Zoltán Reppa: Interest rate expectations and macroeconomic shocks affecting the yield curve

This study briefly presents the tools the Magyar Nemzeti Bank uses to estimate and interpret the yield curve, and to analyse the underlying reasons of yield changes. The first part of the study compares the yields of government securities and those of interbank and interest rate swap markets, and examines the reasons behind their differences. The second part sums up the dynamic model that is used to describe the interaction between the yield curve and the macroeconomy. This model enables us to examine the different macroeconomic shocks which impact the development of the yield curve; from a central bank perspective it is particularly important to gauge the impact of monetary policy shocks and monetary policy measures on long-term yields.

INTRODUCTION

Changing the base interest rate is a means used by the MNB to influence economic processes. The maturity of the base interest rate is extremely short, merely two weeks, therefore it can only impact the short-term yields of the interbank market. Macroeconomic decisions, however, typically depend on the developments of longer-term yields; thus, in order to assess how the MNB can influence these decisions, we need to examine how longer-term yields react to changes in the base interest rate.[1]

This reaction depends on the reason for the base interest rate change. As we will see, long-term yields typically stem from expectations regarding short-term yields; if raising the base interest rate is unexpected or is a reaction to mounting inflation, market participants may draw different conclusions.

Therefore, there is need for a model, which can grasp the dichotomous, instantaneous and delayed correlations between macro variables and different maturity yields. Since a vast majority of macro variables become available with a monthly frequency at best, this model would not be able to explain daily yield shifts. At the same time, in order to handle its tasks related to stability, provisioning and financial market operations, the MNB needs yield curves with a daily frequency.

This study shows the data and methods with which the MNB estimates the daily yield curve, and the models it uses to examine the correlation between the yield curve and the macroeconomy.

THE YIELD CURVE

Theoretical grounds

The zero coupon yield with a maturity of *t* is the return on a security which matures at *t,* and does not pay a yield until maturity. Assuming that a three-month, 1000 forint treasury bill costs 980 forints today, the value of the three-month zero coupon yield will be 4 x 100 (1000/980–1) ≈ 8.16 percentage points.[2] Besides treasury bills, interbank loans are considered zero coupon investments as well; their yields are expressed by BUBOR (Budapest Interbank Offer rate) yields.

The zero coupon yield curve, or simply yield curve, is a graph whose value at *t* corresponds to the yield of a zero coupon with maturity *t*. Obviously, the yield curve is a theoretical construct; in practice, there is no corresponding investment for each individual maturity. The whole point of plotting the yield curve is to produce a continuous yield curve from the yields observed for existing maturities.

Such a continuous yield curve can be used for several purposes. First of all, while smoothing the yield curve, we have the opportunity to remove noise from the core data. Second, we can derive forward yields from the yield curve, which incorporate market expectations of future returns.

The way to calculate a forward yield starting at *t* and maturing at *h* is as follows:

$$f_{t,h} = \frac{100}{h} \times \left(\frac{1 + \frac{t+h}{100} r_{t+h}}{1 + \frac{t}{100} r_t} - 1 \right). \qquad (1)$$

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[1] The role of the information obtained from financial markets in shaping Hungarian monetary policy is described in detail by Delikát (2007).
[2] The multiplier of 4 is needed because we use annualised yields.

Assuming that the three-month and the six-month zero coupon yields are 8% and 8.5% respectively, the three-month forward yield starting three months from now will be

$$f_{3,3} = 4 \times 100 \times \left(\frac{1 + 0.085/2}{1 + 0.08/4} - 1 \right) \approx 8,82\%.$$

The formula derives from the following, simple consideration. There are two ways to make a six-month investment: we either buy a six-month treasury bill today, or we buy a three-month bond today, and when it matures we buy another three-month bond from the proceeds; the forward yield will be the yield which provides the same return for both strategies in six months.

By means of formula (1), a forward curve can be calculated for any maturity h, which creates a link between short-term and long-term yields. In theoretical literature, studies focusing on the relationship between short-term and long-term yields can be divided into two main groups. Papers concentrating on macroeconomics typically apply the expectation hypothesis, which assumes that long-term yields are determined by expectations regarding the future changes of short-term yields, and the forward curve reflects these expectations. In contrast, the financial approach stresses the no-arbitrage theory, according to which it is impossible to realise profits risk-free in efficient markets; what is needed for this is the existence of certain relationships between yields of various maturities, of which formula (1) is one of the most basic examples.

In theory, the link between the two model frames is established by the risk premium, i.e. the difference between the expected and the observed yields, which is defined by the risk sensitivity of investors. Besides this, other distorting factors may play a role in practice, for example the maturity premium, liquidity premium and counterparty risk premium.

DAILY YIELD CURVE

The main objective of daily yield estimates is to assess the current status of financial markets and the expectations of market participants regarding the central bank base rate. For the latter, the objective is to assess short-term expectations regarding short-term or, as the case may be, the next rate setting decision.

The practice of the MNB in estimating daily yield curves is based on two data types: besides standard government bond market yield curves, from the spring of 2008 we have also made adjustments by using interbank yields and interest rate swap data. It is evident that the two markets are in a close relationship, which is primarily due to the hedging activities of interest swap market makers; at the same time, however, they also feature certain differences, which justify the simultaneous use of both yield curves.

Government bond market yields

The MNB uses secondary market yields quoted on the Budapest Stock Exchange to estimate the government bond market yield curve,[3] because this is the only information available for investors not trading actively. However, the reliability of the information content of stock exchange quotes is highly doubtful: as Balogh and Kóczán (2008) have indicated, stock exchange contracts account for a mere one per cent of the total secondary market turnover, and according to anecdotal information, stock exchange bid-ask spreads are ten times higher than the typical spreads of OTC deals (50 and 5-10 basis points).

Another problem stems from the fact that the shortest maturity available for government bonds with a liquid market is usually three months, making the short end of the estimated yield curve a mere extrapolation depending on the functional form assumed during the curve fitting; thus the ability of the estimated yield curve to assess short-term expectations is highly limited.

Due to the presence of 'on the run' bonds, which have a significantly higher turnover than securities of other maturities, the liquidity of the bond market is not perfect across longer maturities either. Typically, markets whose bonds are considered by the Government Debt Management Agency to determine benchmark yields are more liquid.

This certainly does not imply that the government bond market yield curve is not necessary; besides assessing short-term expectations, the yield curve is an important tool in other areas as well, such as reserve management. In addition, since data on the relevant foreign yields are easy to access, it is practical to use government bond market yield curves for the calculation of the 5 x 5 yield spread,[4] which is widely used in international comparison, such as in analyses discussing the expected date of the euro changeover.

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[3] The estimation methodology is discussed in Gyomai & Varsányi (2002).

[4] The 5 X 5 forward yield is the five-year yield expected for a time horizon of five years, denoted by $f_{5,5}$ in formula (1). This is the average value of the yield curve segment between 5 and 10 years, and is used as a measure of expected long-term yields. The 5 X 5 yield spread is the difference between the 5 X 5 yields derived from euro area and forint yield curves.
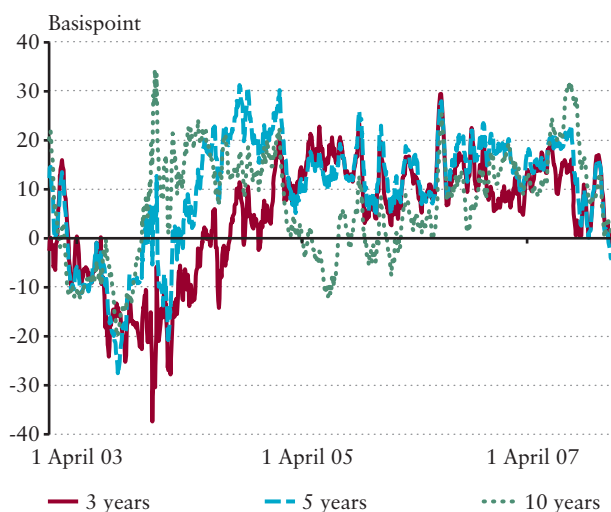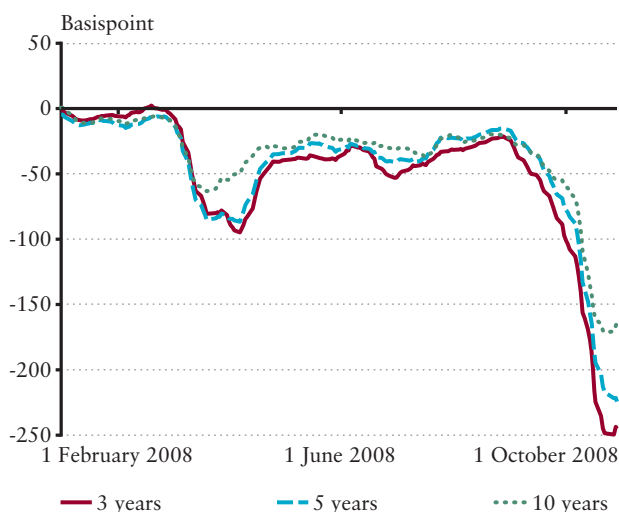
Chart 1

Swap spreads, 2002-2007

Chart 2

Swap spreads, 2008

Interest rate swap and interbank yields

In an interest rate swap transaction, the contracting parties swap a fixed and a floating rate security. For forint swaps, the floating leg is typically[5] the six-month BUBOR yield and the fixed leg is determined such that the net present value of the two cash flows be identical. During the estimation of the swap curve, we determine the yield curve applied by the market to calculate the net present value, which will therefore reflect the expectations of the floating leg or, in our case, the expectations of future interbank yields.[6]

Although the shortest swap yields used by the MNB have a maturity of one year, the fact that the floating leg equals the BUBOR rate enables us to incorporate interbank yields directly into the estimation, thus the swap curve provides observable, reliable data for maturities as short as two weeks.

The short end of the swap curve can be further improved by taking into account the so-called forward rate agreement (in short, FRA) quotes. The FRA yield is essentially a 'bet' made on the future values of BUBOR: assuming that the 3 x 6 FRA yield is currently 8.5 per cent, in three months' time the buyer will gain the difference between the then prevailing three-month BUBOR rate and 8.5 per cent. Of all observable yields, FRA yields reflect market expectations the most directly.

Differences between the yields of the two markets

A crucial difference between the two markets is the type of premia their spreads contain, and the size of the premia. Our analyses suggest that the liquidity of the interest rate swap market exceeds that of the government bond market, thus the distorting effect of liquidity premia is probably less reflected in the swap yields.
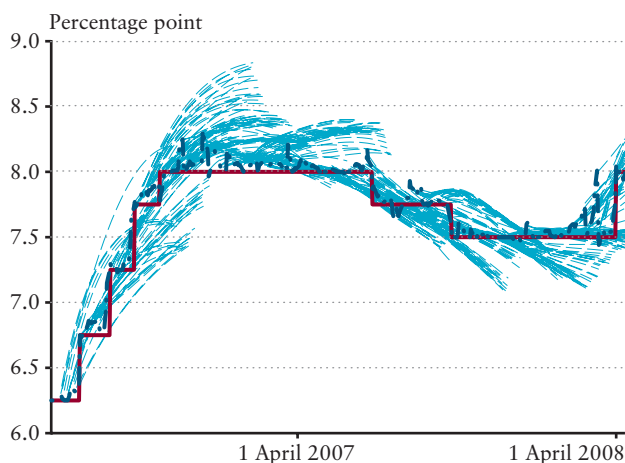
Assessing the size of counterparty risk premia is a complicated task. On the one hand, government bonds represent sovereign debt; traditionally, they are considered the safest investment in a specific country, which implies that government bond yields contain less counterparty risk premium. On the other hand, the credit rating of banks quoting interest rate swaps is often higher than the Hungarian sovereign debt rating, and we should also keep in mind that interest rate swap and FRA contracts are derivative transactions where the principal is not exchanged, which reduces counterparty risk. These arguments suggest that swap yields may in fact contain smaller counterparty risk premia.

Besides premia, the two markets also differ with respect to the range of their final investors. Non-resident investors seeking short-term profit on interest rates play a more significant role in the interest swap market. The reason for

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[5] In the case of one-year swap contracts, the floating leg equals the three-month BUBOR yield.

[6] The main characteristics of the forint interest swap market and the details of swap curve estimation are discussed in Csávás et al. (2007) and Reppa (2008).

Chart 3

Two-week BUBOR yields and yield curves

Percentage point

growth of liquidity premia incorporated in bond prices, resulting in the failure of stock exchange bond yields to meet expectations.

MACROECONOMY AND YIELDS

Dynamic yield curve models

Although mapping market expectations is critical for monetary policy decisions, it is even more crucial to anticipate the impact of these decisions on expectations and other macroeconomic variables. Daily estimated yield curves provide only a highly superficial answer to this question: on the one hand, the effects of different structural macro shocks cannot be separated from one another; on the other, they exclude any potentially delayed impacts of the shocks.

this, besides higher liquidity, is that transaction costs are lower (for example, there are no custodian management fees) and short selling is easier in the swap market. In contrast, the government bond market engages mostly domestic institutional investors and non-resident convergence investors with longer-term goals.

As noted above, the hedging activities of banks in the interest swap markets create a close link between the two markets. Nevertheless, this connection does not imply a perfect correlation between yields; according to the analysis of Csávás et al. (2007), their differences – the so-called swap spreads – could be rather significant and long lasting, as indicated by Chart 1.[7] If that is the case, it is important to know which market is dominant; i.e. in which market new information appears first. Although our quantitative analyses to determine this did not produce affirmative results, it appears reasonable to assume that yields are priced in the more liquid swap market, which is not burdened by transaction costs.

These differences, which are observed under normal market conditions, tend to become more intense during turbulent market periods. The entire year of 2008 – particularly March and October – has been such a period in the Hungarian government bond market. As Chart 2 reveals, the three-year swap spread in March and October stood around -100 and -250 basis points respectively, and in the period following March it barely rose above -30 basis points, which was unprecedented since the end of 2003 and the beginning of 2004. The underlying reason was probably the 'drying up' of the government bond market, which triggered a significant

The separation of structural shocks – also known as structural identification – may become problematic, as by definition structural shocks are unexpected shocks which are independent of each other and can impact several variables simultaneously. Looking at it from another angle, this means that changing the central bank base rate does not necessarily imply a monetary policy shock; the rate-setting decision may in fact be a reaction to a risk premium shock, or a previous (inflation altering) demand shock. The reason why identification is needed is that the effect of rate-setting decisions may differ depending on the type of shock that triggered it.

The simplest and most common method to describe the dynamic relationship between multiple time series is the application of vector autoregression (VAR) models.[8] In this context, 'simple' means that beyond the selection of the number of variables and lags, no other theoretical restrictions are required to estimate a VAR model. However, this comes at a price – a VAR model does not reveal much information on simultaneous effects.

The essence of a structural VAR model, i.e. the combination of the structural approach and the VAR approach, is that a VAR model is applied to describe dynamic relationships, while simultaneous correlations are identified by means of a possibly small number of commonly accepted theoretical restrictions.[9]

There are several ways to extend this model into one that describes the relationship between the yield curve and macro variables. One of the most easy-to-handle models of such

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[7] For the calculation of swap spreads, the par yield computed from the government bond market yield curve was deducted from the swap yields.

[8] The foundations of the method are detailed in Hamilton (1994).

[9] Rubio-Ramírez et al. (2008) provide a comprehensive description of the technical details of structural VAR identification.

Chart 4

The effect of a unit monetary policy shock on the forward curve

Chart 5

The effect of a unit demand shock on three-month forward yields, mean and 68% confidence band
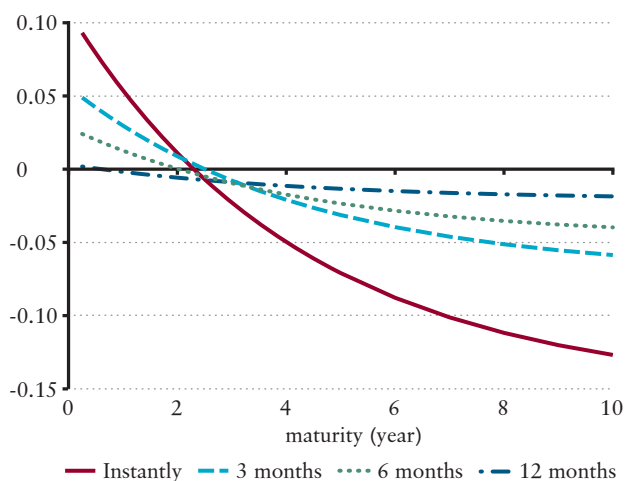
extensions – which involves the least amount of theoretical restrictions – is the dynamic Nelson-Siegel model (DNS) developed by Diebold & Li (2006) and Diebold et al. (2006). This method essentially describes the evolution of yields observed for different maturities by unobservable factors, while the relationship between the macroeconomy and yields is expressed by the VAR, which includes latent factors and macro variables.[10]

Shocks were identified by imposing sign restrictions.[11] This method requires the least amount of theoretical restrictions to separate the shocks; there are no restrictions other than the direction of the effects. The lack of restrictions has its limitations – the computed results are mere uncertainty intervals, which may be rather wide, depending on the number of restrictions.

Estimation results

The macro variables incorporated in the model were inflation, industrial output, forint/euro exchange rate and the central bank base rate. We used monthly data. We identified four structural shocks: with respect to the demand and supply shocks, we assumed that they both increase industrial output in the short run, while the demand shock increases and the supply shock decreases inflation. Our assumptions were similar for the separation of monetary policy shocks and risk premium shocks – they both increase the base rate, while premium shocks weaken and monetary policy shocks strengthen the exchange rate.
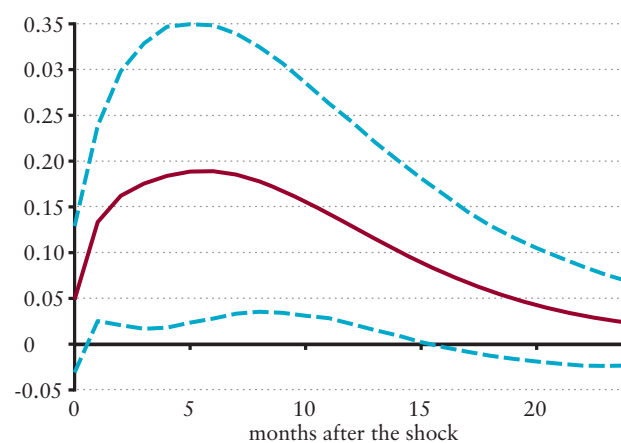
Chart 4 indicates the most crucial findings from the perspective of the central bank: the effect of monetary policy shocks on forward yields. According to the chart, an unexpected, unit[12] raise of the base rate increases short-term forward yields – those with a maturity of approximately 3 to 3.5 years or less – and decreases forward yields with a longer maturity spectrum. However, this effect is neither economically nor statistically significant.

The effect of a monetary policy shock is most dramatic immediately after the shock. The case is not the same for demand and supply shocks. As shown by Chart 5, these yields tend to react to the shock with a degree of lag. Chart 5 indicates the effect of the demand shock on three-month forward yields, based on the time elapsed from the occurrence of the shock. It is evident that the immediate effect is almost zero, while the biggest change is observed 5 to 7 months following the shock. The chart also suggests that this effect is statistically significant and more pronounced than the reaction to monetary policy shocks.

In order to understand the delayed reaction, it is important to see that each shock exerts its effect on the yield curve through the base rate and through the expectations regarding the base rate. It is obvious that monetary policy shocks produce the fastest and most direct effects. Chart 5 can be seen as market participants' expectations of the monetary policy to a demand shock. Considering that the reaction of the monetary policy with respect to demand and supply shocks typically occurs simultaneously with the publication

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[10] The most frequently used yield curve models are compared by Diebold et al. (2005).

[11] See Uhlig (2005).

[12] A unit shock equals one deviation, which is around 25 basis points for monetary policy shocks according to our estimate.

Table 1

Dispersion of forecast errors, expressed in percentage points

(a) One month					
	Premium	**Monetary policy**	**Demand**	**Supply**	**Amount**
Central bank base rate	44.60	17.26	18.52	5.84	86.22
Exchange rate	23.52	13.69	7.30	7.45	51.96
Inflation	1.31	0.79	54.25	40.61	96.97
Output	1.63	1.23	48.08	44.76	95.70

(b) Two years					
	Premium	**Monetary policy**	**Demand**	**Supply**	**Amount**
Central bank base rate	35.05	11.15	21.80	21.93	89.92
Exchange rate	24.87	14.17	8.41	7.59	55.04
Inflation	4.88	3.56	48.80	34.38	91.63
Output	4.18	3.34	45.74	38.29	91.55

of the Quarterly Report on Inflation, and following the shock a period of time elapses until a thorough analysis can be published on its macroeconomic effects, the delayed reaction is quite natural.

This model also reveals the extent to which the forecast error of macro variables can be explained by individual structural shocks. The answer also depends on the time horizon of the error calculation. Table 1 indicates the decomposition of short-term and long-term forecast errors, showing what proportion of these errors can be attributed to the uncertainties surrounding the forecast of the structural shocks.

Evidently, with the exception of the exchange rate, the four shocks account for the majority of the variable variance (the last column of the table). Both the short-term and long-term developments of the base rate are primarily determined by risk premium shocks. The effects of monetary policy shocks are certainly significant over the short term; however, demand and supply shocks have a much more important role in the long run. Therefore, according to the model, the rate-setting decisions of the MNB in the sample period were more likely reactions to the shocks rather than unexpected actions.

This is supported by the fact that monetary policy shocks affect inflation and output only slightly. As a possible interpretation, we could conclude that monetary policy decisions, whether expected or not, have no effect on macro variables. Another possible interpretation – one that is more consistent with the analysis framework we applied – is to conclude that the monetary policy behaviour was predictable in the sample period, which was taken into account in the pricing decisions of market participants.

Comparison with previous results

It is advisable to compare the conclusions drawn from any new model with the findings of previous analyses of the same problem. Since previous analyses mainly concentrate on the effect of monetary policy shocks, we have the same focus below.

With respect to methodology, our model is very similar to the one used in Vonnák (2005) – our basic model is also a VAR and shock identification is performed by means of the same sign restrictions. In that model, the monetary policy variable is the yield of the three-month treasury bill, and the reaction of short-term bonds is consistent with what we concluded from the DNS model. As long-term yields are excluded from the model, we cannot compare the effects made on these yields.

Rezessy examines monetary policy effects on daily data (2005). This paper also analyses the reaction of long-term, five-year and ten-year forward yields; however, it excludes delayed reactions from the analysis. Similar to the findings of the DNS model, the study finds that long-term forward yields decrease as a reaction to a base rate increase, and the size of the decrease is statistically significant. This similarity is particularly important, since the applied methodology is radically different from the one we presented above, making the described results more robust.

Kiss (2004) also focuses on daily yield data. However, the explanatory variables applied there involve macroeconomic news and communications, and the new information they contain. Again, this study focuses on short-term effects and does not find a significant relationship between unexpected rate-setting decisions and yields. However, new information

contained in inflation and GDP data does have a significant effect on yields in general, and long-term yields in particular. This is consistent with our conclusion based on the DNS model – demand and supply shocks have a significant effect.

SUMMARY

The MNB uses the yield curve for two purposes. On a daily basis, our objectives are to assess the short-term interest rate expectations of market participants and to calculate the discount rates required for collateral pricing, while we use monthly data to estimate the model applied for the analysis of the effects of monetary policy decisions.

When extracting expectations, we need to remember that the observed yields contain different kinds of premia, whose value depends, inter alia, on the risk appetite of market participants, liquidity and transaction costs. In view of these factors, we believe that the yield curve estimated from interbank yields and forint interest swap market yields can grasp expectations better.

For the analysis of the macro effects of monetary policy decisions, a model which can separate monetary policy shocks from other major structural shocks affecting the economy is required. The dynamic Nelson-Siegel model we used for our estimation meets this requirement with the least amount of theoretical restrictions.

According to our findings, monetary policy shocks increase short-term forward yields, while yields decrease across maturities of over three years. The shock has the highest impact in the period when it occurs and lasts for about one year.

Reaction to demand and supply shocks is slower and its full impact is delayed. The reaction of yields peaks about half a year following the shock. It is difficult to assess the macro effects of these shocks precisely, which is probably the reason behind the delayed reaction; and the reaction of the MNB to these shocks is inevitably also somewhat delayed.

According to our model, the majority of the MNB's rate-setting decisions in the sample period were a reaction to other unexpected, structural shocks. The volatility of the risk premium played a decisive role in this, while the fluctuations of demand and supply influenced the base rate mainly over a longer time horizon.

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