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Модел за средњорочне пројекције Народне банке Србије

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Апстракт: Средњорочне пројекције представљају важан елемент у процесу доношења одлука у режиму циљања инфлације, који последњих година примењује Народна банка Србије. Основни циљ средњорочних пројекција јесте да дају одговор на питање како треба да се креће референтна каматна стопа да би се инфлација у наредном периоду кретала што ближе циљаној стопи. Као основно средство за средњорочне пројекције користи се макроекономски модел који представља скуп једначина којима се описује механизам формирања цена у Србији и трансмисиони канали утицаја монетарне политике на цене. Модел садржи четири главне једначине: инфлацију, девизни курс, производни јаз и референтну каматну стопу, као и велики број помоћних једначина и идентитета. За оцену трендова и јазова на историјском периоду користимо вишедимензионални Калманов филтер. У садашњој форми модел се користи од краја 2008, с тим што се стално ради на његовом унапређењу.

Кључне речи: модел за средњорочне пројекције, циљање инфлације, Калманов филтер
[JEL Code]: C53, E17, E58

Medium-term projection model of the National Bank of Serbia

Mirko Djukic Jelena Momcilovic Ljubica Trajcev

Abstract: Medium-term projections are an important element of the decision-making process in an 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 give an answer to what should be the policy rate path that would ensure that inflation in the coming period moves close to the targeted inflation rate. The most important tool for medium-term projections is a 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 behavioral equations for inflation, exchange rate, output gap and policy rate, and of a number of side behavioral equations and identities. For estimating trends and gaps on history, we use multivariate Kalman filter. The model in the current form has been used since end-2008 and is subject to regular adjustments and improvements.

Key words: medium-term projection model, inflation targeting, Kalman filter.
JEL Code: **C53, E17, E58**

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Contents:

1. Introduction

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

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

For this purpose a quarterly model for the medium-term projections was developed to support monetary policy makers in making decisions on the repo rate level which is 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 movements, as well as channels through which the central bank affects inflation by adjusting the policy rate.

The model used in the NBS is a new Keynesian type of model. The basic principle of such models is that the role of monetary policy is reflected in anchoring inflation and inflationary expectations. It is the monetary policy that 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, the changes in nominal interest rate result in changes in real interest rate, leading to deviations of real variables (such as economic activity and real exchange rate) from their trends and thus influence inflation. Monetary policy has a lasting impact on nominal variables, and a temporary impact on real variables. Unlike the pure Keynesian economics, rational expectations (expectations that partly depend on the model projections) play an important role in these models, which means that economic agents partially anticipate the actions of monetary policy so that the surprise effect is reduced.

The basic structure of our model is very similar to models used in a number of central banks, except that our model contains some specific features related to the characteristics of the Serbian economy. Like other 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 side equations that describe the movement of other relevant economic parameters and a large number of identities. The main equations of the model will be presented in Section 3.

Although the model contains 90 equations, it belongs to a group of relatively simple models. The advantage of simple models is the ability to describe the interconnections of the main variables that affect inflation and relate to the transmission mechanism of monetary policy in a clear and simple way, while maintaining theoretical coherence. At the same time, clarity and simplicity of the model allow the monetary policy makers to have a good understanding of the model, which provides a good basis for discussion within the central bank, both among members of Executive Board (EB) and between the direct projection creators and members of EB. Members of EB are not just users of model projections (support to decision making), but active contributors to their creation, as well. It is therefore very important that the model should not be a "black box"for monetary policy makers.This is why in developing the model, we tried to include all the relevant factors, while keeping the model as simple as posible.

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 reffered to as the gap model. The monetary policy with its measures can temporarily affect only the gaps but not the trends. As the gaps and the trends are unobserved components, an important (initial) stage of the medium-term projections is their estimation on the history. For this purpose we use a methodology based on the Kalman filter (Section 6).

This model is semi-structural. This means that, although the model has clear economic and theoretical interpretation, in its development we wanted it to reflect trends in the Serbian economy as much as possible. Model coefficients are not estimated, but mostly calibrated in order to follow economic intuition and theory, but also taking into account the basic characteristics of the Serbian economy and developments in the recent past. Econometric estimation is used as an auxiliary tool whenever possible. The reasons why the model was calibrated and the methods of calibration used are explained in Section 4.

There is much more to the process of medium-term projection than a simple use of the model. In practice, models do not produce the forecasts: economists do1. It could even be said that defining the assumptions of the projections and generally economic analysis dominantly determine the results of projections. The model in that sense is primarily used to systematize assumptions and judgements about the future in a unique and consistent framework. The process of medium-term projection will be described in detail in Section 7.

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 case 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 describe an economic interpretation of the model. The model structure, detailed description and explanation of the equations that make the model, are presented in the third part. The

[1]Berg, A. 2006

fourth part deals with the determination of model parameters, while the fifth discusses the properties of the model. In the sixth part we describe Kalman filter model that we use for estimation of trends and gaps on the history. Seventh part explains use of the model in the medium-term projection process and generally the role of the model in monetary policy implementation. The paper ends with concluding remarks on the NBS experience in the use of models for medium-term projections.

2. Economic interpretation of the model

In line with the inflation targeting regime, pursued by the NBS, the main role of the medium-term projection model is to encompass key factors that influence price formation, as well as the channels through which monetary policy can influence price movement.

2.1. Factors that influence inflation

When it comes to factors that influence inflation, it is important to keep in mind that the headline measure of inflation, consumer price index (CPI), is a heterogeneous basket of goods and services, by the way their prices are formed and by the factors that influence them. In our model, inflation is broken down into three groups:

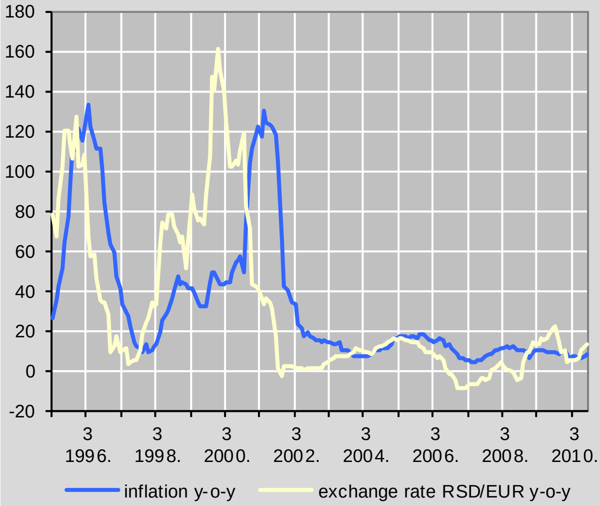
- Core inflation
- Non-core inflation excluding oil derivatives
- Oil derivatives inflation

The main criterion for this division is the way these prices are formed and the impact of monetary policy on their movement.

Core inflation is inflation excluding changes in regulated prices and agricultural product prices, which makes two thirds of the CPI. This group of goods and services is formed freely on the market, which is why monetary policy can have an impact on their movement with its instruments. The factors that affect core inflation are numerous.

Exchange rate has traditionally been a very important price formation factor in Serbia. This is a consequence of expansionary fiscal and monetary policy implemented over a long period of time (throughout 80’s and 90’s), that has led to a loss of confidence in the domestic currency and tight link between the exchange rate (first against the German Mark and then against the Euro). Changes in exchange rate, together with changes in foreign prices, result in changes in import prices, which have a significant impact on domestic prices. Numerous authors from the NBS and elsewhere (Mladenović, Petrović (2009), Palić, Vilaret (2006)) estimated short-term pass-through from exchange rate to inflation in the range of 0.2 to 0.3.

Graph 1. **Relation between exchange rate and inflation**
(monthly growth rates, in %)



The influence of the exchange rate on prices doesn't end here. Considering that the change in the exchange rate, i.e. import prices, is normally followed by smaller changes in domestic prices in the short run, the resultant change in real marginal costs of net importers puts pressure on prices on the medium run.

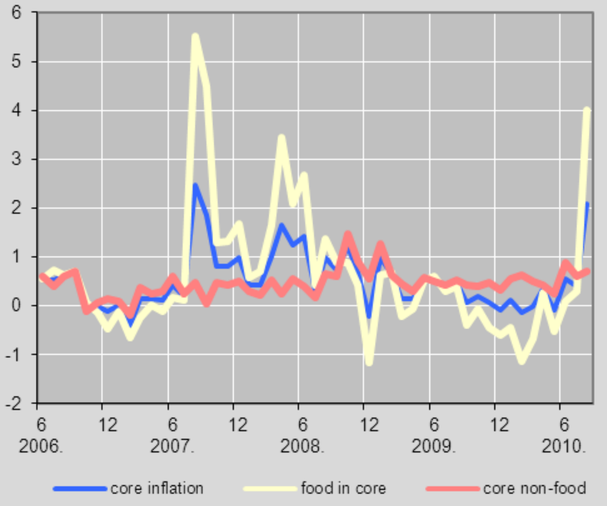
The ratio of domestic to foreign prices expressed in the same currency is a definition of the real exchange rate, and its deviation from equilibrium is used as a measure of inflationary pressures stemming from net importers real marginal costs. For instance, during 2007 and 2008, nominal appreciation of the dinar was not followed by the fall in prices, but, on the contrary, by their increase, which resulted in net importers' real marginal costs being very low (i.e. appreciation gap opened). This meant that there was room for the increase in real marginal costs through lower growth in domestic prices relative to import prices (exchange rate + foreign inflation), which actually ensued with the escalation of world economic crisis in late 2008, when the increase in domestic prices was much lower than the depreciation rate.

The important assumption of the model is that a central bank cannot influence the real exchange rate trend (nor trends in other real variables) but only its fluctuations around the trend. The trend itself is determined by the fundamental economic factors, above all by the fact that Serbian economy is in transition and has high capital inflow (save during the crisis), and a higher productivity growth than the developed economies. As a consequence, there is a price-convergence trend towards developed economies – Eurozone in our case – i.e. appreciation trend of the real exchange rate (Balassa-Samuelson effect), which was indeed the case in 2001-2008 period. A consequence of the assumption of the exogeneity of the real exchange rate trend is that in the long run any change in the nominal exchange rate is fully transmitted to prices.

In Serbia, as well as in the other economies, demand is an important factor of price formation. In the periods of high demand, producers and retailers are in a position to increase their margins, while in the periods of low demand they have to lower their margins. In our analysis we use output gap i.e. deviation of economic activity from its equilibrium level as a measure of demand side pressures. Like with other real variables, monetary policy cannot influence the trend of the economic activity, but only its deviation from the trend.

Inflation expectations, even when not based on realistic grounds, can have a significant impact on movements in prices. Firms base their prices (today) on, among others, expected price growth in the period ahead; trade unions base their wage demands on expected inflation; households tend to increase purchases if they expect high inflation in the future; while commercial banks take into account future inflation when setting interest rates. Therefore, high inflation expectations can cause inflation to rise even when there are no realistic reasons for that to happen. In countries with long history of high inflation, such as Serbia, inflation expectations largely mirror movement in inflation itself.

Graph 2. **Food prices significantly effects core inflation movements**
(monthly growth rates, in %)



Since the weight of food in core and headline inflation is very high (38%), and food prices are much more volatile than those of non-food products, it is obvious that food prices have a significant impact on inflation. Processed food prices are a component of core inflation, while agriculture product prices (fruit and vegetables) are excluded. Movement of processed food prices depends to a large extent on the prices of primary agriculture products (wheat, corn, sunflower…), which are the main inputs into production of processed food products.

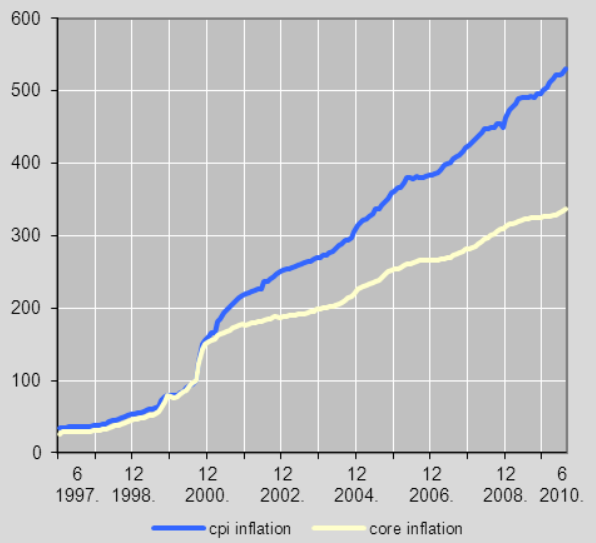
The second component of the CPI is non-core inflation excluding oil derivatives. Monetary policy only has a small impact on this group of prices. It is comprised of regulated prices (excluding oil derivatives) and agriculture product prices.

Regulated prices include prices that are directly or indirectly determined by the general government. Prices of electricity and postal and telecommunication services are directly determined by the central government, while the majority of prices of utilities and public transport are determined by municipalities, with the central government sometimes setting limitations. Prices of cigarettes, though not under government control, largely depend on its excise tax policy, and are hence classified as regulated prices.

The prices of agricultural products that are included in the CPI (fruit and vegetables), though formed freely in the market, are included in the group of non-core prices, since their movement is largely determined by the weather conditions. Hence, impact of monetary policy on these prices is very small.

On the other hand, monetary policy can have a more significant impact on prices of oil derivatives (third component of the CPI in our model). These prices depend to a large extent on world oil prices (expressed in dinars) and the level of the excise tax. Excise tax, according to the current regulation, is adjusted once a year (at the beginning of the year) by the retail price growth in a previous year. World oil price expressed in dinars depends on the world oil price expressed in the USD and on the exchange rate of the RSD against the USD. Most of the monetary policy impact on prices of oil derivatives goes through exchange rate, and only to a lesser extent through excise tax (because it is indexed to inflation). Still, most fluctuations in prices of oil derivatives result from fluctuations in world oil prices, which are highly volatile.

Graph 3. **Overal inflation growth faster then core inflation**
(9. 2000. = 100)



Important characteristic of price movements in Serbia is that the overall inflation throughout the 2000's was higher than the core inflation. This is a result of the policy implemented by the government prior to the political changes of October 2000, when, in a bid to preserve social peace, regulated prices were allowed to rise at a much slower pace than those freely formed in the market. As a result, regulated prices were unsustainably low in 2000 i.e. below the cost of production (for instance, electricity and other utilities, etc.). Because of that, since 2001 the government has been pursuing a policy of faster growth in regulated prices, which systematically rise faster than other prices included in core inflation, resulting in overall inflation being higher than the core inflation.

2.2 The influence of monetary policy on prices

In pursuing inflation targeting regime, the NBS uses several instruments of monetary policy, the main being the key policy rate, i.e. the interest rate on two-week repo bills. Simply put, through that instrument the NBS borrows Dinars from the commercial banks for two weeks offering to pay a certain (key policy) interest rate. A reverse mechanism can also be exercised, so that the central bank lends Dinars to banks against the collateral of prime securities. But, because of the structural liquidity surplus in the banking sector, this is still not done in Serbia.

The NBS can also use other instruments of monetary policy, such as foreign exchange interventions, reserve requirements and prudential measures. These instruments are used only exceptionally, so that the key policy rate is singled out as the only monetary policy instrument in the medium-term projection model.

By changing its key policy rate a central bank encourages or discourages commercial banks to invest part of their liquidity into repo bills. If, for instance, central bank raises its policy rate, investing into repo bills becomes more attractive and banks are encouraged to redirect part of their other assets into repos. This can be done by converting part of their FX assets into Dinars and/or by reducing their other Dinar assets, such as credits to firms and households.

In literature (Mishkin F., 1996) various transmition channels from policy rate to inflation are listed, of which most important are: exchange rate channel (nominal and real), interest rate channel, credit channel, inflation expectations channel and asset channel. There are two main channels in our model: exchange rate and interest rate channels.

Change in the policy rate makes the Dinar more or less attractive relative to other currencies, which has an effect on the exchange rate. For instance, an increase in the policy rate raises returns on the Dinar for the commercial banks, which encourages them to convert a certain amount of their foreign currency holdings into Dinars, which then leads to the appreciation of the domestic currency.

In reality, the impact of numerous other factors is intertwined with the impact of the policy rate on the exchange rate. This is particularly true of the risk premium, which can fluctuate significantly because of, say, political events or some external factors. For instance, because of the world financial crisis, capital outflow and the increase in risk premium in late 2008 and early 2009, the Dinar depreciated against the Euro by around 20% despite the key policy rate being relatively high during this period.

Since a change in the exchange rate also affects the real exchange rate, i.e. net importers’ real marginal costs, monetary policy can also affect prices through this channel.

Besides this direct effect (through net importers’ real marginal costs), real exchange rate also has an effect on the demand for the domestic goods, which is also a factor of inflation. When the real exchange rate is over-appreciated (domestic goods are expensive relative to foreign goods), demand for domestic goods will fall, and vice versa.

Central bank can influence the demand through the interest rate channel as well. Increasing the key policy rate should encourage banks to increase their lending rates, because the returns on alternative (repo transactions) increases. This should result in lower demand for loans from firms and households, and a fall in their consumption. The opposite is true when the key policy rate is lowered. Hence, the importance of the interest rate channel depends on the transmition from the policy rate to lending rates of commercial banks, as well as on the elasticity of the demand for credits to changes in interest rates.

In the Serbian case, it is important to note that a large share of loans is Euro indexed (around 70% of loans to firms and 80-85% of loans to households in 2009). Interest rates on these loans depend on the deposit rates charged by commercial banks on foreign currency savings and borrowing from abroad, on which monetary policy can have only a small impact.

To conclude, the real exchange rate channel affects intratemporal, while interest rate channel affects intertemporal distribution of demand. Simply put, based on the real exchange rate movements, i.e. domestic relative to import prices, consumers decide whether to “consume” domestic or foreign goods during a certain period, while on the basis of the level of real interest rates they decide whether to consume “now” or “later”. In transition economy, real exchange rate channel is typically stronger then the interest rate channel.

Also, for countries in transition in the early stages of inflation targeting, it is common that the real channel as a whole (demand and real exchange rate) is weaker than the nominal one (exchange rate). Still, we can expect that the real channel will strengthen, in the period ahead, if the NBS proves successful in achieving inflation target.

3. Structure of the model

The model for medium-term projection is based on the transmission mechanism of the monetary policy, i.e. the channel through which monetary authorities affect inflation by changing the key policy rate (2w repo rate). We have tried to include in our model all relevant inflation factors and, at the same time, to keep it relatively simple.

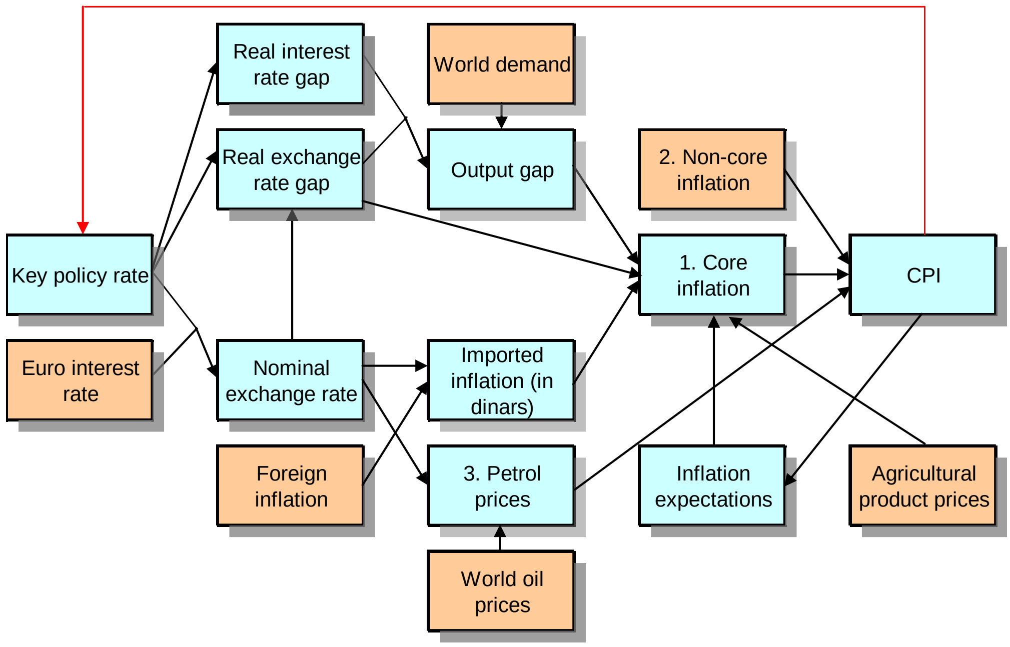
In line with the rationale outlined in the previous section, in our model, inflation is decomposed into three components of CPI:

1. Core inflation (66.5%)

2. Non-core inflation excluding oil derivatives (29%), which includes regulated prices (excluding oil derivatives) and agricultural product prices,

3. Oil derivatives inflation (4.5%).

Scheme 1. Structure of the quarterly projection model



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

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

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

The model contains four basic equations:

- inflation equation (Phillips curve),

- aggregate demand (output gap),

- exchange rate equation (uncovered interest rate parity), and

- repo interest rate equation (monetary policy rule).

Besides, the model 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.

3.1 Inflation

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

$$\pi_t = a_{11} \cdot \pi_t^{core} + a_{12} \cdot \pi_t^{non\_core} + (1 - a_{11} - a_{12}) \cdot \pi_t^{petr} \tag{3.1}$$

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

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

$$\begin{aligned}\pi_t^{core} = a_{21} \cdot \pi_{t-1}^{core} + a_{22} \cdot \left(E_t\pi_{4,t+4} - \overline{kor}\right) + (1 - a_{21} - a_{22}) \cdot (\pi_t^M - \Delta\overline{lz}_t - \overline{kor}) \\ + a_{23} \cdot zgap_{t-1} + a_{24} \cdot ygap_{t-1} + a_{25} \cdot RMCPgap_t + \varepsilon_t^{\pi core}\end{aligned} \tag{3.2}$$

Core inflation lag (π_{t-1}^{core}) reflects the existence of some degree of inflation inertia. Namely, it takes a certain time period for changes in inflation factors to have an effect on inflation. If the inflation rate in the previous quarter was, for example, 2% it is unlikely that it will be negative in the next period, even in the event of, say, strong appreciation of the RSD.

Inflation expectations ($E_t\pi_{4,t+4}$), are expectations (E_t) of the financial sector in terms of price growth over the next year, i.e. y-o-y inflation four quarters ahead ($\pi_{4,t+4}$). Due to the fact that inflation expectations are largely formed on the basis of past inflation, different inflationary shocks (e.g. increased prices of agricultural products or oil) have not just a direct impact on inflation, but also an indirect impact, through the increase in inflation expectations.

Inflation expectations in the model are a function of current y-o-y inflation ($\pi_{4,t}$), and rational expectations (π_{t+1}). A dependent variable with a lag is also introduced in this equation $E_{t-1}\pi_{4,t+3}$ to reflect inertia in inflation expectation.

$$E_t\pi_{4,t+4} = a_{31} \cdot E_{t-1}\pi_{4,t+3} + (1 - a_{31}) \cdot [a_{32} \cdot \pi_{t+1} + (1 - a_{32}) \cdot \pi_{4,t}] + \varepsilon_t^{E0\pi} \qquad (3.3)$$

Note that equation (3.3) describes headline inflation expectations. However, in the core inflation equation, it is necessary to have expectations expressed in terms of core inflation. In Section 2 we mentioned that the headline inflation in Serbia systematically exceeds core inflation. Therefore a corrective variable $(\overline{kor})$, introduced in the equation (3.2), represents the trend difference between headline and core inflation, so that the term in the brackets $(E_t\pi_{4,t+4} - \overline{kor})$ reflects the expectations in terms of core inflation.

Imported inflation (π_t^M) is a change in import prices denominated in RSD. Imported inflation depends on the movement of import prices denominated in foreign currency (π_t^{ef}) and exchange rate movements (Δls_t^{ef}). The weighted average of inflation in the Euro zone and in 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.

$$\pi_t^M = a_{41} \cdot \pi_{t-1}^M + (1 - a_{41}) \cdot \left(\pi_t^{ef} + \Delta ls_t^{ef}\right) + \varepsilon_t^{\pi M} \qquad (3.4)$$

Note that equation (3.4) contains imported inflation with a lag (π_{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 there is a considerable fall in imported inflation in the same quarter, considering that importers will, for some time, continue to sell the products which are 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 (3.2), the element of the imported inflation is adjusted with *a change in real exchange rate trend*. The difference in real exchange rate (Δlz_t) is the difference between Euro zone inflation (π_t^{EU}) and domestic inflation (π_t) expressed in the same currency:

$$\Delta lz_t = \Delta ls_t + \pi_t^{EU} - \pi_t \qquad (3.5)$$

As the consequence of Balassa-Samuelson effect in Serbia (as mentioned in the previous Section), there is a presence of trend of price convergence to the Euro zone countries, i.e. appreciation trend of the real exchange rate of the RSD against the EUR $(\Delta lz_t < 0)$.[2]

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, so 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 $(\pi_t^M - \Delta\overline{lz}_t -$

[2]Nominal and real exchange rates are defined in a way that their increase means depreciation and their decrease means appreciation.

$\overline{kor}$) 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 a deviation of the real exchange rate from its equilibrium level ($\overline{lz}_t$):

$$zgap_t = lz_t - \overline{lz}_t \tag{3.6}$$

This is viewed as an approximation of net importers' real marginal cost. Real exchange rate gap is a measure of excess depreciation or appreciation relative to its trend. If, for example, we have appreciation gap, this means that the marginal cost of net importers is relatively low compare to what would be expected based on long term trend of real exchange rate.

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

$$ygap_t = ly_t - \overline{ly}_t \tag{3.7}$$

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, such as the movement of wages and credit activities, or the monetary policy stance. Positive output gap means that inflationary pressures are coming from the 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 prices of agricultural products (lP_t^{agr}) and prices of processed food (lP_t^{food}):

$$RMCP_t = lP_t^{agr} - lP_t^{food} \tag{3.8}$$

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

As a measure of prices of agricultural products we use a composite index of these products, which are the most important inputs in the production of food (such as wheat, corn, soybean, sunflower, fruits and vegetables).

High values of the gap in *RMCP* suggest that the costs of producing food are relatively high, which generates cost-push inflationary pressures, and vice versa.

Oil-derivatives inflation (π_t^{petr}), next to core and non-core inflation excluding oil derivatives, is the third component of overall inflation (equation 3.1).

Oil price derivatives are formed on the basis of movements in world oil prices denominated in USD (π_t^{oil}) and exchange rate movement of the RSD against the USD (Δls_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:

$$\pi_t^{petr} = a_{51} \cdot \left(\Delta ls_t^{usd} + \pi_t^{oil}\right) + (1 - a_{51}) \cdot exc_t \tag{3.9}$$

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.

3.2 Output gap – measure of demand

Demand, as a factor of inflation, in the macroeconomic models is usually estimated with output gap (ygapt). 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 on 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 pushing the economy 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).

Similar to the production, the trend of real interest rate and trend of 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, 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 ($rrgap_t$).

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

$$ygap_t = a_{61} \cdot ygap_{t-1} - a_{62} \cdot [a_{63} \cdot (-zgap_t) + (1 - a_{63}) \cdot rrgap_t] + \\ + a_{64} \cdot ygap_{t-1}^{EU} + \varepsilon_t^{ygap} \tag{3.10}$$

The real exchange rate gap has already been discussed in chapter 3.1. _Real interest rate gap_ ($rrgap_t$) is the deviation of real interest rate from its equilibrium level:

$$rrgap_t = rr_t - \overline{rr}_t \tag{3.11}$$

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

$$rr_t = i_t - E_t \pi_{4,t+4} \tag{3.12}$$

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

$$ygap_t^{EU} = ly_t^{EU} - \overline{ly}_t^{EU} \quad (3.13)$$

3.3 Exchange rate

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

$$ls_t = E_t ls_{t+1} + (-i_t + i_t^{eu} + prem_t)/4 + \varepsilon_t^{ls} \quad (3.14)$$

By increasing the repo interest rate (i_t), the central bank increases the yield on RSD, which makes the domestic currency more attractive and therefore more demanding on the FX Market, which results in its appreciation. Equation (3.14) shows that the higher interest rate on RSD (i_t) compared to Euro Zone interest rate (i_t^{eu}), the higher is expected depreciation ($E_t ls_{t+1} - ls_t$) meaning lower current exchange rate (ls_t), i.e. domestic currency appreciation.

The exchange rate is, however, formed not only on the basis of differences between the two interest rates. In the financial and the 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 the dominant influence on the movement of exchange rate. For instance, in late 2008 significant depreciation of the RSD was the result of the rising risk premium, caused by the global economic crisis. The unpredictability of this factor makes the projections of the exchange rate the least reliable.

Expected exchange rate ($\mathrm{E_t ls_{t+1}}$) is formed based on rational expectations, i.e. model based projection for one period ahead ($\mathrm{ls_{t+1}}$), and purchasing power parity of the RSD against the EUR adjusted for the change in the real exchange rate trend ($\pi_t - \pi_t^{EU} + \Delta\overline{lz}_t$). Purchasing power parity of the RSD tells us by how much the nominal exchange rate must depreciate in a country with higher inflation so that the real exchange rate appreciates in line with this trend.

$$E_t ls_{t+1} = a_{71} \cdot ls_{t+1} + (1 - a_{71}) \cdot [ls_{t-1} + 2/4 \cdot (\pi_t - \pi_t^{EU} + \Delta\overline{lz}_t)] \quad (3.15)$$

3.4 Monetary policy rule

Monetary policy rule defines the way the central bank decides about the level of the repo interest rate (i_t):

$$i_t = a_{81} \cdot i_{t-1} + (1 - a_{81}) \cdot \left[i_t^n + a_{82} \cdot \left(\pi_{4,t+4} - \pi_{t+4}^{tar}\right)\right] + \varepsilon_t^i \quad (3.16)$$

A key element in making decisions on the repo interest rate, which sets monetary policy rule, is deviation of projected inflation from the target inflation ($\pi_{4,t+4} - \pi_{t+4}^{tar}$). When the projected inflation (four quarters ahead) is above the target inflation, monetary policy should be restrictive, i.e. repo interest rate should be above the 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 (3.16) 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 which have 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 ($E_t\pi_{4,t+4}$):

$$i_t^n = \overline{rr}_t + E_t\pi_{4,t+4} \tag{3.17}$$

Repo interest rate should be at a neutral level if it is estimated that inflation in the monetary policy horizon would be on a 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 Euro zone, by the real uncovered interest rate parity equation:

$$\overline{rr}_t = \Delta\overline{lz}_t + prem_t + \overline{rr}_t^{EU} \tag{3.18}$$

This equation is the real counterpart of the nominal uncovered interest parity equation (3.14). Equation (3.18) shows that the higher risk premium and the higher level of depreciation of the real exchange rate trend, financial markets will require higher real return on domestic currency. This would have direct implications for the height of the repo interest rate, since the central bank in this case would have to offer higher yields.

Note that our monetary policy rule does not include the output gap, which is typically a component of the Taylor rule. The reason for leaving out the output gap is in the fact that inflation targets for the first few years of implementation of this regime were set at a very high level (8 ± 2% for 2009 and 6 ± 2% for 2010) in order to avoid restrictive monetary policy[3], in the midst of the global economic crisis, which could further worsen the economic situation. Thus, the economic activity was taken into account in setting objectives. Inclusion of the output gap, which in 2009 and 2010 was extremely negative, in the monetary policy rule could lead to overshooting of the targets which are already set high. Also, a question arises as to the reliability of the assessment of the output gap in transition countries like Serbia. When the target is stabilized at a lower level it is possible that we will include the output gap in the monetary policy rule.

[3] Setting the targets at the lower level would require more restrictive monetary policy.

4. 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 parameters are based on history. Parameters are estimated econometrically, using the criteria such as coefficient of determination, to explain the history as good as possible. The calibrated model parameters are not estimated, but their values are assigned based on specific criteria.

There are several common reasons why econometric estimation of models for medium-term projection is not reliable. First, sometimes econometric estimation does not provide possibility to separate the cause and the effect. This is especially true when it comes to monetary policy rule and 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 the target all the time. In this case if we estimate the econometric equation of repo interest rate (3.16), we would not be able to explain its changes with the monetary policy rule, given the fact that inflation is always on the target and therefore there would be no need for the reaction of monetary policy[4].

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 pressures and that the central bank reacts immediately by raising the policy rate. A simple econometric analysis would, in this case, contrary to economic theory, show that the increase in policy rate leads to depreciation pressures. 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 lack of long and stable time series. Serbian economic time series in most cases are short and have structural breaks, and as such they are most often unsuitable for reliable econometric estimates (it is often impossible to get estimations that satisfy both statistical criteria and economic theory). Besides, frequent structural changes in economic, and particularly monetary policy (political changes in 2000, stable exchange rate policy, inflation targeting) leads to change in 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 it’s possible. The model parameters are calibrated in a way the model’s properties (relationships between variables) are consistent with economic theory and to reflect some well-known features of the

[4]Example is shown in The Czech National Bank forecasting and policy analysis system (2003).

Serbian economy. It is desirable, at the same time, for the model to explain macroeconomic movements in the recent past, as good as possible. In addition, the experience of other countries, especially countries in transition, can be the great benefit for 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 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 which better explains recent developments. A logical assumption is that parameters from the recent past are more relevant for the period ahead.

During the calibration process we used some different approaches, depending on the extent to which parameters can be determined based on history data. For example, we used econometric estimation and properties of the model for the purpose of the calibration of the core inflation equation and output gap equation. 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.

In any case, the relationship between variables in the model must be consistent with economic theory and should reflect recent past as best they can.

Core inflation

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

In the case of some variables in the equation, econometric estimations of parameters were not statistically significant. That was, for example, the case with the output gap. However, based on a simulation on the history it is estimated that this variable significantly improves explanatory power of core inflation in recent years (since 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 which should reflect some familiar features of the Serbian economy. One of them is relatively highly significant short-term pass-through effect from exchange rate (i.e. imported inflation) to inflation. Our estimate, as well as some others estimates, ranges between 0.2 and 0.3. Model parameters are calibrated so that short-term pass through effect from exchange rate to inflation (over imported inflation) is around 0.2. Calibrated equation of core inflation (3.2) is:

$$\pi_t^{core} = 0.4 \cdot \pi_{t-1}^{core} + 0.4 \cdot \left(E_t \pi_{4,t+4} - \overline{kor}\right) + 0.2 \cdot \left(\pi_t^M - \Delta \bar{lz}_t - \overline{kor}\right) + \\ +0.3 \cdot zgap_{t-1} + 0.3 \cdot ygap_{t-1} + 0.2 \cdot RMCPgap_t + \varepsilon_t^{\pi core} \quad (4.1)$$

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

Exchange rate

Uncovered interest rate parity equation (3.14), which describes the movement of the exchange rate, is purely theoretical. Econometric evaluation of exchange rate movements is almost impossible task even in far more developed economies, which in our case was tougher because of the fact that only since 2006 the movement of the exchange rate has been mostly free.

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 that reason we went for pure theoretical approach. This equation does not contain parameters that need to be calibrated.

Policy rate

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

Coefficient a_{81} in equation (3.16) takes a value between 0 and 1. The high value of this coefficient indicates that monetary policymakers are not inclined to sudden changing of policy rate, thereby securing its stable motion. 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” (becoming expansive or restrictive) to deviation of inflation from the target.

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 slower returning of inflation to the target. In the opposite case, inflation will return to the target more quickly, but the policy rate movement would be less stable. Therefore, in determining these coefficients it is needed to find a proper balance between stability of monetary policy and speed of achieving the target. Having that in mind, 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. Calibrated equation of policy rate (3.1) looks like:

$$i_t = 0.5 \cdot i_{t-1} + 0.5 \cdot \left[i_t^n + 2 \cdot \left(\pi_{4,t+4} - \pi_{t+4}^{tar}\right)\right] + \varepsilon_t^i \qquad (4.2)$$

Movement of the repo interest rate is also determined by forward looking component of monetary policy. Similar to the analysis of the coefficient values, 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 (3.10) were estimated using the ordinary least squares method, and then calibrated to meet the values of coefficients in transition countries which are theoretically suggested.

Before the estimation of parameters it is necessary to estimate the gaps themselves first, since these variables are unobservable, i.e. are not measured directly. For this purpose we use a multivariate Kalman filter (Section 6), 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 the estimated gaps using the (one dimensional) Hodrick - Prescott filter.

Some of the estimated coefficients, however, were different from those that theory suggests. 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). 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:

$$ygap_t = 0.75 \cdot ygap_{t-1} - 0.2 \cdot [0.8 \cdot (-zgap_t) + 0.2 \cdot rrgap_t] +$$
$$+0.8 \cdot ygap_{t-1}^{EU} + \varepsilon_t^{ygap} \qquad (4.3)$$

Deviation from the theoretically suggested values is particularly pronounced in the case of the real exchange rate gap coefficient (a_{63} in equation 3.10). The estimated coefficient in our case (0.3) shows that within the monetary restrictiveness index real interest rate is more important than the real exchange rate. However, according to Laxton and Scott small open economies should have 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 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.

5. 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.

Considering the interconnectedness of the model variables, the answer cannot be given on the basis of the model coefficients only. 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. Namely, the exchange rate affects core inflation, which generates changes in the policy rate, which again has an effect on the exchange rate, and as a result, the exchange rate influences core inflation again.

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 to check whether the model behaves in accordance with economic theory and how well it reflects some 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 a result of significant price change of a single product in the CPI basket.

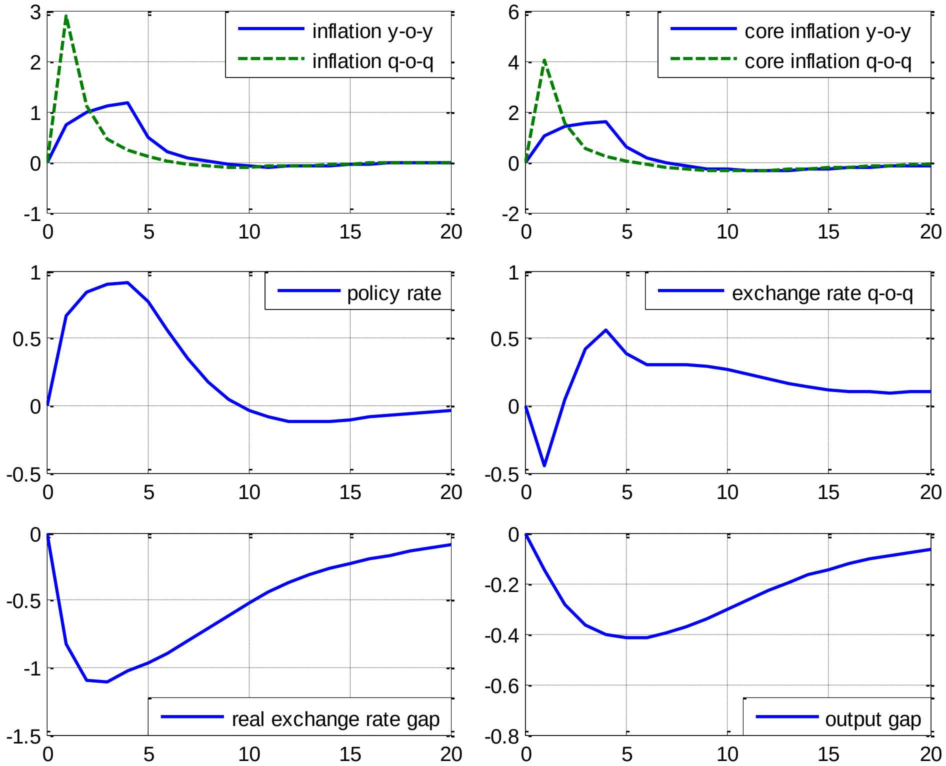
If we assume that there was a sudden rise in core inflation of 1% in one quarter, it directly leads to the growth of year-on-year inflation over the next four quarters. The central bank responds by raising repo interest rate, basing its decision on the year-on-year overall inflation four periods ahead, which means that the central bank does not respond directly to the shock, but only on 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, result in opening of appreciation real exchange rate gap.

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, starting with the second quarter, the nominal exchange rate depreciates, adjusting to the increased price level and narrowing the appreciation gap.

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, because of, among other things, the reaction of the central bank, i.e. increased restrictiveness in its monetary policy.

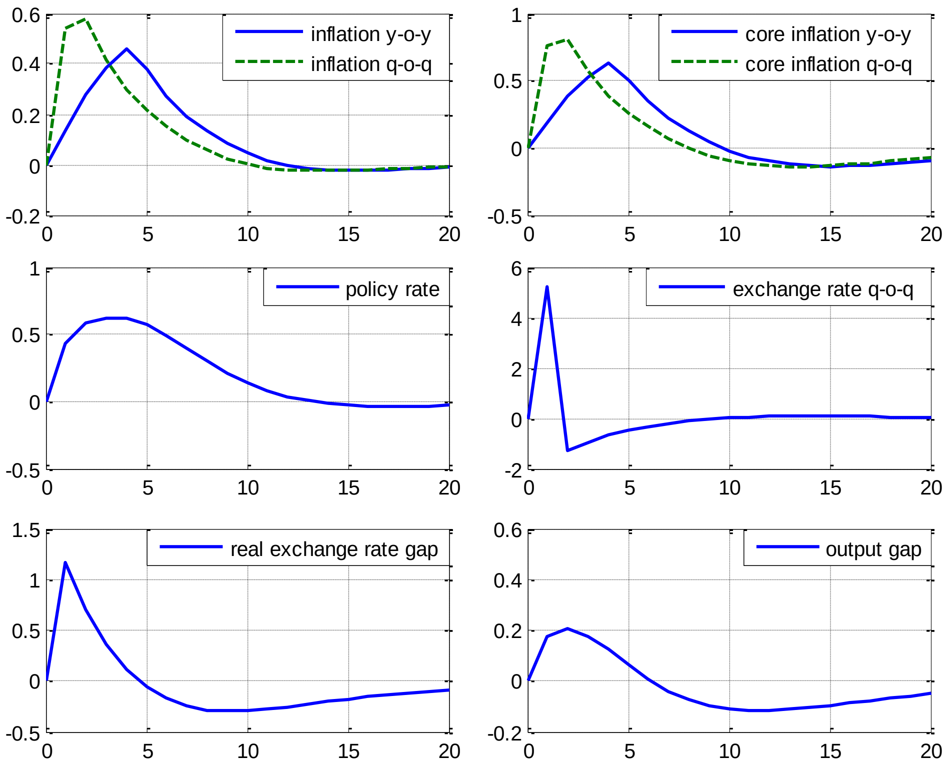
Graph 4. Impulse response function of shock in core inflation



Shock in the nominal exchange rate

Suppose that there has been an autonomous depreciation of exchange rate of 1% in one quarter, i.e. depreciation not caused by changing the interest rate spread or risk premium. Such depreciation could occur for examplelj because of some big companies' payment 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 5. Impulse response function of shock in exchange rate

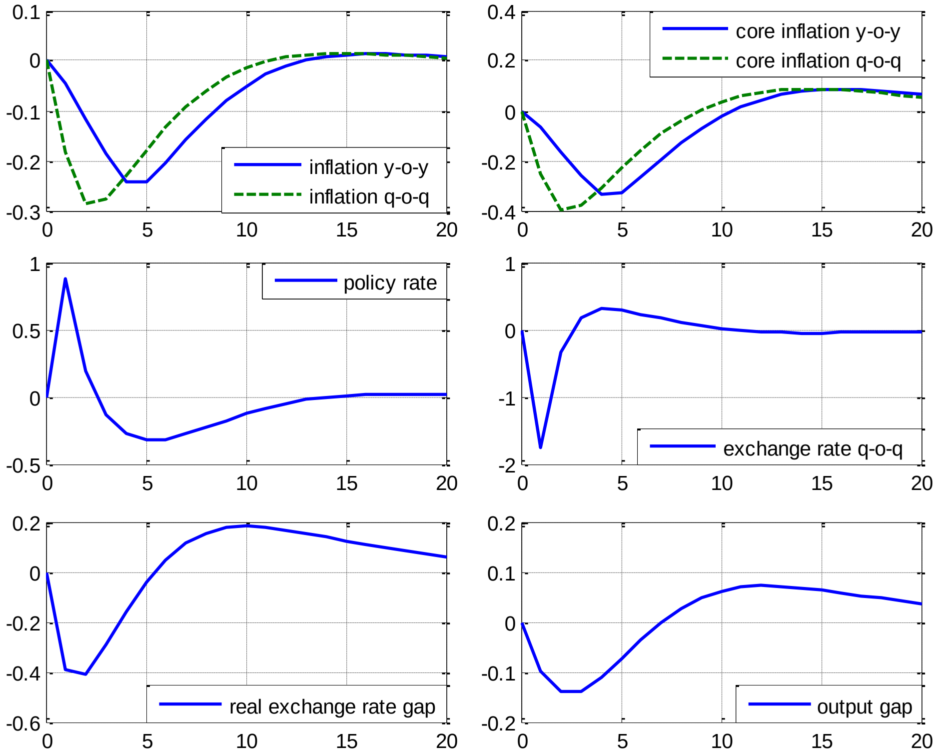


The effects of the shock gradually die out, which is supported by the increase in the policy rate. These lead to a moderate appreciation of the nominal exchange rate, gradually closing of depreciation gap of the real exchange rate, lowering inflationary pressures and thus core inflation back to the initial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

Shock in the policy rate

Policy rate increase results in nominal appreciation, which leads to fall in core inflation by reducing the import prices. Because of greater nominal appreciation compared to the price fall, real exchange rate appreciation gap opens. Tighter monetary policy (increase in repo interest rate above the neutral level and opening of appreciation gap) results in the opening of the negative output gap. In the period ahead, the nominal appreciation, through the fall of the 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 6. Impulse response function of shock in policy rate



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

6. Estimation of trends and gaps – Kalman filter

Estimation of unobserved components (trends and gaps of real variables) is an important initial phase in the medium-term projection process, which provides an answer as to where does economy stand now.

As we saw in Section 3, the factors which directly influence core inflation are the output gap (as a measure of "surplus/deficit" of demand) and the real exchange rate gap (as an approximation of net-importers' real marginal costs). In addition, the real interest rate gap has an indirect influence on core inflation through the output gap. The model includes few more trends and gaps which influence the outcome of medium-term projections.

Unlike other variables (inflation, exchange rate etc.), gaps and trends cannot be measured directly and are often referred to in economic literature as unobserved components. These variables are estimated over the history spanned by the model, where estimated values for the last quarter in the history are taken as initial values in the medium term projection.

In order to decompose the observed variables into unobserved components we use univariate or multivariate filters. While the observed series are decomposed into a trend and a gap by the univariate filters only on the basis of information about the series itself, multivariate filters take into account information from other series. We use multivariate Kalman filter to estimate the key unobserved components, while for the estimation of some less important components (e.g. output gap in Euro zone) we use univariate Hodrick Prescott (HP) filter. In the case of RMCP, we use a simple mid-term average as a trend.

A model for estimation of unobserved components is based on the methodology of Kalman filter (Hamilton, JD, 1994) and consists of a system of equations which decompose the observed variables (economic activity, real exchange rate, real interest rate) into trends and gaps. This system of equations can be divided into three groups: behavioural equations, identities and autoregressive equations of trends.

The first group of equations consists of three behavioural equations - core inflation, output gap and real uncovered interest parity –which connect different unobserved components, among themselves and with some observed variables. These equations are identical to equations (3.10), (3.2) and (3.18), explained in the third part:

$$ygap_t = a_{61} \cdot ygap_{t-1} - a_{62} \cdot [a_{63} \cdot (-zgap_t) + (1 - a_{63}) \cdot rrgap_t] + \\ + a_{64} \cdot ygap_{t-1}^{EU} + \varepsilon_t^{ygap} \tag{6.1}$$

$$\pi_t^{core} = a_{21} \cdot \pi_{t-1}^{core} + a_{22} \cdot \left(E_t \pi_{4,t+4} - kor^{eq}\right) + (1 - a_{21} - a_{22}) \cdot \left(\pi_t^M - \Delta lz_t^{eq} - kor^{eq}\right) + \\ + a_{23} \cdot zgap_{t-1} + a_{24} \cdot ygap_{t-1} + a_{25} \cdot RMCPgap_t + \varepsilon_t^{\pi core} \tag{6.2}$$

$$rr_t^{eq} = \Delta lz_t^{eq} + prem_t + rr_t^{EU\_eq} \tag{6.3}$$

The model also includes simple identities which decompose observed variables (real interest rate, real exchange rate and economic activity) into trends and gaps:

$$rr_t = rr_t^{eq} + rrgap_t \tag{6.4}$$

$$lz_t = lz_t^{eq} + lzgap_t \tag{6.5}$$

$$ly_t = ly_t^{eq} + lygap_t \tag{6.6}$$

In addition, autoregressive equations (6.7), (6.8) and (6.9) describe the dynamics of the real interest rate trend, the real exchange rate trend and real GDP trend:

$$rr_t^{eq} = a_{31} \cdot rr_{t-1}^{eq} + (1 - a_{31}) \cdot ss\_rr_t^{eq} + \varepsilon_t^{rr\_eq} \qquad (6.7)$$

$$\Delta lz_t^{eq} = a_{41} \cdot \Delta lz_{t-1}^{eq} + (1 - a_{41}) \cdot ss\_\Delta lz_t^{eq} + \varepsilon_t^{lz\_eq} \qquad (6.8)$$

$$\Delta ly_t^{eq} = a_{51} \cdot \Delta ly_{t-1}^{eq} + (1 - a_{51}) \cdot ss\_\Delta ly_t^{eq} + \varepsilon_t^{ly\_eq} \qquad (6.9)$$

Parameters $ss\_rr_t^{eq}$, $ss\_\Delta lz_t^{eq}$ and $ss\_\Delta ly_t^{eq}$ are steady states to which the real interest rate trend (rr_t^{eq}), change in the real exchange rate trend (Δlz_t^{eq}) and the change in the GDP potential (Δly_t^{eq}) converge in the long run.

Estimates of trends and gaps are consistent between one another and with the inflation movements. As the output gap and the real exchange rate gap are factors in the equation of core inflation (6.2), it is clear that in periods of high inflation (unexplained by other factors), the estimation of these two unobserved components will be higher[5], ceteris paribus. In addition, the output gap and the assessment of monetary policy stance (the real exchange rate gap and the real interest rate gap) are mutually dependent (6.1), so during the periods of high real appreciation and high real interest rate, the estimation of the output gap tend to be lower, ceteris paribus. Besides, the trends must converge to the steady states (6.7 - 6.9) in the long run, which also affects the assessment of gaps.

The real exchange rate gap and real interest rate gap, besides being associated with the output gap, must satisfy the equation of the real uncovered interest parity (6.3), which connects the two components with the risk premium and with the trend of Eurozone real interest rate. The equation of the real uncovered interest parity says that the higher risk premium and the more depreciated real exchange rate trend, the higher will be the real interest rate trend.

As in the case of the model for medium-term projections, the model for estimating the unobserved components is also calibrated. This is true both for the parameters of the model (including the equilibrium values (steady states) of the trends) and for the variances of shocks in the equations.

Calibration of the three behavioural equations (core inflation, output gap and real uncovered interest parity) is the same as in the medium-term projections model.

Equilibrium values of trends are based on the experiences of other countries in transition and our expectations regarding the future development of the transition process in Serbia. Thus, in the medium term in Serbia[6] we expect relatively high growth rate of economic activity (as they were in Eastern European countries in transition during the 90's). In the model we assumed that $ss\_\Delta ly_t^{eq}$ takes value of 5. This high economic growth should have (with productivity growth faster than in the euro zone) as a consequence price convergence to the euro zone, i.e. appreciation trend of the real exchange rate $-ss\_\Delta lz_t^{eq}$ takes the value of 3. The above

[5]The real exchange rate is defined in a way that positive gap means depreciation gap.

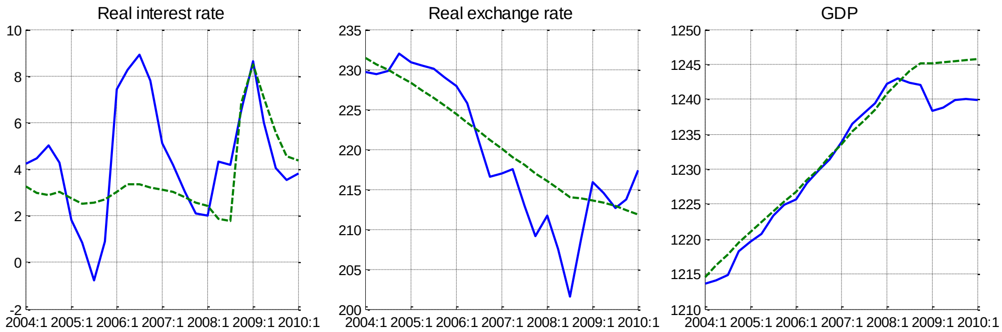
[6]The global economic crisis temporarily affect slowed down the growth, but with the easing of recession the growth rates should be again relatively high.

assumptions, together with expected fall in risk premium should lead to a fall in the real interest rate trend in the future.

Relative variances of the shocks in the model equations significantly affect the final estimation of unobserved components. If, for example, the variance of the shock in the equation of the real exchange rate trend is relatively small (compared to other variances) it will result in smaller fluctuations in the real exchange rate trend, but larger fluctuations in its gap. If the variance of the shock in the core inflation equation is relatively small, the model will tend to use unobserved variables (output gap and the real exchange rate gap) as much as possible to explain a part of core inflation not explained by the observed variables. This will result in a greater variability in these two gaps. Increasing the shock variance in the core inflation equation, on the other hand, will allow the model to put more of the unexplained inflation to the shock, which would reduce the variations of the output gap and the real exchange rate gap around the trends.

The following graph shows the real interest rate, real exchange rate, non-agricultural value added[7] and their trends. We may conclude from the graph that the monetary policy implemented by the NBS in the earlier period was predominantly countercyclical. Namely, monetary policy of the central bank was restrictive (appreciation gap of the real exchange rate and positive real interest rate gap) during the period of high aggregate demand (a positive output gap) before the crisis, while becoming expansionary with the onset of the crisis.

Graph 7. Movement of real interest rate, real exchange rate and real non-agricultural value added in relation to their trends



Also, we see that the monetary policy in the first quarter of 2010 was expansive, i.e. the real exchange rate was depreciated relative to the trend, and the real interest rate was below the trend. Therefore, monetary policy operated in the direction of rising inflation in early 2010, while, by contrast, a negative output gap (non-agricultural value added below the trend) had a disinflationary impact. These

[7]Non-agricultural added value is obtained when we exclude agricultural production and taxes from the total GDP and adding subsidies.

estimates of the gaps were entered as initial values in the projection we completed in early May 2010.

7. 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 the target in the medium term (within the tolerance bands). To achieve this, it is necessary to anticipate the pressures on inflation in the projection period. The projected path of the repo interest rate is used by monetary policy makers as a starting point in making the decisions about its level.

The medium term projection process is much more than just a simple running of the model. In practice, it is not a model that creates a projection, it is the economists who are doing the work. We can even say that the defining assumption of the projection and, in general, economic deliberations not directly related to the model are dominant in determining the projection. In that sense, a model is used primarily for the purpose of systemising the assumptions and expectations about future within a unified and consistent framework.

Apart from running the model, the projection process includes number of activities, such as: short-term projection of inflation, defining the projection assumptions regarding the exogenous variables, 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 the inflation in the past. This analysis to a great extent influences the definition of initial conditions and the assumptions of the projection.

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

Model for medium-term projections does 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 movements in the future. Movement of trends is generally projected into the future based on the assumption that the trends in the medium term is moving (faster or slower) towards steady-state.

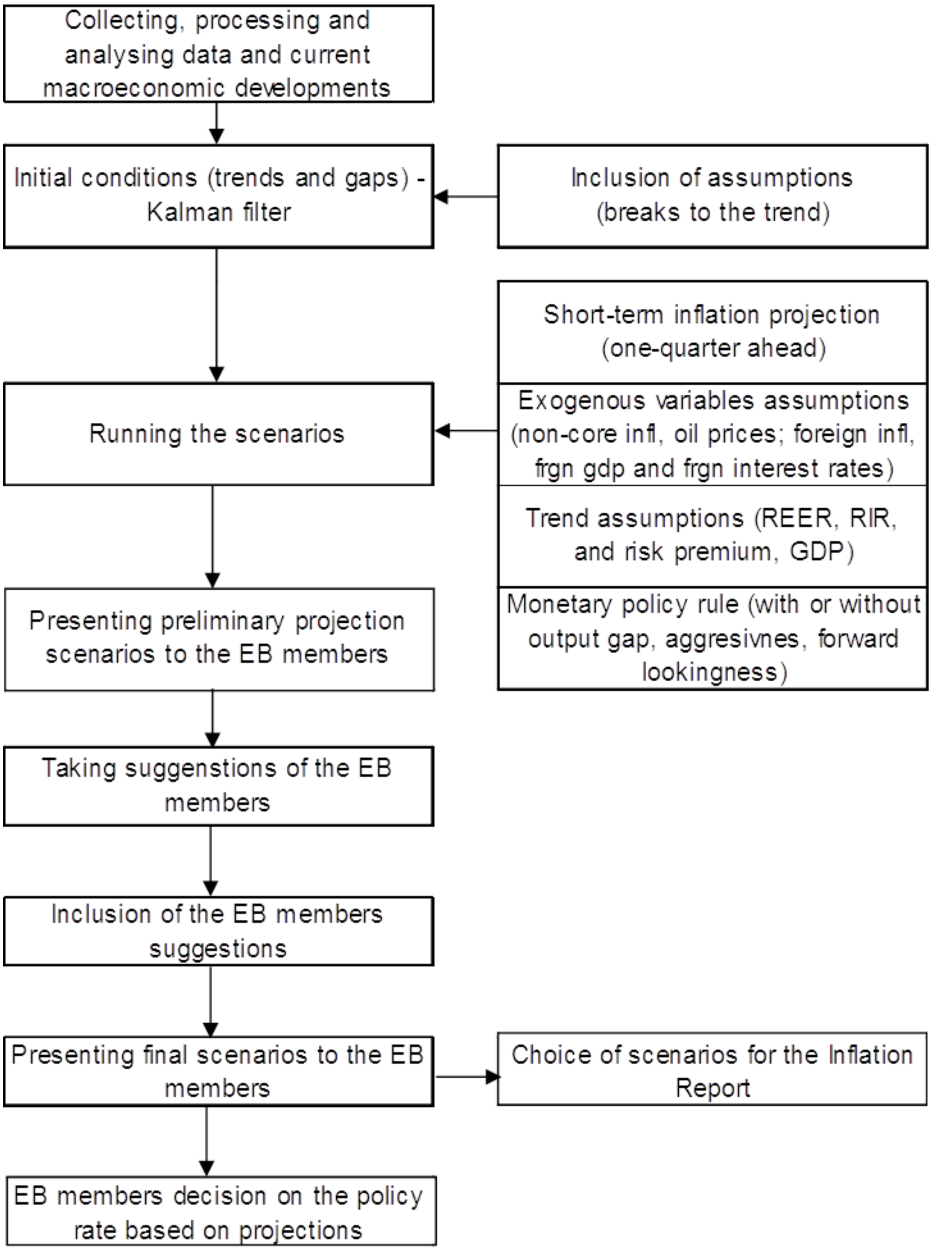
Assumptions and predictions regarding the movements of some exogenous variables are taken from external sources or made internally, because it is hard to describe their movement by equation or the forecasts of other institutions are considered more reliable. The assumed movements of exogenous variables - global oil prices, foreign inflation, the key ECB policy rate, the dollar vs euro exchange rate (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 fruits and vegetables) since it represents about a quarter of CPI and therefore it is direct input to the inflation projection. These projections are based on the Government plan about the corrections of regulated prices and the assumptions about the movement in agricultural prices (based on their current level and expected harvest).

For one quarter ahead, instead of model projection of inflation, we include short-term projections based on experts’ judgement. In the short term, experts' judgement 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 short-term influences 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 indirectly affects the 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 would be necessary to include a shock in the exchange rate (ε_t^{ls} in equation (3.14)). 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 (ε_t^{ygap} in equation (3.10)).

Scheme 3. Medium-term projection process



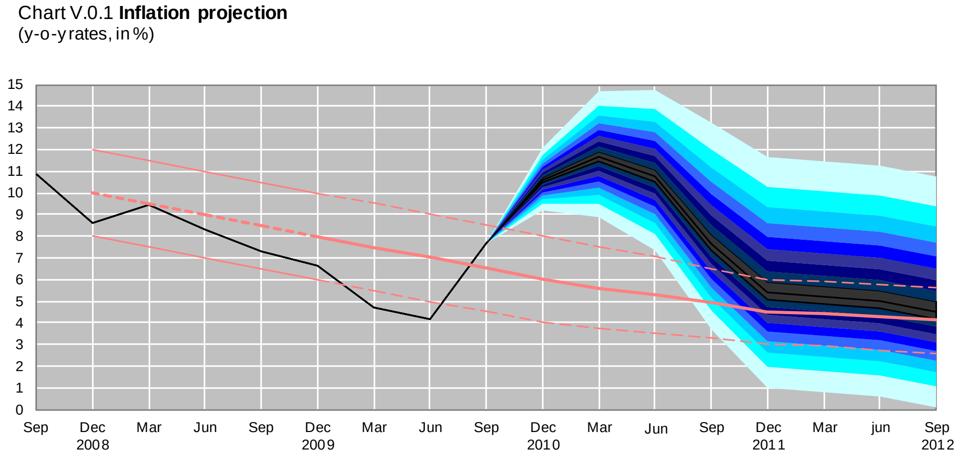
Based on the assumptions and short-term projections we generate scenarios of medium-term projections. The main scenario is based on assumptions that are considered the most probable. In addition, varying assumptions of projections in accordance with risk assessments, a number of alternative scenarios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

The whole process of medium-term projections includes intensive communication between the members of EB and the direct creators of the projections. The members of EB are not only the final "users" of medium-term projections, but their analysis and suggestions actually actively create them. The members of EB and the actual creators of projections define the projection assumptions in meetings; they analyse the risks and choose alternative scenarios. Finally, they adopt a fan chart of inflation projections that will be presented in the Inflation Report.

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

Deviations from the last projection are analysed in between the two medium-term projections. Deviations from projections result from the fact that projections are based on assumptions which may not be fullfiled. According to this analysis, we also consider whether and by how much the policy rate should deviate from the projected path of the last medium-term projections, as well as whether the macroeconomic trends are in line with some of the alternative scenarios. Members of EB make decisions about the policy rate on the basis of these considerations.

Graph 8. Inflation projection for Inflation Report – November 2010



8. 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 it can never be entirely accurate in describing and predicting macroeconomic trends. However, the model can provide useful information to monetary policy makers about the measures which should be taken in achieving the primary objective.

Model for medium-term projection is, the 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 an economists after all. The model, serves to systematize these thoughts into a unified macroeconomic framework.

In developing the model we took into account two conflicted 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 that out of model factors are not taken into account, but they are included through the shocks, in the case if it is assessed that their impact on the projection is significant.

By 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. Deviations from the projected path of the policy rate are, however, possible and depend on the assessment of the risk. Such deviations may also occur in case of significant deviations from the medium term projection in between the two projections.

After almost two years of using the model in medium-term projections, it is probably still early to judge its performance. During 2009, except in two months, inflation moved within the target tolerance band. In the first half of 2010 it was below the target tolerance band, but retreted within it in Q3 2010. Besides, for its major part the actual inflation moved within the projection band that we publish in our Inflation report. Of course, it is still early to draw conslusions on that basis and we certainly need a longer time prespective to judge how successful the model is in forecasting inflation and as a monetary policy supporting tool.

In the future we will carefully monitore realization of projections and correct identified shortcomings of the model. In this sense, the version of the model that we presented in this paper is not final and the model will regularly change either by changing coefficients or by changing its structure.

Appendix: Technical explanations

Model for medium-term projections is a log-linearized quarterly model. Series are seasonally adjusted (whenever it was needed), 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 indicies 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:

  $$\pi_t = 4 \cdot (lp_t - lp_{t-1}),$$

  and year on year growth rate is:

  $$\pi_{4,t} = lp_t - lp_{t-4},$$

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

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Abbreviations

NBS – National Bank of Serbia

ECB – European Central Bank

EB – Executive Board

CPI –Consumer Price Index

GDP – Gross Domestic Product

HP–Hodrick Prescottfilter

UIP–Uncovered interest parity

RMCP – Real marginal cost of processed-food production