients of determination are found for forecast horizons over 6 months. Third, the hypothesis that $b_{m,n}$ is significantly different from zero is not rejected only for *m,n* pairs of 12,6 and 12,9 months forecasts. The latter forecast horizon also shows at 5% level that $b_{m,n}$ is not significantly different from one.

We interpret the results as follows. Interest rate spreads in the Czech inter-bank market contain useful information regarding future changes in (net) inflation only for forecast horizons where m = 12 and n = 6 and for horizon with m = 12 and n = 9. Only the latter spread, however, contains information solely about the development of inflation and not also, as the former does, about the development of the real term structure. Our results well compare with those reported by Mishkin (1990a, 1991) in that interest rates with maturities below six months usually provide only very little information on the development of future inflation. We believe

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[7] Net inflation in the Czech Republic is calculated from CPI basket excluding items with regulated prices. These form about 18% of all the items.

[8] Since monthly CPI data are published in the beginning of the following month it would seem logical to use end of month interest rates. The data for CPI are, however, collected in various times during the month and interest rates in CR are quite volatile. We thus consider the average measure of interest rates more appropriate.

[9] Another source of possible serial correlation pointed out by Mishkin (1990a) is serial correlation in term premiums.

that the reason might be found in greater variability of real interest rates (and their term structure) in the short run. The restrictive assumption of constant real term structure slope is relaxed in a theoretical model developed by Frankel and Lown (1994). Even though empirical tests undertaken therein lead to somewhat better results than the ones using equation (5), the authors themselves conclude that „most of the benefit can be obtained from simply looking at a wide long-short spread“ (pp. 527).[10] Mehra (1998) takes a different approach when he adds two variables that capture movements in the real rate of interest to his model. The short term influence of monetary policy on the real rate is proxied by the Fed funds rate and the influence of real economy by output gap. Such a specification is due to unsuitable data series (highly volatile data, short series), however, not possible in our case. The generally low explanatory power of the performed regressions is caused by highly volatile inflation even though the series were seasonally adjusted. The reason that more positive results are found for net inflation series confirms the presumption that headline inflation is difficult to forecast due to the gradual relaxation of regulated prices.[11]

Term structure and future level of inflation

It has been proven many times that inflation is unit root non-stationary and integrated of order one. The ADF stationarity tests we performed confirmed this assumption for inflation and also for the short (2 week) interest rate. Performing the OLS analysis according to equations (6) and (7) with variables in levels could lead to spurious regression and we thus estimate both equations in first difference forms where all the variables are stationary at 5% significance level.[12] The results for equation (6) reported in *table 2* show several interesting facts. First, the coefficient on the spread is positive only when inflation enters the equation either with no lead or with an 18 month lead. While the 18 month lead results in f_1 being both positive and significantly different from zero when forecasting *headline inflation*, the f_1 coefficient is both positive and significantly different from zero using the no-lead equation when predicting *net inflation*. The 18 month lead coefficients for net inflation forecasts fall just one or two percentage points short of the 10% significance range (see the notes below *tables 2* and *3*). The results further show that the explanatory power of the term spread decreases with rising maturity of the short rate even though it is still rather high for equation in first differences (see the adjusted R^2s in the fifth column of *table 2* and in the seventh column of *table 3*). After the two week interest rate proxying for the central bank's rate is introduced into the regression (*table 3*), the results from equation (6) do not change significantly. The q_2 coefficient is never significant, the term spread coefficients change only very little and the fit of the regression also remains virtually unchanged. This confirms the belief that the term spread is a better proxy of the stance of monetary policy than just the short rate by itself.

VI. Conclusions

The aim of this paper was to explore the predictive capabilities of the term structure spread regarding the development of future inflation in the Czech Republic. We have tested two types of models. The first examines the information contained in the term spread for future changes in inflation and is based on a decomposition of nominal interest rates in line with the theory of

[10] Frankel and Lown (1994) introduce a 5-year minus fed funds spread and compare it to 12-month minus 3-month spread.

[11] Any relaxation of the prices of regulated goods/services will, of course, also spill over to the unregulated goods/services sector. The net inflation is thus not completely free from this influence either.

[12] First differences are denoted by Δ symbol.

Irving Fisher. The second model is based on the assumption that the term spread contains significant information about the stance of monetary policy which then affects future inflation. The results well compare to previous research on the subject. Namely in that we have shown that the short end of the term structure contains virtually no information on the future development of inflation. The „longer spreads“ - spreads between 12 and 6 and 12 and 9 months - contain some information regarding future inflation. The explanatory power of the regressions is, however, insufficient to formulate a serious forecast model.

The empirical tests of the second hypotheses brought about more positive results. The assumption that the term spread contains significant information about the stance of monetary policy was confirmed. Further the results suggest that the term spread contains significant information about future inflation 18 months ahead. The fact that net inflation regression coefficients for zero lead equations are also positive and significant may suggest that market participants form their inflation expectations in a more adaptive than rational way. The challenging search for appropriate model of inflation expectations formation in the Czech Republic is, however, not the subject of this article. Even though the 18 month lead equations provide certain information on the development of future inflation (see *figure 1*), great amount of caution should be exercised when interpreting these predictions since the Czech capital market so far lacks both sufficient liquidity[13] and stability in order for financial prices to act as reliable inflation indicators.

[13] Not only the bond market but also the money market where 95 per cent of all transactions concern the short end of the yield curve.

Table 1 Results of equation (5)

$p_{t,m} - p_{t,n} = a_{m,n} + b_{m,n}(i_{t,m} - i_{t,n}) + h_{t,m,n}$					
m,n	$b_{m,n}$	*SE of* $b_{m,n}$	*adjusted* R^2	*Wald test*[a] $b_{m,n} = 0$	*Wald test*[a] $b_{m,n} = 1$
Results for headline inflation (CPI)					
3,1	0,12	1,66	0,02	0,94	0,59
6,3	-0,26	2,11	0,02	0,90	0,55
9,6	0,47	0,96	-0,04	0,63	0,58
12,6	0,86	0,59	-0,01	0,15	0,81
12,9	0,88	0,77	0,01	0,25	0,88
Results for net inflation (CPIx)					
3,1	-3,65	2,76	0,03	0,19	0,09
6,3	-1,58	1,29	0,03	0,23	0,05
9,6	0,86	0,56	0,03	0,13	0,81
12,6	1,07**	0,43	0,09	0,01	0,86
12,9	1,00**	0,49	0,08	0,05	0,99

Note: Equation (5) included two dummy variables for May and June 1997 where the interest rates time series were biased due to exchange rate crises. ** denotes coefficient significance at the 5% level. Standard errors calculated for Newey-West adjusted covariation matrices. ([a]) Wald test: p-values of F-statistic reported.

Table 2 Results of equation (6) in first differences

$\Delta p_{t+k} = g_1 + f_1 \Delta(i_{t,m} - i_{t,n}) + e_{t,m,n}$					
m,n	*k* (*in months*)	f_1	*SE of* f_1	*adjusted* R^2	*Wald test*[a] $f_1 = 0$
Results for headline inflation (CPI)					
12,1	0	0,44	0,41	0,04	0,28
12,1	6	-0,72**	0,34	0,14	0,03
12,1	12	-0,09	0,13	-0,02	0,49
12,1	18	0,48***	0,16	0,11	0,08
12,3	0	0,34	0,40	0,01	0,39
12,3	6	-0,75**	0,36	0,10	0,04
12,3	12	-0,02	0,08	-0,01	0,74
12,3	18	0,56**	0,25	0,11	0,03
12,6	0	0,24	0,35	-0,01	0,49
12,6	6	-0,72**	0,36	0,06	0,04
12,6	12	0,02	0,07	-0,01	0,77
12,6	18	0,59**	0,23	0,08	0,01
Results for net inflation (CPIx)					
12,1	0	1,57**	0,67	0,45	0,02
12,1	6	-0,58	0,62	0,07	0,34
12,1	12	-0,36	0,25	0,02	0,15
12,1	18	0,86	0,54	0,26	0,11
12,3	0	2,07**	0,83	0,40	0,02

12,3	6	-0,72	0,77	0,05	0,35
12,3	12	-0,28	0,21	-0,01	0,18
12,3	18	1,22[b]	0,75	0,28	0,11
12,6	0	2,90**	1,28	0,30	0,03
12,6	6	-1,14	1,15	0,05	0,32
12,6	12	-0,26	0,28	-0,01	0,36
12,6	18	1,72[c]	1,08	0,25	0,12

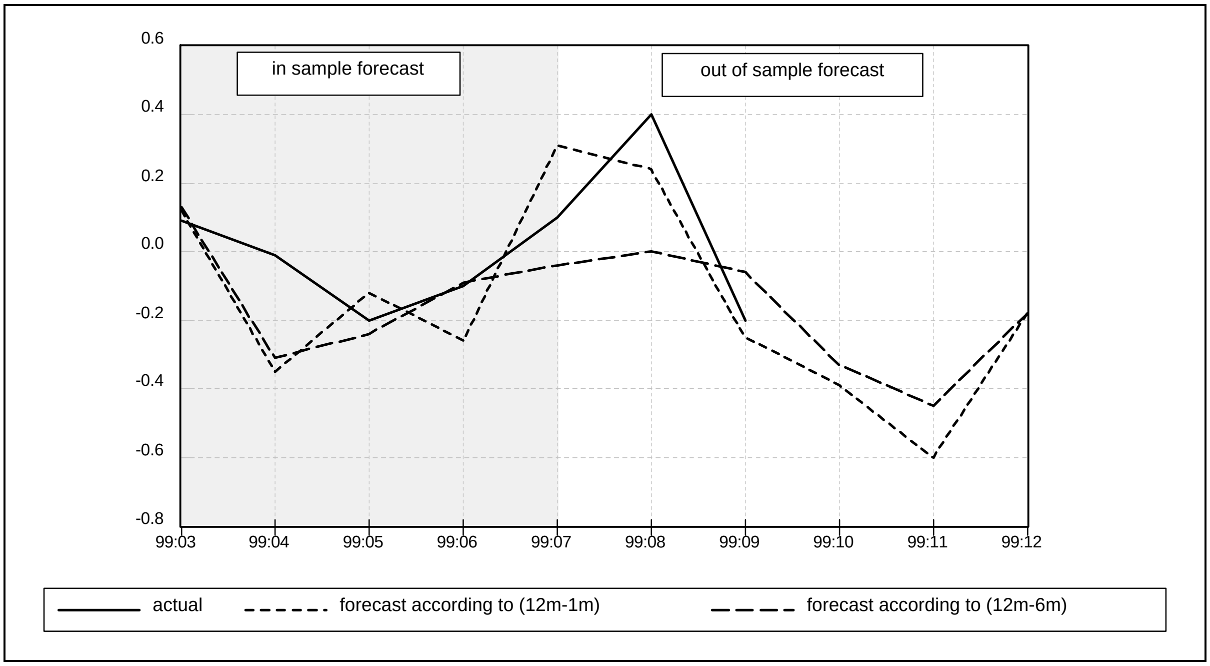
, * denotes coefficient significance at the 5% and 10% level respectively. Standard errors calculated for Newey-West adjusted covariation matrices. Values for 5/97 and 6/97 omitted from calculations due to biases connected with the currency crisis. ([a]) Wald test: p-values of F-statistic reported; ([b]) coefficient significant at 11,03% level; ([c]) coefficient significant at 12,21% level.

Table 3 Results of equation (7) in first differences

$\Delta p_{t+k,t+k+12} = g_2 + f_2 \Delta(i_{t,m} - i_{t,n}) + q_2 \Delta is_t + e_{t,m,n}$						
m,n	*k* *(in months)*	f_2	*SE of* f_2	q_2	*SE of* f_2	*adjusted* R^2
Results for headline inflation (CPI)						
12,1	0	0,61	0,51	0,18	0,16	0,04
12,1	6	-0,46	0,29	0,29	0,22	0,17
12,1	12	-0,07	0,11	0,03	0,10	-0,02
12,1	18	0,59**	0,22	0,12	0,12	0,10
12,3	0	0,40	0,42	0,06	0,13	0,00
12,3	6	-0,44***	0,25	0,36	0,24	0,16
12,3	12	0,03	0,09	0,06	0,12	-0,02
12,3	18	0,61**	0,20	0,05	0,14	0,09
12,6	0	0,24	0,32	-0,01	0,14	-0,02
12,6	6	-0,39***	0,21	0,40	0,25	0,15
12,6	12	0,07	0,11	0,07	0,11	-0,02
12,6	18	0,57**	0,17	-0,02	0,16	0,06
Results for net inflation (CPIx)						
12,1	0	1,65**	0,67	0,08	0,13	0,44
12,1	6	-0,17	0,35	0,40	0,33	0,11
12,1	12	-0,47***	0,25	-0,07	0,07	0,01
12,1	18	1,29***	0,77	0,30	0,20	0,30
12,3	0	2,05**	0,75	-0,02	0,19	0,39
12,3	6	-0,16	0,38	0,42	0,36	0,11
12,3	12	-0,15	0,29	0,06	0,14	-0,01
12,3	18	1,63[b]	0,99	0,21	0,16	0,30
12,6	0	2,67**	1,11	-0,16	0,26	0,29
12,6	6	-0,40	0,62	0,40	0,36	0,12
12,6	12	0,04	0,05	0,11	0,16	-0,02
12,6	18	2,05[c]	1,28	0,13	0,13	0,26

, * denotes coefficient significance at the 5% and 10% level respectively. Standard errors calculated for Newey-West adjusted covariation matrices. Values for 5/97 and 6/97 omitted from calculations due to biases connected with the currency crisis. ([b]) coefficient significant at 10,64% level; ([c]) coefficient significant at 11,48% level.

Figure 1 Forecast of first differences of year-to-year net inflation



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