Ágnes Horváth, Csaba Köber and Katalin Szilágyi: MPM – The Magyar Nemzeti Bank's monetary policy model*

March 2011 marked the introduction of the MNB's Monetary Policy Model (MPM), representing a paradigm shift in both inflation forecasting and monetary policy decision support. In contrast to the previous conditional projections, the MPM offers an endogenous definition for both the policy rate and the exchange rate. Given the forward-looking nature of this model, expectations by economic agents play a key role in monetary transmission; therefore, instead of one-off interest rate measures, the achievement of inflation target is guaranteed by the entire interest rate path over the forecast horizon. In the following, we discuss the underlying structure and logic behind the MPM, as well as the functioning of key behavioural equations, while also examining how the channels of monetary transmission appear in the model. We also present our motivations regarding the model switch and review how developing and operating this new tool have changed our current processes.

WHY WAS THE MONETARY POLICY MODEL LAUNCHED?

The legally mandated, primary objective of the MNB is to achieve and maintain price stability. In order to comply with this obligation, in 2001 the central bank decided to adopt the inflation targeting system. Under this regime, interest rates are set by monetary policymakers on the basis of future developments in inflation and economic growth, with the aim of stabilising the consumer price index at a level suitable for the inflation target.[1] Thus, one of the main tasks for the MNB's staff is to provide increasingly accurate forecasts for processes impacting both inflation and economic activity. This requires experts with a thorough understanding of individual segments of the Hungarian economy, as well as a system capable of displaying such knowledge concurrently with fundamental economic foundations.

In the past, the MNB prepared its inflation forecasts using the Quarterly Forecasting Model (Negyedéves Előrejelző Modell, NEM),[2] which, after a lengthy development process, was replaced by the DELPHI[3] model in 2010. Both belong to the category of so-called macroeconometric models which – while offering a detailed description for the structure of an economy – imply accounting correlations and usually contain a large number of variables and equations. Although the logic of economics prevails in these models as well, behavioural equations are typically defined along empirical correlations observed in the past. Their excellent empirical match enabled the central bank to prepare reliable, so-called conditional projections.[4] For quite some time, central banks considered macroeconometric modelling to be the best practice for preparing inflation forecasts. Conditional projection was seen to assist the decision-making process in that it provided information as to whether a given central bank could achieve its target with monetary conditions (interest and exchange rates) remaining unchanged. However, it was unable to directly identify the exact interest rate path necessary for achieving the inflation target.

Macroeconometric models are therefore a less suitable option when we need a tool which, in addition to being useful for forecasting, can also provide direct monetary policy support. In order for a given forecast to also outline an interest rate trajectory ensuring a consistent monetary policy and the achievement of inflation target, a forward-looking, general equilibrium-based model which

* The views expressed in this article are those of the author(s) and do not necessarily reflect the offical view ot the Magyar Nemzeti Bank.

[1] For details on inflation targeting systems, see for instance, Csermely (2006).

[2] Refer to Benk et al. (2006).

[3] Refer to Horváth et al. (2010).

[4] Such conditional projections assume unchanged interest and exchange rates over the forecast horizon. This indicates that, according to the model, monetary policy does not react to future real economic processes.

incorporates the monetary transmission mechanism must be developed. Our accumulated theoretical and empirical knowledge of monetary policy also confirmed that central banks can only influence the cyclical position of macro variables and have no long-term effect on real economic developments. Therefore, most central banks started to develop various models in which behavioural equations were applied to the cyclical position of real economic variables (known as gap models).

For a number of years, the Hungarian central bank has also been involved in the development of dynamic stochastic general equilibrium (DSGE) models. Nicknamed PUSKAS,[5] the MNB's basic model is now available in multiple versions (single-sector, amended with labour market frictions)[6] and even served as the basis for the Fiscal Council's model[7] as well. DSGE models are forward-looking, have their foundation in microeconomics and assume rational expectations – an easy fit for the inclusion of endogenous monetary policy. At the same time, due to strict structural restrictions, the external consistency (i.e. empirical alignment) of these models is often inadequate. Although some central banks also use DSGE models for forecasting purposes, the MNB applies them primarily in various simulations precisely because of their lower empirical performance relative to our models used for forecasting.

In keeping with the best central banking practices in inflation targeting, last year the MNB started developing a tool which can be used simultaneously for forecasting and decision support. The Technical Assistance Programme of the International Monetary Fund provided assistance in the development of the new model from the start. In formulating the Monetary Policy Model (MPM), our key aspect was to provide a firm grasp on monetary transmission, using the most transparent structure possible. Therefore, in comparison with earlier macroeconometric models, the MPM operates with a less disaggregated economic structure, while it still manages to integrate all variables relevant to monetary policy. Despite our deviation from the logic used in our previous tools, this structure does not imply that the accumulated (disaggregated and often partial) knowledge of the central bank's experts could not be incorporated in the forecasts in a model consistent way.

The first time our staff prepared an MPM-based forecast was at the end of 2011 Q1. The significance of endogenous interest and exchange rate trajectories was also reflected in the updated structure of the MNB's Quarterly Report on Inflation (MNB, 2011). The inflation forecast and the interest rate path – consistent with achieving the inflation target over the time horizon relevant to policymakers – serve as the basis for the rate-setting decisions of the Monetary Council, even though members of the Council also request our staff to prepare alternative interest rate path simulations and risk scenarios. Once they have assessed all possible scenarios, the decision on the policy rate is based solely on their discretion.

MAIN EQUATIONS OF THE MPM

The primary reason behind launching the MPM was our intention to develop a tool that can be used simultaneously for forecasting and decision support purposes. Only models with an adequate empirical score are suitable for forecasting, whereas decision support requires a valid representation of the impacts which fluctuations in monetary conditions, the policy rate and the exchange rate may have on the real economy and, eventually, on inflation.

Major transmission channels of monetary policy are incorporated into the model's behavioural (structural) equations, in which expectations by economic agents play a crucial role. The MPM has been designed with the duration of business cycles in mind, as this is the time horizon over which monetary policy exerts its impact. As is the case with their DSGE counterparts, equations of the model have been formulated for the cyclical components – that is, deviations from main trends also known as gaps – of variables. Since these variables are unobserved, we must rely on expert knowledge, as well as tools (see for example, Tóth, 2010), with which to define the relevant values.

The MPM operates on a quarterly frequency, with its parameters calibrated on theoretical and empirical foundations.[8] It is a new-Keynesian model suitable for describing a small, open economy. One common feature shared by all members of this model family is that their underlying mechanisms can be defined with the following four basic relationships:

- inflation depends on demand and production costs (Phillips curve),
- domestic demand depends on the real interest rate (IS curve),

[5] Refer to Jakab and Világi (2008).
[6] For details, see Jakab and Kónya (2011).
[7] Refer to Baksa et al. (2009).
[8] We intend to publish a detailed description of the model together with a quantification of related parameters in the MNB's Working Papers.

- policymakers draw up the interest rate path based on the rule that works towards their targets (monetary policy reaction function, Taylor rule),
- the exchange rate depends on the current and future interest rate differential and the risk premium (uncovered interest rate parity).

Given the mission of inflation targeting, the key variable in this model is the consumer price index (CPI) or, more precisely, its fluctuations and dynamics over time. We have divided inflation into three components: core and non-core inflation excluding indirect taxes, and the effects of indirect taxes. Within non-core inflation, we distinguish between two categories: administered and market priced goods. Tax effects and administered prices are exogenous variables of the model.

The MPM describes fluctuations in core inflation – adjusted for the effects of indirect taxes – (COREVAI) with a new-Keynesian type Phillips curve:

$$COREVAI = \beta_1 * COREVAI_{-1} + (1-\beta_1) * COREVAI_{+1} + \\ +\beta_2 * \left(\beta_3 * \hat{C} + ((1-\beta_3) * \hat{Z}\right) + \beta_4 * \widehat{W} + \beta_5 * MARKET + \varepsilon_{COREVAI}$$

- Based on available data, it can be established that the indicator is persistent, i.e. economic actors attach considerable weight to previous prices *(COREVAI$_{-1}$)* (indexing).
- Today's pricing decisions are also influenced by actors' expectations of inflation *(COREVAI$_{+1}$)*.
- In this model, inflationary pressure from the real economy is expressed in the cyclical position of domestic demand, particularly of household consumption *($\hat{C}$)*.
- To a certain extent, the endogenous real wage gap *($\widehat{W}$)* represents the changes in production costs.
- The real exchange rate gap *($\hat{Z}$)* indicates, in real terms, whether the domestic currency is overvalued (positive) or undervalued (negative) relative to other countries, thus conveying information on imported inflation.
- Price fluctuations of the market priced component of the non-core inflation *(MARKET)* (production costs) pass through to core inflation.

The price dynamics of the market-priced component of non-core inflation *(MARKET)* are generally linked to changes in energy prices. This is a less persistent indicator, and the pricing of individual items does not depend on inflation expectations. It is defined by the values of oil price inflation *(OIL)* as expressed in foreign currency, the nominal change in exchange rates *(ΔS)* and the processes inherent to core inflation *(COREVAI)*:

$$MARKET = \omega * MARKET_{-1} + (1-\omega) * (\mu_1 * COREVAI + \\ + (1-\mu_1) * (\mu_2 * \Delta S + \mu_3 * OIL)) + \varepsilon_{MARKET}$$

The cyclical position of household consumption *($\hat{C}$)* is expressed in the model with the following equation:

$$\hat{C} = \alpha_1 * \hat{C}_{-1} + (1-\alpha_1) * \hat{C}_{+1} - \alpha_2 * \left(\widehat{RR} + CCH\right) + \\ + \alpha_3 * \left(\widehat{HI} - \alpha_4 * \hat{Z} - \hat{C}\right) + \varepsilon_{\hat{C}}$$

The consumption gap depends on:

- its position in the past *($\hat{C}_{-1}$)*, which represents acquired consumption habits,
- expectations *($\hat{C}_{+1}$)* and the real interest rate *($\widehat{RR}$)*, based on the Euler equation that is used to describe the intertemporal substitution of consumption and savings,
- the (household) spread *(CCH)* above the real interest rate that, which while indicating the supply of consumption loans also captures the effects of financial friction,
- income status of households: real value of the labour income gap *($\widehat{HI}$)* and, due to significant FX-denominated debts, the changes in real exchange rate gap *($\hat{Z}$)* (balance sheet channel).

The path for the policy rate is defined by the monetary policy reaction function – an equation of the Taylor rule:

$$R = \delta_1 * R_{-1} + (1-\delta_1) * \left(\bar{R} + \delta_2 * (CPIVAI_{+4} - TARG) + \\ + \delta_3 * \hat{Y} + \delta_4 * \Delta S\right) + \varepsilon_R$$

- We use this model with an assumption of interest rate smoothing *($\delta_1 * R_{-1}$)*, partly because the policy rate's high level of volatility would otherwise cause unjustified fluctuations in real economic activity, but also because rate-setting decisions also imply the prevalence of certain aspects of financial stability.
- In an inflation targeting system, monetary policymakers react to deviations from the expected inflation targets *(TARG)*. The model's underlying rule on interest rates takes into account inflation expectations *(CPIVAI$_{+4}$)* excluding indirect taxes over a one-year horizon. Through the output gap *($\hat{Y}$)*, the central bank's policy also keeps track of developments in economic activity (known as flexible inflation targeting).
- Upon sudden notable changes in the nominal exchange rate *(ΔS)*, the interest rate trajectory changes due to economic activity and stability considerations.

The dynamics of the nominal exchange rate is described by modified uncovered interest parity (UIP). The modification is necessary because, on one hand, very few empirical results confirm a pure UIP context and, on the other, the strong nominal exchange rate volatility would make the forecast even more volatile. The equation deviates from the classic UIP in that today's nominal exchange rate *(S)* is defined not only by exchange rate expectations *(S$_{+1}$)*, interest rate premiums *(RW–R)* and risk premium *(PREM)* but also by past exchange rate (S_{-1}) (technically, therefore, the exchange rate is the weighted average of a "classical" UIP and a random walk).

$$S = \eta_1 * \left(S_{+1} + \frac{RW - R + PREM}{4}\right) + (1 - \eta_1) * S_{-1} + \varepsilon_S$$

GDP COMPONENTS

In accordance with the underlying MPM logic, the gross domestic product is comprised of two parts: potential output and the cyclical GDP position. The output gap is defined within the model, whereas potential GDP is assessed to the best of experts' knowledge and is exogenous as far as the model is concerned. This is in line with mainstream economics, where monetary policy cannot exert a lasting impact on real economic variables beyond the time horizon of business cycles. Amongst other things, this also implies that price stability and fast-paced economic growth can go hand-in-hand only in a period characterised by brisk potential growth and not when the output gap is predominantly positive.

In our model, the output gap is realised not directly but as the weighted sum of the components' cyclical positions. These components of real economic activity have been defined from the absorption side: the level of aggregate excess demand is specified as the sum of final consumption expenses, gross fixed capital formation, net exports and the cyclical positions of inventory changes. In defining behavioural variables, there were three key aspects to consider. Although the primary aspect was to use demand categories relevant to monetary policy and monetary transmission, maintaining continuity with our previous forecasting practices was also important. Finally, we also took into consideration the types of variables, namely whether they are endogenous or exogenous to the model. In the following, we elaborate on the components of the output gap and present an equation describing the behaviour of cyclical positions of final household consumption, private investment, government spending, net exports and changes in inventories.

The cyclical position of consumption spending by households $(\hat{C})$ has already been discussed in detail.

The behaviour of the cyclical position of private investments $(\hat{I})$ can be defined as follows:

$$\hat{I} = \psi_1 * \hat{I}_{-1} + (1 - \psi_1) * \hat{I}_{+1} + \psi_2 * RK + \psi_3 * \left(\hat{Y} - \hat{I}\right) + \varepsilon_{\hat{I}}$$

Amounting to one-third of domestic demand, this category represents the weighted aggregate of cyclical positions of retail and corporate investments. The backward-looking element in this equation implies that prospective adaptation is not possible (entirely) immediately due to existing adjustment costs. In an empirical sense as well as in terms of classic economics, expectations and forward-looking behaviours play a particularly important role when investment decisions are made; therefore, the parameter for the forward-looking element is higher than for other variables. Changes in the cyclical position of private investments are defined by the cyclical component of current income $(\hat{Y})$ and the alternative cost of capital *(RK)*, the latter being a kind of Tobin's Q measure. The cyclical component of current income reflects the liquidity constraints faced by corporate agents of the economy.

Trends in the cost of capital are defined by three variables. Firstly, an increase (decrease) in real interest rate makes postponement (advance implementation) of an investment project more attractive to companies. The tightness of the loan market is indicated by the conditions on corporate lending, as a type of credit spread. Moreover, future economic activity – in particular, the performance of exports – has a direct influence on the development of household investments. Thirdly, we have also included the crowding-out effect of government investments.

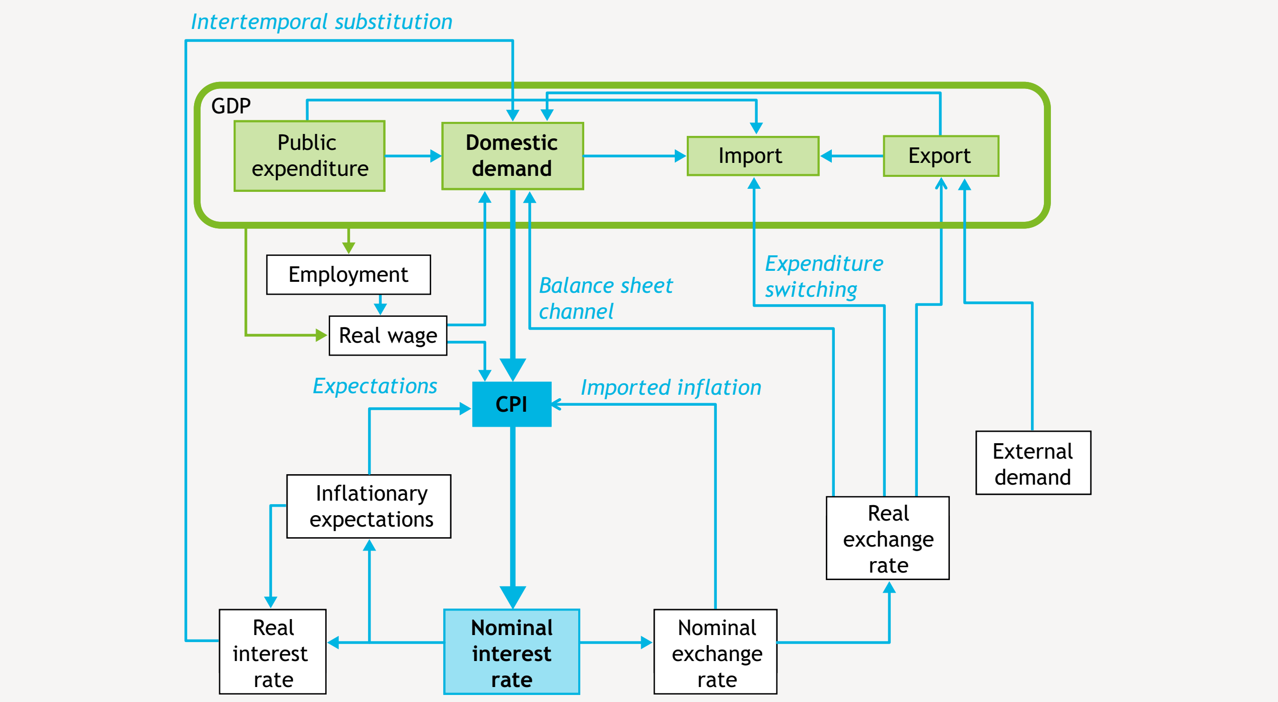
The extent $(\hat{G})$ to which government spending deviates from trends is defined as the weighted aggregate of cyclical components in final government consumption and government investments. From the model's point of view, this variable is exogenous and is set for the forecasting horizon on the basis of expert knowledge.

The behaviour of the cyclical position of exports $(\hat{X})$ can be defined as follows:

$$\hat{X} = \theta_1 * \hat{X}_{-1} + (1 - \theta_1) * \hat{X}_{+1} + $$
$$+ \theta_2 * \left(\widehat{YW} - \hat{X} + \theta_3 * \hat{Z}\right) + \varepsilon_{\hat{X}}$$

Development of the cyclical position of exports is characterised by a backward-looking and a forward-looking element, as well as the cyclical position of key determinants: external demand $(\widehat{YW})$ and real exchange rate $(\hat{Z})$. Here too, the backward-looking element implies past performances and assumes adjustment costs under pressure

Chart 1
Flowchart of the MPM



to adapt, while the forward-looking element represents expectations. The cyclical position of exports is defined by the demand of our export partners and the competitive prices of domestic products.

The cyclical position of imports is derived from the development (import content) of other components of the output gap. For the purposes of this model, we distinguish between consumption and production determined imports, the latter of which are driven by current utilisation needs and do not depend on real exchange rate sensitivity. By contrast, consumption determined imports are driven primarily by an attitude towards expenditure switching and sensitivity to real exchange rates, the equation manifesting the behaviours of both inter and intratemporal substitution.

MONETARY TRANSMISSION IN THE MPM

The monetary transmission mechanism refers to a complex, multi-level process through which central banks can exert influence on output and inflation. We can distinguish between various monetary transmission channels, all of which represent a unique mechanism: monetary policy measures have an impact on the real economy's demand and – in terms of changing production costs – supply as well, thereby influencing the consumer price index. In the following, we will be looking at how the main transmission channels appear in the MPM.

The interest rate channel (intertemporal substitution in Chart 1). Over the short term and with sticky prices, a nominal interest rate increase results in higher real interest rates, thus impacting key demand decisions by the private sector. First, the rising real interest rate encourages households to focus more on savings, which in turn translates into lower consumption on a temporary scale. Second, it also makes postponement more of an option for company investments, as fewer projects are able to generate an output that can still ensure profitability. These two factors seem to reinforce one another, thereby lowering domestic demand and mitigating demand-side inflationary pressures.

The expectations channel. Given the forward-looking nature of the model, not only does monetary policy prevail through the developments of a given period, it also influences economic agents' expectations. A good example for this mechanism is that, in view of the central bank's policy rule, agents of the model are aware what measures the central bank is likely to take in the future should the level of expected inflation vary from the target already announced. In the event that, for instance, inflation overshoots the target, the private sector would anticipate stricter monetary conditions and immediately lowers its expectations concerning future inflation. That, in turn, will have an effect on current pricing decisions and wage demand as well. This is how expectations become the central decisive elements of a given forecast. It must be noted that forward-looking behaviour also implies that actors do not react to temporary inflation shocks which have no second-round effects. They ignore these because of their understanding that in this case, over the medium term, inflation will return to its target level even without central bank intervention.

The exchange rate channel. The higher the central bank's policy interest rate (assuming that all other factors remain unchanged), the more desirable HUF-denominated instruments become, and thus demand for the forint grows, resulting in the appreciation of the Hungarian currency. Through the reduction of import prices, a stronger nominal exchange rate can also have a direct curtailing effect on inflation. The exchange rate does not leave the real economy unaffected either; it exerts two opposing effects on inflation:

– appreciation, on the one hand, damages the competitiveness of domestic companies, thereby restricting economic activity and, *ceteris paribus,* mitigating price increases
– given the considerable FX-denominated debt held by domestic actors, appreciation increases available income (as the amount of FX-denominated debt is reduced and loan instalments are revaluated), thus boosting domestic demand which, *ceteris paribus,* leads to higher inflation.

MPM SUPPORTS THE FORECASTING AND DECISION-MAKING PROCESS SIMULTANEOUSLY

The latest addition to the MNB's toolkit, the Monetary Policy Model (MPM) is suitable for underpinning both the expert forecasts and the decision support for the relevant interest and exchange rate paths. Accordingly, it exhibits significant structural and logical differences compared to our previous models. Its predecessors typically used a bottom-up forecasting approach (by aggregating sector-level developments), thus yielding a rather detailed and highly disaggregated snapshot of the Hungarian economy, in which monetary policy transmission did not play a central role. Notwithstanding, this was not necessary, because our staff was involved in so-called conditional forecasting, where the monetary policy did not react to future inflationary and real economic developments. In many aspects, the MPM represents a radically new approach. First of all, their accumulated theoretical and empirical knowledge on monetary policy prompted central banks to develop models with a firm grasp on the cyclical position of real economic variables. The MPM also belongs to this gap model family. Secondly, the MPM typically represents a top-down approach, in which focus is intentionally shifted to variables that are relevant in terms of monetary policy. A more transparent economic structure also implies that the impact mechanisms of the key monetary transmission channels are easier to trace and interpret. Last but not least, the MPM is a forward-looking model, in which the expectations of economic agents have a central role in the development of both the inflation forecasts and the interest rate path.

On the face of it, however, our forecasting process itself has changed very little. Experts continue to deliver three types of inputs in our MPM-based forecasting as well. On the one hand, they define the exogenous variables of the model (e.g. import-based external demand or the level of government spending) for the entire forecast horizon; on the other hand, they also prepare so-called short-term forecasts (for a period of 1 to 2 quarters) for each behavioural variable used in the model. Thirdly, they translate all of the information not included directly in the model into shifts in model variables and perform "expert corrections" (for instance, by quantifying the effects of large-scale investment projects such as those of Audi or Opel on investment, or the impacts of the disbursement of the real yields of pension funds on consumption).

Even in the past, members of the decision-support team have always focused on how price stability, the central bank's primary objective, can be attained. However, the only input gained in this regard from forecasts prior to the launch of the MPM was whether a change was needed in monetary conditions. Forecasts operating with fixed interest and exchange rates could yield no information on the actual extent of necessary interest rate measures. In the new system, the MPM presents an interest rate path which, while ensuring the achievement of the inflation target, can also provide a starting point for monetary policymakers. In addition, the pre-decision information package presents the alternative interest rate path simulations and risk scenarios requested by the members of the Monetary Council. In contrast to previous practices, it is now the Monetary Council that pronounces, based on its own risk assessment, the main risks inherent to MPM-based forecasting (e.g. commodity price assumptions of our staff).

The MPM therefore offers background support while also improving transparency both in forecasting and in pre-decision processes, within the central bank's own internal staff as much as outside of the bank. It is an excellent tool for organising the Bank's existing expert knowledge into a uniform framework and a logically consistent structure, as well as for demonstrating the alternative-scenario consequences of interest rate policy. To the extent that we will continue to rely on the best knowledge of individual field experts, both forecasting and banking analytics will remain unchanged. We maintain the same opinion on the fundamental relationships of the Hungarian economy, and this is very much reflected in our latest tool as well.

Nevertheless, under no circumstances should the MPM's launch be interpreted as marking the end of our need for monetary policymakers. No model will ever be able to fully grasp the complexity of economic processes and the entire range of decision aspects held important by members of the Council. Their forethought and deliberation – whether it is the inclusion of data that cannot be modelled, or the careful negotiations and consideration of opinions and aspects expressed by various other areas – will remain of key importance. An MPM-based inflation forecast and its consistent interest rate path can only be a point of reference and provides an initiative for monetary policymakers.

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