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## **STRUCTURE AND USE OF THE MEDIUM-TERM PROJECTION MODEL IN THE NATIONAL BANK OF SERBIA**

**ABSTRACT:** *Medium-term projections are an important element of the decision-making process in the inflation-targeting regime that the National Bank of Serbia has been implementing for the past several years. The main goal of medium-term projections is to project the policy rate path that will ensure that inflation in the coming period moves close to the targeted inflation rate. The most important tool for medium-term projections is a new Keynesian macroeconomic model, which is a set of equations aiming to describe the price-*

*formation mechanism in Serbia and the transmission channel of monetary policy to prices. The model is comprised of four main behavioural equations for inflation, exchange rate, output gap, and policy rate, and of a number of side behavioural equations and identities. The model in the current form has been used since the end of 2008 and is subject to regular adjustments and improvements.*

**KEY WORDS:** *medium-term projection model, inflation targeting.*

**JEL CLASSIFICATION:** C53, E17, E58.

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## 1. INTRODUCTION

The purpose of this paper is to present the main features of the model for medium-term projections used by the National Bank of Serbia (NBS), as well as its role in the decision-making process in the inflation targeting regime.

In mid-2006 the NBS defined the achievement of a core inflation target (calculated on the basis of the retail price index) as its primary goal. At the end of 2008 the regime of inflation targeting was officially introduced, in agreement with the Government of the Republic of Serbia, with a shift to overall consumer price index targeting. 2w repo interest rate is used as the main monetary policy instrument. Since this instrument affects inflation with a time lag, the regime of inflation targeting requires an additional tool with which to project (and forecast) inflation and, most of all, to project the path of repo rate to be followed in order for inflation to move within the target range.

For this purpose a quarterly model was developed for medium-term projections, to support monetary policy makers in making decisions on the repo rate level consistent with achieving the inflation target. In accordance with the monetary policy regime implemented by the NBS, the main objective in developing the model was to include the key factors that influence price movement, as well as the channels through which the central bank affects inflation by adjusting the policy rate.

The NBS model belongs to a wide class of new Keynesian-models. The basic principle of such models is that the role of monetary policy is reflected in anchoring inflation and inflationary expectations. Only monetary policy ultimately determines the rate of inflation, by changing the repo interest rate in response to various shocks in the economy. Because of rigidity in the movement of prices and wages, changes in the nominal interest rate result in changes in the real interest rate, leading to deviations of real variables (such as economic activity and real exchange rate) from their trends, and thus to their influence on inflation. Monetary policy has a lasting impact on the nominal variables, and a temporary impact on the real variables. Unlike in pure Keynesian economics, in these models rational expectations play an important role (expectations that

partly depend on the model projections), which means that economic agents partially anticipate the actions of monetary policy so that the effect of ‘surprises’ is reduced.

The basic structure of our model is very similar to models used in a number of central banks, except that it contains some specific features related to characteristics of the Serbian economy. Like all models of this type, our model contains four main equations: the equation of aggregate demand, ie. output gap equation (IS curve), the equation of core inflation (Phillips curve), the equation of exchange rate (uncovered interest rate parity), and the equation of monetary policy reaction function. In addition, the model contains a large number of extra equations that describe the movement of other relevant economic parameters and a large number of identities.

Although the model contains 90 equations, it belongs to a group of relatively simple models. The advantage of simple models is their ability to describe the interconnections of the main variables that affect inflation and to relate to the transmission mechanism of monetary policy in a clear and simple way, while maintaining theoretical coherence. At the same time the clarity and simplicity of the model allows the monetary policy makers to have a good understanding of the model, which provides a good basis for discussion within the central bank, both between the members of the Executive Board (EB) themselves and between the direct projection creators and the members of the EB. The members of the EB are not just the users of the model projections (as a support to decision making) but actively create model projections with their suggestions, and therefore it is very important that the model for monetary policy makers is not a ‘black box’.

Real variables in the model, such as economic activity, real exchange rate, real interest rate, etc., are expressed as deviations from their trend, ie. gaps, which is why this type of model is sometimes also referred to as the gap model. The monetary policy with its measures can temporarily affect only the gaps and not the trends. As the gaps and the trends are unobserved components, an

important (initial) stage of the medium-term projections is their estimation of the history. For this purpose we use a methodology based on the Kalman filter<sup>1</sup>.

This model is semi-structural. This means that, although the model has a clear economic and theoretical interpretation, in its development we wanted the model to reflect trends in the Serbian economy as well as possible. Model coefficients are not estimated but mostly calibrated in order to follow economic intuition and theory, but also take into account the basic characteristics of the Serbian economy and developments in the recent past. Econometric estimation is used whenever possible. Details about the reasons why the model is calibrated and about calibration will be explained in the third part.

The process of medium-term projection is much more than a simple use of the model. In practice models do not produce the forecasts: economists do<sup>2</sup>. It could even be said that defining the assumptions of the projections and general economic analysis dominantly determine the results of the projections. In this sense the model is primarily used to systematize assumptions and judgements about the future in a unique and consistent framework.

Apart from the main projection of the policy rate path which is consistent with achieving the targeted level of inflation, the model has some other applications. It can be used for analyzing the risks of achieving the projections and the reaction of monetary policy in the case that some of the risks materialize. In addition, the model has a very important role in external communications: inflation projections are published in a quarterly NBS publication, Inflation Report.

This paper consists of several parts. After the introduction we will present the model structure and a detailed description and explanation of the equations that make up the model. The third part deals with the determination of model

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<sup>1</sup> For details see Djukić, Momčilović and Trajčev (2010, p. 29).

<sup>2</sup> See Berg (2006).

parameters, while the fourth discusses the properties of the model. The paper ends with concluding remarks.

## **2. STRUCTURE OF THE MODEL**

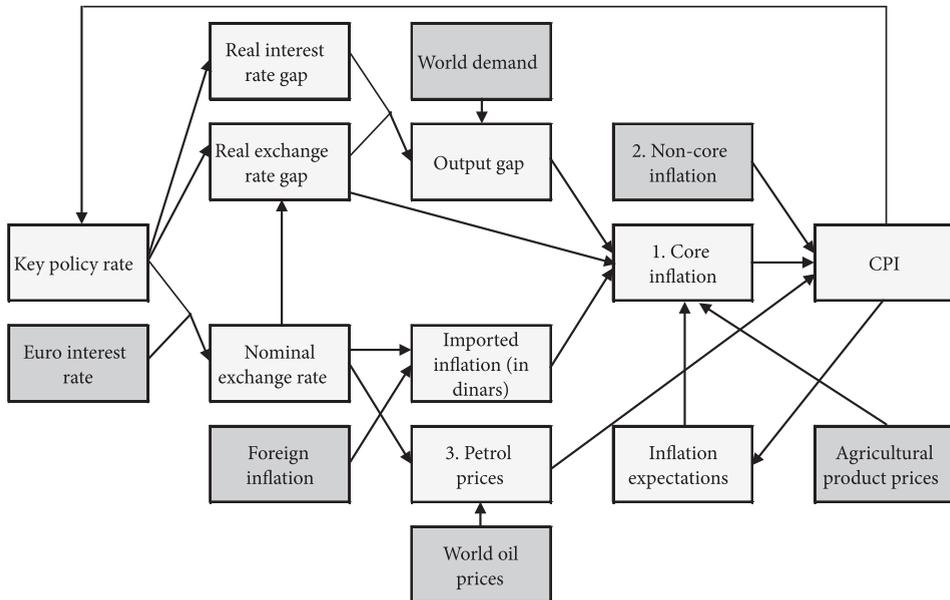
The model for medium-term projection is based on the transmission mechanism of monetary policy, i.e. the channel through which the monetary authorities affect inflation by changing the policy rate (2w repo rate).

Inflation in the model is broken down into the three components of the Consumer Price Index (CPI):

1. Core inflation (66.5%) – CPI excluding change in regulated prices, prices of fruit and vegetables, and oil derivatives inflation.
2. Non-core inflation (29%), which includes regulated prices and prices of fruit and vegetables.
3. Oil derivatives inflation (4.5%).

The central bank's decision on the repo interest rate is based on the deviation of the projected (overall) inflation from the target (top line of Scheme 1). The repo interest rate affects mainly the core inflation, and to a lesser extent oil derivatives inflation, through the nominal channel (exchange rate) and the real channel (real exchange rate and output gap).

Non-core inflation is assumed not to be influenced by the monetary policy. Although in reality this is not entirely true, we estimated that by adopting this assumption we do not lose much of the explanatory power of the model but contribute significantly to its simplicity. In practice this means that in the medium-term projections non-core inflation is exogenous, which means that its movements are not projected by the model but exogenously, on the basis of government plans and expected movements in fruit and vegetable prices.

**Scheme 1.** Structure of the quarterly projection model

**Source:** Extrapolated by the authors

In addition to factors which monetary policy can influence, a number of external factors affect inflation, such as foreign inflation, foreign demand, world oil prices, foreign interest rates, agriculture product prices, etc. The model also includes other factors which are not shown in the scheme because of the complexity of graphical presentation.

The model contains four basic equations:

- inflation equation (Phillips curve),
- output gap (demand side),
- exchange rate equation (uncovered interest rate parity), and
- policy rate equation (monetary policy rule).

The model also contains a large number of extra equations and identities. In total there are 90 equations, of which we have chosen 18 to present in this paper.

## 2.1 Inflation

Overall inflation (consumer price index) ( $\pi_t$ ) is broken down into three components in the model: core inflation ( $\pi_t^{core}$ ), non-core inflation ( $\pi_t^{non-core}$ ), and oil derivatives inflation ( $\pi_t^{petr}$ ). Therefore, the overall inflation is the weighted average (based on shares in the overall index) of these three components:

$$\pi_t = a_{11} \cdot \pi_t^{core} + a_{12} \cdot \pi_t^{non-core} + (1 - a_{11} - a_{12}) \cdot \pi_t^{petr} \quad (2.1)$$

For non-core inflation, the assumption is that it is completely exogenously determined. On the other hand, core inflation and oil derivatives inflation are influenced by market factors and monetary policy, and as such they are endogenous in the model.

Core inflation includes prices which are formed freely in the market and which monetary policy has an impact on. In the model the movement of core inflation ( $\pi_t^{core}$ ) is explained by the following factors: core inflation lag ( $\pi_{t-1}^{core}$ ), inflation expectation ( $E_t \pi_{4,t+4}$ ), the movement of import prices ( $\pi_t^M$ ), real exchange rate gap of the RSD against the EUR in the previous quarter ( $zgap_{t-1}$ ), output gap in the previous quarter ( $ygap_{t-1}$ ), as well as cost pressures on processed food prices ( $RMCPgap_t$ ):

$$\begin{aligned} \pi_t^{core} = & a_{21} \cdot \pi_{t-1}^{core} + a_{22} \cdot (E_t \pi_{4,t+4} - \overline{kor}) + (1 - a_{21} - a_{22}) \cdot (\pi_t^M - \Delta \overline{lz}_t - \overline{kor}) + \\ & + a_{23} \cdot zgap_{t-1} + a_{24} \cdot ygap_{t-1} + a_{25} \cdot RMCPgap_t + \varepsilon_t^{\pi^{core}} \end{aligned} \quad (2.2)$$

Core inflation lag ( $\pi_{t-1}^{core}$ ) reflects the existence of a degree of inflation inertia. It is typical for transition economies such as Serbia to have a high degree of inertia.

Inflation expectation ( $E_t \pi_{4,t+4}$ ) are expectations ( $E_t$ ) of the financial sector in terms of price growth over the following year, i.e. y-o-y inflation four quarters ahead ( $\pi_{4,t+4}$ ). Inflation expectations in the model are a function of current y-o-y inflation ( $\pi_{4,t}$ ), and rational expectations ( $\pi_{t+1}$ ). Also in this equation a

dependent variable with lag is introduced ( $E_{t-1}\pi_{4,t+3}$ ), to reflect inertia in inflation expectation.

$$E_t\pi_{4,t+4} = a_{31} \cdot E_{t-1}\pi_{4,t+3} + (1 - a_{31}) \cdot [a_{32} \cdot \pi_{t+1} + (1 - a_{32}) \cdot \pi_{4,t}] + \varepsilon_t^{E0\pi} \quad (2.3)$$

Note that equation (2.3) describes expectations of overall inflation. However, in the equation of core inflation it is necessary to have expectations in terms of core inflation. Overall inflation in Serbia is systematically higher than core inflation. Therefore a corrective variable ( $\overline{kor}$ ) is introduced in the equation (2.2), which represents the trend difference between overall inflation and core inflation, so that the term in brackets ( $E_t\pi_{4,t+4} - \overline{kor}$ ) reflects the expectations in terms of core inflation.

*Imported inflation* ( $\pi_t^M$ ) is a change in import prices denominated in RSD. Imported inflation depends on the movement of import prices denominated in foreign currency ( $\pi_t^{ef}$ ) and exchange rate movements ( $\Delta Is_t^{ef}$ ).

$$\pi_t^M = a_{41} \cdot \pi_{t-1}^M + (1 - a_{41}) \cdot (\pi_t^{ef} + \Delta Is_t^{ef}) + \varepsilon_t^{\pi M} \quad (2.4)$$

The weighted average of inflation in the Eurozone and the US is used as a measure of foreign inflation, and the weighted average of RSD/EUR and RSD/USD as a measure of effective exchange rate. In both cases the ratio is 80:20.

Note that equation (2.4) contains the imported inflation with a lag ( $\pi_{t-1}^M$ ), in order to reflect inertia in its movement. For example, if there is a significant appreciation of the RSD, it is not realistic to assume that in the same quarter there has already been a considerable fall in imported inflation, as for some time importers will continue to use products which have been previously imported at higher prices.

As the exchange rate shows a higher level of volatility than foreign inflation, its impact on the movement of imported inflation is dominant. Through the

exchange rate (RSD against the EUR, in our case) monetary policy can affect inflation.

In the equation (2.2), the element of imported inflation is adjusted with a change in real exchange rate trend. The difference in real exchange rate ( $\Delta l z_t$ ) is the difference between Eurozone inflation ( $\pi_t^{EU}$ ) and domestic inflation ( $\pi_t$ ) expressed in the same currency:

$$\Delta l z_t = \Delta l s_t + \pi_t^{EU} - \pi_t \quad (2.5)$$

As a consequence of the Balassa-Samuelson effect in Serbia, there is a trend of price convergence to the Eurozone countries, i.e. appreciation trend of the real exchange rate of the RSD against the EUR ( $\Delta \bar{l z}_t < 0$ )<sup>3</sup>.

In other words, in the medium term it is expected that price growth in Serbia will be faster than abroad expressed in the same currency. Therefore imported inflation in the core inflation equation is adjusted for the change in the real exchange rate trend, which is further adjusted for trend difference between overall and core inflation ( $\pi_t^M - \Delta \bar{l z}_t - \overline{kor}$ ), for similar reasons as in the case of inflation expectations (in order to adjust real exchange rate trend to core inflation).

The real exchange rate gap ( $zgap_t$ ) is the deviation of the real exchange rate from its equilibrium level ( $\bar{l z}_t$ ):

$$zgap_t = l z_t - \bar{l z}_t, \quad (2.6)$$

This equation is viewed as an approximation of net importers' real marginal cost. If, for example, we have an appreciation gap, this means that the marginal

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<sup>3</sup> Nominal and real exchange rates are defined in such a way that their increase means depreciation and their decrease means appreciation.

cost of net importers is relatively low compared to what would be expected based on the long term trend of the real exchange rate.

*Output gap* ( $ygap_t$ ) is a measure of demand defined as the difference between actual production ( $ly_t$ ) and its equilibrium level, i.e. trend ( $\bar{ly}_t$ ):

$$ygap_t = ly_t - \bar{ly}_t \quad (2.7)$$

The equilibrium level of production is the level which can be achieved with existing labour, capital, and productivity, without putting pressure on prices. Unlike the trend which is defined by long-term supply factors, the gap is determined by medium- and short-term demand factors. A positive output gap means that inflationary pressures are coming from demand, and vice versa.

*Real marginal cost of processed-food production gap* ( $RMCPgap_t$ ) is used as a measure of cost pressures on food prices in core inflation.  $RMCP$  is a (log) difference between the price of agricultural products ( $IP_t^{agr}$ ) and price of processed food ( $IP_t^{food}$ ):

$$RMCP_t = IP_t^{agr} - IP_t^{food} \quad (2.8)$$

while the  $RMCPgap_t$  is the deviation of  $RMCP_t$  from its medium term average.

As a measure of the price of agricultural products we use a composite index of products that are the most important inputs in the production of food (such as wheat, corn, soybeans, sunflower oil, fruit, and vegetables). High values of the gap in  $RMCP$  suggest that the costs of producing food are relatively high, resulting in cost-push inflationary pressures, and vice versa.

*Oil derivatives inflation* ( $\pi_t^{petr}$ ), next to core and non-core inflation, is the third component of overall inflation (equation 2.1).

Oil derivative prices are based on movements in world oil prices denominated in USD ( $\pi_t^{oil}$ ) and exchange rate movement of the RSD against the USD

( $\Delta I_s_t^{usd}$ ). Also, oil derivatives prices depend on the level of excise tax ( $exc_t$ ), which is adjusted at the beginning of each year for overall price growth in the previous year:

$$\pi_t^{petr} = a_{51} \cdot (\Delta I_s_t^{usd} + \pi_t^{oil}) + (1 - a_{51}) \cdot exc_t \quad (2.9)$$

Change of the exchange rate of RSD against USD depends on the change of exchange rate of RSD against EUR and the changing relation between USD and EUR.

## 2.2 Output gap – demand side

Demand, as a factor of inflation, is usually estimated with output gap ( $ygap_t$ ) in the macroeconomic models. The idea behind this concept is that the trend of production is determined by the factors of supply, such as capital and productivity, and the deviations from the trend (i.e. output gap) are determined by demand factors.

The monetary policy authorities influence demand via the real interest rate and real exchange rate. High real interest rate discourages consumption and high real appreciation of domestic currency reduces the demand for domestic goods. In both cases the economy is pushed below the long-term trend. The reverse is the case of an expansionary monetary policy (low real interest rate and high real depreciation of domestic currency).

As with production, the trends of real interest rate and real exchange rate are determined by fundamental factors, and monetary policy can only affect the cyclical fluctuations of real interest rate and real exchange rate around the trend. Therefore the monetary policy stance is often calculated through the index of monetary restrictiveness, which is a linear combination of the real exchange rate gap ( $zgap_t$ ) and the real interest rate gap ( $rrgap_t$ ).

The output gap is influenced to a large extent by the foreign demand cycle, which is approximated by the output gap of the Eurozone in our model ( $ygap_{t-1}^{EU}$ ). The equation of the output gap, therefore, is given as:

$$\begin{aligned}
ygap_t = & a_{61} \cdot ygap_{t-1} - a_{62} \cdot [a_{63} \cdot (-zgap_t) + (1 - a_{63}) \cdot rrgap_t] + \\
& + a_{64} \cdot ygap_{t-1}^{EU} + \varepsilon_t^{ygap}
\end{aligned} \tag{2.10}$$

The real exchange rate gap has already been discussed in chapter 2.1.

*Real interest rate gap* ( $rrgap_t$ ) is the deviation of real interest rate from its equilibrium level:

$$rrgap_t = rr_t - \overline{rr}_t \tag{2.11}$$

Equilibrium is usually defined as the level of interest rate consistent with the equilibrium level of output and stable inflation. Real interest rate is the difference between nominal interest rate and inflation expectations.

$$rr_t = i_t - E_t \pi_{4,t+4} \tag{2.12}$$

*World demand lag* is approximated by the output gap lag of the Eurozone, Serbia's main trading destination, and which is correlated with economic cycles of other countries that are our trade partners (mainly countries in the region):

$$ygap_t^{EU} = ly_t^{EU} - \overline{ly}_t^{EU} \tag{2.13}$$

### 2.3 Exchange rate

The exchange rate (RSD against EUR) is presented in the model by the equation of uncovered interest rate parity, which is based on the assumption that the yields of two currencies, adjusted for the risk premium, tend to be equal:

$$ls_t = E_t ls_{t+1} + (-i_t + i_t^{eu} + prem_t) / 4 + \varepsilon_t^{ls} \tag{2.14}$$

By increasing the repo interest rate ( $i_t$ ), the central bank increases the yield of RSD, which makes the domestic currency more attractive and therefore more in demand on the FX Market, which results in its appreciation. Equation (3.14) shows that the higher the interest rate of RSD ( $i_t$ ) compared to the Eurozone

interest rate ( $i_t^{eu}$ ), the higher its expected depreciation ( $E_t l_{s_{t+1}} - l_{s_t}$ ) resulting in a lower current exchange rate ( $l_{s_t}$ ), i.e. domestic currency appreciation.

However the exchange rate is formed not only on the basis of differences between the two interest rates. In the financial and foreign exchange markets for riskier currencies (such as RSD) an additional yield is required – the so-called risk premium ( $prem_t$ ). The risk premium equals preferences of investing in RSD and EUR and it often has a dominant influence on the movement of the exchange rate. For instance, in late 2008 significant depreciation of the RSD was the result of an increase in the risk premium caused by the global economic crisis.

*Expected exchange rate* ( $E_t l_{s_{t+1}}$ ) is formed based on rational expectations, i.e. model-based projection for one period ahead ( $l_{s_{t+1}}$ ), and purchasing power parity of the RSD against the EUR, adjusted for the change in the real exchange rate trend ( $\pi_t - \pi_t^{EU} + \Delta \bar{l}z_t$ ).

$$E_t l_{s_{t+1}} = a_{71} \cdot l_{s_{t+1}} + (1 - a_{71}) \cdot [l_{s_{t-1}} + 2/4 \cdot (\pi_t - \pi_t^{EU} + \Delta \bar{l}z_t)] \quad (2.15)$$

## 2.4 Monetary policy rule

*Monetary policy rule* defines the way in which the central bank decides the level of the repo interest rate ( $i_t$ ):

$$i_t = a_{81} \cdot i_{t-1} + (1 - a_{81}) \cdot [i_t^n + a_{82} \cdot (\pi_{4,t+4} - \pi_{t+4}^{tar})] + \varepsilon_t^i \quad (2.16)$$

A key element in deciding the repo interest rate, which determines the monetary policy rule, is deviation of projected inflation from target inflation ( $\pi_{4,t+4} - \pi_{t+4}^{tar}$ ). When projected inflation (four quarters ahead) is above target inflation, monetary policy should be restrictive, i.e. the repo interest rate should be above neutral ( $i_t^n$ ), and vice versa. In order to avoid instability of the financial markets monetary policy should not make sharp moves, and therefore equation (2.16) includes the repo interest rate from the previous period ( $i_{t-1}$ ), as an element that ensures the relative stability of monetary policy, i.e. stability of the movement of the repo interest rate.

*Neutral interest rate* is the level of interest rate that has a neutral impact on inflation (neither inflationary nor disinflationary) and is the sum of the real interest rate trend ( $\overline{rr}_t$ ) and inflation expectations ( $E_t\pi_{4,t+4}$ ):

$$i_t^n = \overline{rr}_t + E_t\pi_{4,t+4} \quad (2.17)$$

The repo interest rate should be at a neutral level if it is estimated that inflation in the monetary policy horizon is on target.

*Real interest rate trend* is related to the change in the real exchange rate trend, risk premium, and real interest rate trend in the Eurozone, by the real uncovered interest rate parity equation:

$$\overline{rr}_t = \Delta\overline{lz}_t + prem_t + \overline{rr}_t^{EU} \quad (2.18)$$

This equation is the real counterpart of the nominal uncovered interest parity equation (2.14). Equation (2.18) shows that the higher the risk premium and the higher the level of depreciation of the real exchange rate trend, the higher the real return on local currency ‘demanded’ by the financial markets. This has direct implications for the height of the repo interest rate, since in this case the central bank would have to offer higher yields.

Note that our monetary policy rule does not include the output gap, which is a typical component of the Taylor rule. The reason for omitting the output gap is that inflation targets for the first few years of the implementation of this regime were set at a very high level ( $8 \pm 2\%$  for 2009 and  $6 \pm 2\%$  for 2010) in order to avoid restrictive monetary policy<sup>4</sup> in the midst of the global economic crisis, which could further worsen the economic situation. Thus if economic activities are taken into account in setting objectives by including the output gap, which was extremely negative in 2009 and 2010, the monetary policy rule could lead to overshooting already high set targets. When the target is stabilized at a lower

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<sup>4</sup> Setting the targets at the lower level would require a more restrictive monetary policy.

level it is possible that we will include the output gap in the monetary policy rule.

### **3. PARAMETERS OF THE MODEL**

Characteristics of the model are determined not only by the structure but also by the values of the parameters. Parameter values define the dynamic relationships between variables in the model, such as the effects of some factors on inflation, the speed and intensity policy rate influence on inflation, the formation of the exchange rate, etc.

In general, models can be estimated on data or calibrated. In the former group of models parameters are estimated econometrically, using criteria such as the coefficient of determination, to explain the history as well as possible. The calibrated model parameters are not estimated, but their values are assigned based on specific criteria.

There are several common reasons why the econometric estimation of models for medium-term projection is not reliable. First, sometimes in econometric estimation it is difficult to distinguish between cause and effect. This is especially true when it comes to the monetary policy rule and the transmission mechanism of monetary policy. Suppose that the monetary authorities precisely anticipate inflationary shocks and by frequently changing the policy rate manage to keep inflation exactly on target all the time. In this case, if we estimate the econometric equation of the repo interest rate (2.16), we will not be able to explain its changes with the monetary policy rule, given the fact that inflation is always on target and therefore there is no need for monetary policy to react<sup>5</sup>.

The problem will also arise if we try to estimate the relationship between policy rate and exchange rate. Suppose the domestic currency is under strong depreciation pressure and that the central bank reacts immediately by raising

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<sup>5</sup> An example is shown in Czech National Bank Forecasting and Policy Analysis System (2003).

the policy rate. In this case a simple econometric analysis would, contrary to economic theory, show that the increase in policy rate leads to depreciation pressure. Such a conclusion would suggest that we could strengthen the domestic currency by cutting the policy rate.

In the case of Serbia econometric estimates are especially difficult because of a lack of long and stable time series. In most cases Serbian economic time series are short and have structural breaks, and as such they are usually unsuitable for reliable econometric estimates. Also frequent structural changes in economic and particularly monetary policy (political changes in 2000, stable exchange rate policy, inflation targeting) lead to changes in the relationships between economic variables, which further makes econometric estimations unreliable.

For all these reasons the NBS medium-term projection model is calibrated, with econometric estimations used whenever possible. The model parameters are calibrated in such a way that the model's properties (relationships between variables) are consistent with economic theory and reflect some well-known features of the Serbian economy. At the same time it is desirable for the model to explain macroeconomic movements in the recent past as well as possible. In addition, the experience of other countries, especially countries in transition, can be of great benefit to the process of calibrating the model.

Besides the econometric estimates, the explanatory power of the data by the calibrated model is usually checked by so-called history simulations. The objective is to evaluate how well the model projects the movement of variables (inflation, exchange rate, output gap, etc.) in the history, i.e. to evaluate how much projected values deviate from the actual values. Of course it is desirable for these deviations to be as small as possible, especially in the recent past. The reason is that as the relationship between variables (i.e. model parameters) changes, so explanation of history data by the model may not be equally good for the whole period. Since the model is used for projections it is better to accept the set of parameters that better explains recent developments.

During the calibration process we used some different approaches, depending on the extent to which parameters can be determined based on historical data.

For example, we used the econometric estimation and properties of the model for the purpose of calibration of the core inflation equation and output gap equations. The uncovered interest parity equation is purely theoretical, while the monetary policy rule equation is calibrated solely on the basis of the properties of the model in order to satisfy the specific features of monetary policy.

### **Core inflation**

The core inflation equation is calibrated by combining historical data analysis with model properties analysis. Estimated parameters of the core inflation equation (3.2) were used as a starting point for calibration, which in the next stage is mainly based on simulations of the history and features of the model.

In the case of some variables in the equation, econometric estimations of parameters were not statistically significant. For example, that was the case with the output gap. However, based on a simulation of the history, it is estimated that this variable significantly improves the explanatory power of core inflation in recent years (late 2008). Because we believed that the output gap would play an important role in the future, this variable was included in the model.

Special attention was also paid to the properties of the model, that are supposed to reflect some familiar features of the Serbian economy. One of them is the relatively highly significant short-term pass-through effect from the exchange rate (i.e. imported inflation) to inflation. Our estimate, as well as others, ranges between 0.2 and 0.3.<sup>6</sup> Model parameters are calibrated so that the short-term pass through effect from exchange rate to inflation (over imported inflation) is around 0.2. The calibrated equation of core inflation (2.2) is:

$$\begin{aligned} \pi_t^{core} = & 0,4 \cdot \pi_{t-1}^{core} + 0,4 \cdot (E_t \pi_{4,t+4} - \overline{kor}) + 0,2 \cdot (\pi_t^M - \Delta \overline{Iz}_t - \overline{kor}) + \\ & + 0,3 \cdot zgap_{t-1} + 0,3 \cdot ygap_{t-1} + 0,2 \cdot RMCPgap_t + \varepsilon_t^{\pi^{core}} \end{aligned} \quad (3.1)$$

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<sup>6</sup> See Mladenović, and Petrović (2009) and Palić and Vilaret (2007).

Parameters on core inflation lag, inflation expectations (adjusted with trend difference between overall and core inflation), and imported inflation (adjusted with the real exchange rate trend and the trend difference between overall and core inflation) are linearly homogeneous (the sum of parameters with these variables is equal to one). This reflects the (theoretical) requirement that these three variables converge to the same value in the long run.

### **Exchange rate**

The uncovered interest rate parity equation (2.14), which describes the movement of the exchange rate, is purely theoretical. Econometric evaluation of exchange rate movements is an almost impossible task even in far more developed economies, and in our case was tougher because it is only since 2006, by and large, that the movement of the exchange rate has been free.

The UIP equation has to explain the effect of the repo interest rate on the exchange rate. We have already mentioned the problems that may arise in assessing the relation between these two variables, and for this reason we went for a pure theoretical approach. This equation does not contain parameters that need to be calibrated.

### **Policy rate**

It is also not possible to econometrically estimate the monetary policy reaction function, because of reasons already explained. One additional problem is that inflation targeting as a monetary policy regime was recently introduced. This equation is therefore calibrated to ensure a balance between two opposite demands: on the one hand, stability of the repo interest rate, and on the other, a sufficiently fast and strong response of monetary policy to bring inflation to the target.

Coefficient  $a_{81}$  in equation (2.16) takes a value between 0 and 1. The high value of this coefficient indicates that monetary policymakers are not inclined to suddenly change the policy rate, thereby securing its stability. Coefficient  $a_{82}$  (takes the positive value) determines the aggressiveness of the monetary policy response to deviations of inflation from the target. The high value of this

coefficient means that the central bank reacts ‘aggressively’ to deviation of inflation from the target.

The high value of the coefficient  $a_{81}$  and low value of  $a_{82}$  results in a more stable movement of the policy rate, but also a slower return of inflation to the target. Therefore in determining these coefficients it is necessary to find a proper balance between stability of monetary policy and speed of achieving the target. Having that in mind and based on the properties of the model, we calibrated the coefficient  $a_{81}$  to the value of 0.5 and  $a_{82}$  to the value of 2. The calibrated equation of policy rate (2.15) looks like:

$$i_t = 0,5 \cdot i_{t-1} + 0,5 \cdot \left[ i_t^n + 2 \cdot (\pi_{4,t+4} - \pi_{t+4}^{tar}) \right] + \varepsilon_t^i \quad (3.2)$$

Movement of the repo interest rate is also determined by a forward-looking component of monetary policy. Similar to the analysis of the coefficient values, a more forward-looking monetary policy is more stable but inflation goes back to target slower, and vice versa. In our case, the central bank responds to deviations of inflation from the target four quarters ahead.

### **Output gap**

Parameters of the output gap equation (2.10) were estimated using the ordinary least squares method, and then calibrated to meet the values of theoretically suggested coefficients in transition countries.

Before the estimation of parameters it is necessary to first estimate the gaps themselves, since these variables are unobservable, i.e. are not measured directly. For this purpose we use a multi-dimensional Kalman filter, which contains the same output gap equation as the core model. Of course, at the beginning of the estimation process of this equation we could not use gaps which are based on the Kalman filter because the model had not yet been calibrated. Instead, the first estimate was based on estimated gaps using the (one dimensional) Hodrick - Prescott filter.

Laxton and Scott (2000) suggested the coefficient of the monetary restrictiveness index ranges between 0.1 and 0.4, which is consistent with our estimation (0.2).

Some of the estimated coefficients, however, were different from those that theory suggests. Estimated coefficient on output gap lag in our case is 0.7, which is below the theoretically suggested range from 0.75 to 0.95, so we have slightly corrected the estimation in the model:

$$ygap_t = 0,75 \cdot ygap_{t-1} - 0,2 \cdot [0,8 \cdot (-zgap_t) + 0,2 \cdot rrgap_t] + 0,8 \cdot ygap_{t-1}^{EU} + \varepsilon_t^{ygap} \quad (3.3)$$

Deviation from the theoretically suggested values is particularly pronounced in the case of the real exchange rate gap coefficient ( $a_{63}$  in equation 2.10). The estimated coefficient in our case (0.3) shows that, within the monetary restrictiveness index, real interest rate is more important than real exchange rate. However, according to Laxton and Scott, small open economies should have a greater value of coefficient for the real exchange rate gap relative to the coefficient of the real interest rate gap ( $a_{63}$  is greater than 0.5). It is, in our opinion, especially pronounced in the case of Serbia, since, due to the high level of euroization, the interest rate channel is still weak. Therefore in our case for the coefficient of the real exchange rate gap we made a significant correction from 0.3 to 0.8.

#### 4. THE MODEL PROPERTIES

The main method we use for testing model properties is an impulse response function. This function provides an answer to the question of how variables in the system react to a shock in one of them.

It is not possible to see the reaction only on the basis of the model coefficients. For example, the coefficient of short-term impact of imported inflation on core inflation is 0.2, but due to the simultaneous influences in the model the effect of exchange rate on inflation is not that significant.

Therefore these relationships are analyzed by changing one variable for say 1%, and then analyzing the responses of all variables in the model. Such analysis, in a simple way, provides the possibility of checking whether the model behaves in

accordance with economic theory and how well it reflects known facts about the domestic economy.

### **Shock in the core inflation**

Unexpected, smaller or larger, autonomous or external shocks to core inflation are a regular occurrence. They may be the result of various factors (bad harvest, jump in world oil prices, etc.), and they are sometimes the result of significant price change of a single product in the CPI basket.

If we assume that there was a sudden rise in core inflation of 1% in one quarter<sup>7</sup>, it directly leads to the growth of year-on-year inflation over the next four quarters. The central bank responds by raising the repo interest rate, basing its decision on the year-on-year overall inflation four periods ahead, which means that the central bank does not respond directly to the shock<sup>8</sup>, but only to its secondary effects, which are a primarily consequence of inertia and increased inflationary expectations.

Rising inflation leads to a one-off permanent increase in prices, which, together with an initial nominal appreciation caused by the repo interest rate increase, results in opening of the appreciated real exchange rate gap. The appreciated real exchange rate gap means that the real marginal cost of net importers is relatively low, which puts disinflationary pressure in the medium term. In addition, along the opened positive real interest rate gap, it also affects the opening of the negative output gap, i.e. it reduces demand, which also creates disinflationary pressure. On the other hand, after the initial appreciation after the second quarter the nominal exchange rate depreciates, adjusting to the increased price level and narrowing the appreciation gap.

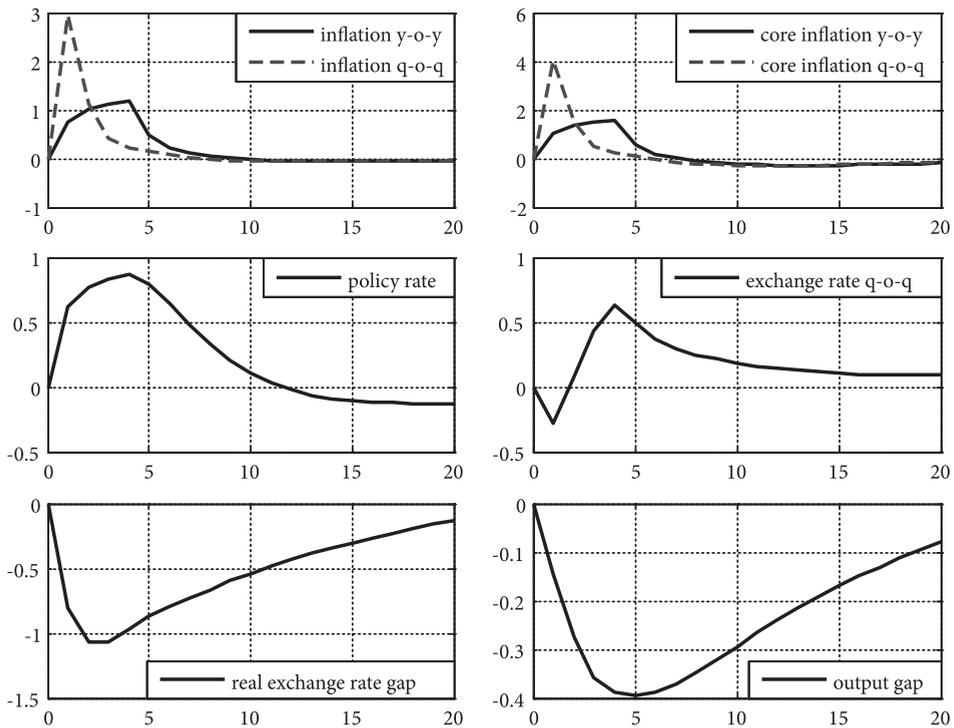
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<sup>7</sup> Growth rates in the model are annualized (multiplied by four), and therefore in Graph 1 core inflation is 4% in the first quarter, although the shock is 1%.

<sup>8</sup> Specifically, in the first quarter, the central bank responds to the year-on-year inflation in the fifth quarter when the direct effects of price shock on the year-on-year inflation have already been exhausted.

Although the prices grow for some time (inflation is greater than zero after the first quarter), as a result of inertia, increasing inflationary expectations, and depreciation of the RSD from the second quarter, the shock gradually fades away and inflation returns to zero; among other reasons because of the reaction of the central bank, i.e. increased restrictiveness in monetary policy.

**Graph 1.** Impulse response function for shock in core inflation



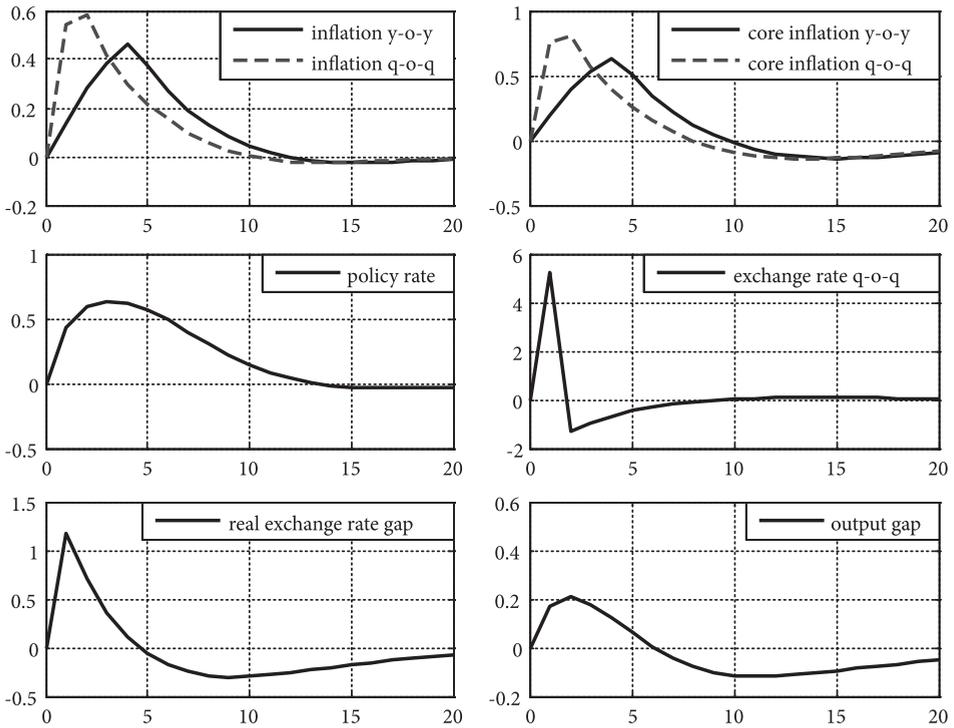
Source: authors' calculations

**Shock in the nominal exchange rate**

Suppose that there has been an autonomous depreciation of the exchange rate of 1% in one quarter, i.e. depreciation not caused by changing the interest rate spread or risk premium. As an example, such depreciation could occur because of large companies' payments of foreign liabilities. This change causes the growth of import prices in local currency, resulting in increase of the core inflation, and thus overall inflation. As the nominal depreciation is not

accompanied by an increase in prices to the same extent, the real exchange rate depreciation gap opens, leading to opening of the positive output gap. Together with the inertia and increase of inflationary expectations, these will result in inflationary pressures in the next quarter.

**Graph 2.** Impulse response function for shock in exchange rate



Source: authors' calculations

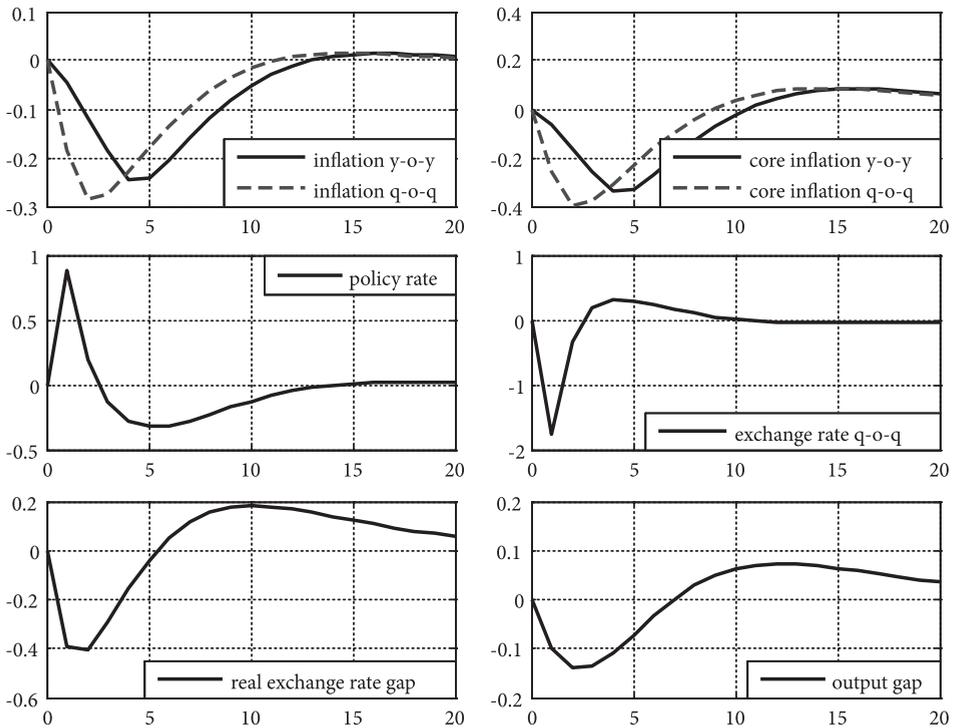
The effects of shock gradually die out, which is contributed by the increase in the policy rate. These lead to a moderate appreciation of the nominal exchange rate, gradual closing of the depreciation gap of the real exchange rate, lowering inflationary pressures, and thus core inflation returning to the initial level.

**Shock in the policy rate**

Policy rate increase results in nominal appreciation, which leads to a fall in core inflation by reducing import prices. Because of a greater nominal appreciation

compared to the price fall, the real exchange rate appreciation gap opens. Tighter monetary policy (increase in repo interest rate above the neutral level and opening of the appreciation gap) results in the opening of the negative output gap. In the period ahead the nominal appreciation, through the fall of import prices in local currency and the real exchange rate appreciation gap, leads to a fall in the core and hence the overall inflation.

**Graph 3.** Impulse response function for shock in policy rate



**Source:** authors' calculations

The central bank is then forced to relax monetary policy in the coming quarters in order to return inflation to target. By cutting the policy rate appreciation pressures are calmed, which leads to the closure of the appreciation gap along with a fall in prices (negative inflation), which together with closing of the negative output gap brings inflation back to target.

## **5. PROCESS OF MEDIUM-TERM PROJECTION AND ITS ROLE IN MONETARY POLICY**

The model which is presented in this paper is a basic tool in the process of developing medium-term projections. The main result of this process is the projected path of the policy rate that should be followed by the central bank in order to maintain inflation close to target in the medium term. The projected path of the repo interest rate which is used by monetary policy makers is a starting point in making decisions about its level.

Apart from running the model the projection process includes a number of activities, such as short-term projection of inflation, defining the projection assumptions regarding the exogenous variables and the assumptions on trends of real variables, including effects of the factors out of the model and the adoption of assumptions regarding the shocks during the forecasting period.

The process of medium-term projection begins with an analysis of inflation and the factors that contributed to inflation in the past. To a large extent this analysis influences the definition of initial conditions and the assumptions of the projection.

As we have mentioned, unobserved components (trends and gaps of real variables) are estimated on the history by the model based on the Kalman filter. Their last estimated values in history are the initial values in the medium-term projection. The estimation of unobserved components includes not only the simple application of the Kalman filter but also economic judgements on the initial state of the economy. For example, projections in January 2009 included the consequences of the global economic crisis in late 2008: the assumption of significant breaks in the trends of the real exchange rate, the real interest rate, the risk premium, and production.

Models for medium-term projections do not tell us anything about how the trends of real variables are formed. Therefore at this stage it is necessary to adopt assumptions about their future movements. The movement of trends is

generally projected into the future based on the assumption that their state in the medium term (faster or slower) is moving towards equilibrium.

Assumptions and predictions regarding the movements of some exogenous variables are taken from external sources or made internally, because it is hard to describe their movement by equations, or the forecasts of other institutions are considered more reliable. The assumed movements of exogenous variables - global oil prices, foreign inflation, the European Central Bank (ECB) interest rate, the relationship between dollar and euro (USD/EUR) - are based on expectations from foreign sources (we mainly use the publication Consensus Forecast).

Particularly important is an assumption about the movement of non-core inflation (regulated prices and prices of fruit and vegetables) since it represents about a quarter of CPI and therefore has direct input into the inflation projection. These projections are based on the government plan for the correction of regulated prices and assumptions about the movement in agricultural prices (based on their current level and the expected harvest).

For one quarter ahead, instead of a model projection of inflation, we include short-term projections based on expert judgements. In the short term expert judgements are more reliable because they include specific information that the model cannot encompass. These projections include the current implemented or announced price adjustments, as well as assessment of the short-term influence of the inflation factors on price movements. Short-term quarterly inflation projection is very important, first because it directly affects year-on-year projected inflation for the period of one year, but also because it affects quarterly inflation in the future due to inflation inertia and through inflation expectations.

The model does not include all the relevant variables, so it is sometimes necessary to include implicitly factors which are out of the model. For example, if the central bank intervenes in the foreign exchange market it will affect the exchange rate, and therefore it is necessary to include a shock in the exchange rate ( $\varepsilon_t^{ls}$  in equation (2.14)). Or increased expansiveness of fiscal policy will

affect the increase of demand, which will be included in the projections through the positive shock in the output gap ( $\varepsilon_t^{y^{gap}}$  in equation (2.10)).

Based on the assumptions and short-term projections we generate scenarios of medium-term projections. The main scenario is based on assumptions that are considered the most probable. In addition, by varying assumptions of projections in accordance with risk assessments a number of alternative scenarios are generated by the model, which have the role of indicating a course of action for monetary policy if things do not go as expected. This is very important considering the fact that the projections are made once in three months, and that in the meantime discrepancies from the assumptions of the baseline scenario are likely. For example, scenarios may be based on different assumptions regarding the movement of regulated prices or world oil prices.

The whole process of medium-term projections includes intensive communication between the members of the Executive Board (EB) and the direct creators of the projections. The members of the EB are not only the final ‘users’ of medium-term projections, but their analysis and suggestions actually actively create them. The members of the EB and the direct creators of projections define the projection assumptions at meetings, the risks are analyzed and accordingly alternative scenarios are chosen, and eventually a fan chart of inflation projections is adopted that will be presented in the Inflation Report.

The starting point for deciding the policy rate is primarily the projected policy rate path from the baseline scenario of medium-term projections, but also the risk assessment in relation to the baseline scenario. Based on the baseline and alternative scenarios we produce a chart of inflation projection which is published in the Inflation Report, and it consists of the central projection and the range which should reflect the risks of projection.

Between two medium-term projections we analyze deviations from the last projection. Deviations from the projections result from the fact that projections are based on assumptions which may not be fulfilled. According to this analysis we also consider whether and how much the policy rate should deviate from the projected path of the last medium-term projections, as well as if the

macroeconomic trends are in line with alternative scenarios. Members of the EB make decisions about the policy rate on the basis of these considerations.

## **6. CONCLUDING REMARKS**

"All models are wrong but some are useful" (George Box) – is a frequent quote in the literature on macroeconomic models. Each model provides only a simplified picture of reality and can never be entirely accurate in describing and predicting macroeconomic trends. However, the model can provide useful information to policy makers about the measures which should be taken to achieve the basic goals.

The model for medium-term projection is first of all a good way to summarize the knowledge and the known facts about the domestic economy in an exact and consistent manner. Not only in developing the model but also in the preparation of medium-term projections we include all relevant information that we think of as economists. The model serves to systematize these thoughts into a unified macroeconomic framework.

In developing the model we took into account two conflicting requirements: on the one hand, to include as much relevant information as possible, and on the other, to keep the model as simple as possible. For the latter reason some of the variables that may be argued to be important are not in the model. However, it does not mean they are not taken into account, but if it is assessed that their impact on the projection is significant they are included through the shocks.

Projecting the policy rate path which is consistent with the targeted level of inflation, the model for the medium-term projections has a supportive role in the conduct of monetary policy. However deviations from the projected path of the policy rate are possible depending on the assessment of the risk, as well as when significant deviations from the last medium term projections happen between the two projections.

In the future we will carefully monitor the realization of the projections and correct identified shortcomings of the model. In this sense the version of the

model that we have presented in this paper is not final, and the model will regularly change either by changing coefficients or by changing its structure.

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## APPENDIX: TECHNICAL EXPLANATIONS

The model for medium-term projections is a log-linearized quarterly model. Series are seasonally adjusted (as necessary), logarithmed, and their values are the averages for the quarter. Quarterly growth rates are annualized in order to be comparable with y-o-y ones.

For these purposes, the original series are transformed in several steps:

- Monthly and daily series are transformed in quarterly data based on the average series values. Series that were originally available as growth rates (i.e. inflation) were transformed into base indices first, and then transferred from monthly to quarterly frequency as averages.
- The levels of series are seasonally adjusted wherever it is estimated that the series have seasonal fluctuations (eg. economic activity, inflation, etc.). In some case seasonal adjustment was not needed (interest rates, exchange rate, etc.).
- Levels of seasonally adjusted series are in logarithmic form, except in the case of variables which appear only as rates in the model (interest rates, inflation expectations, etc.). A logarithmic transformation was made in order to linearize the model, which makes its solution much easier. The levels of series that are linearized begin with the letter *l* in the notation (for example *lz*, *ls*, ...).
- Growth rates were calculated as the differences of logarithmic series. Quarterly growth rates are calculated as the first difference (logarithmic and seasonally adjusted) in level of the series multiplied by four (in order to annualize) and year on year growth rates are calculated as the fourth differences. For example, the quarterly inflation rate is calculated:

$$\pi_t = 4 \cdot [lp - lp(-1)],$$

and year on year growth rate is:

$$\pi_{4,t} = lp - lp(-4),$$

where *lp* is logarithmic and seasonally adjusted level of prices.

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