NEUTRAL INTEREST RATE ESTIMATE FOR SERBIA

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Abstract: The aim of this paper is to estimate the neutral interest rate for Serbia using various methods and to compare the resulting estimates. The analysis was conducted for a period of the previous 17 years (2008–2024), and the following models were used for the estimation: the HLW model, two versions of quarterly small structural models that account for the effect of real exchange rate appreciation on the level of the neutral interest rate (the so-called Penn effect in economic literature), as well as a time-varying parameter vector autoregression model TVP-VAR. The results of the analysis show that including the equilibrium real exchange rate as an explanatory variable results in a lower estimate of the neutral interest rate compared to the HLW model. Furthermore, according to most of the estimated models, monetary policy remains restrictive.

According to all the estimated models, as has been the case for other countries, the neutral interest rate in Serbia exhibited a declining trend in the initial years following the 2008 global economic crisis until the beginning of 2014. Thereafter, the models that include the real exchange rate for neutral interest rate estimate, as well as the TVP-VAR model, indicate a relatively low neutral interest rate or even a continuation of its declining trajectory. An exception is the HLW model, which suggests that, as a result of growth in potential output, the neutral interest rate displayed an upward trend until the coronavirus pandemic. A common characteristic of all the estimated models is that the neutral rate has been on an upward trajectory over the last two years; however, for most models (with the exception of the HLW model, which estimates the neutral rate at a higher level) the estimate of the neutral (real) rate is below or around 1%..

Key words: neutral interest rate, monetary policy, inflation, output gap, real appreciation, QPM, HLW approach.
[JEL Code]: E47, E58, E37

Non-Technical Summary

In global professional literature, one of the most prominent topics is that of the neutral interest rate. Its importance stems from the fact that it serves to assess the monetary policy stance. When making monetary policy decisions and evaluating the monetary policy stance, it is not sufficient to know only the direction in which the policy rate will be changed. To achieve the desired effect within the monetary policy cycle, it is most often necessary to adjust the policy rate multiple times, which can take several months or even years, to ensure its level is adequate for achieving the intended effect on monetary conditions, and thereby on economic activity and inflation. It is therefore essential to determine the level of the neutral interest rate, which is most commonly defined as the interest rate consistent with stable inflation at target and full utilisation of productive capacities – i.e. the rate at which monetary policy is neither restrictive nor expansionary.

Prior to the outbreak of the coronavirus pandemic, both nominal and real policy rates of central banks were exceptionally low in both developed and emerging economies. In such circumstances, the question increasingly arose: was the decline driven by a fall in the neutral interest rate, or by persistent economic shocks? This, in turn, raised the question of the level of the neutral rate itself. Similarly, following the sharp increase in central bank policy rates in response to elevated global inflation following the pandemic, a new question emerged: what will happen to the neutral interest rate in the period ahead – namely, whether it is realistic to assume it will return to its pre-pandemic level.

As the neutral interest rate is a theoretical concept and is not a rate directly set by monetary authorities, nor a rate at which transactions are conducted, it is not directly observable and must be estimated. One of the most commonly used methods for estimating the neutral interest rate is the approach of Laubach and Williams (2003), and subsequently Holston, Laubach and Williams (2017), where the neutral rate is linked to potential output. However, in small, open economies like Serbia, periods of high economic growth and substantial foreign capital inflows are typically accompanied by appreciation of the real exchange rate, a phenomenon known in economic theory as the Penn effect. Practically, besides the yields achievable from production, foreign investors also realise a part of their yields from the real appreciation of the currency of the country they invest in.

Given the importance of the neutral interest rate concept for monetary policy conduct, this paper estimates the level of the neutral interest rate for Serbia over the past 17 years (Q1 2008 – Q4 2024). Our estimate is based on several models. The first model, which the NBS also uses for its medium-term inflation projection, was adapted to estimate the trend of the real interest rate incorporating the Penn effect – i.e. including the equilibrium real exchange rate, as considered in the paper of Hlédik and Vlček (2018). The second model follows the approach proposed by Bulíř and Vlček (2024), which also incorporates the equilibrium real exchange rate into a small structural model with four core equations (a Phillips curve equation, an IS curve equation, an uncovered interest parity equation, and a Taylor rule equation). The third is based on the approach of Holston, Laubach and Williams (2017), which links the real interest rate to potential output, and finally, an estimate of a time-varying parameter vector autoregression model (TVP-VAR).

The estimates of the neutral interest rate for Serbia based on the above methods were largely consistent until the beginning of 2014 and displayed a declining trend, which was also a characteristic of Western countries and the rest of the CSEE region, primarily due to reduced potential output and low investment. Thereafter, the models that include the real exchange rate for estimating the neutral interest rate, as well as the TVP-VAR model, indicate a relatively low neutral interest rate or even a continuation of its declining trajectory. In contrast, according to the HLW model, the neutral interest rate exhibited an upward trend until the coronavirus pandemic, driven mainly by potential output growth. A common feature of all the estimated models is that the neutral rate has recorded an upward trend over the last two years; however, for most models (with the exception of the HLW model) the estimate of the neutral (real) rate is below 1%. The results of the analysis show that for estimating the neutral interest rate in Serbia, it is more appropriate to use models that also account for the effect of real appreciation, as the estimate obtained from the HLW model is quite volatile for the observed period, especially considering that Serbia recorded significant FDI inflows during the analysed period and that foreign companies also achieved a part of their yields from the real appreciation of the dinar.

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1 Introduction

Following the outbreak of the coronavirus pandemic, global inflationary pressures increased significantly, resulting in monetary policy tightening by most central banks worldwide. Concurrently, the level of public debt in many countries also rose, given the substantial fiscal stimulus packages provided to facilitate economic recovery from the pandemic. In the pre-pandemic period, many economies recorded a considerable decline in real interest rates, which had already sparked a debate on whether such a trend was the result of a fundamental decline in the neutral interest rate (r*) or was instead a consequence of economic shocks. As the period since the pandemic's outbreak has driven interest rates higher, the question of the level of the neutral rate has gained additional significance for the conduct of monetary policy. Consequently, central banks' interest in this topic has increased markedly over the past several years.

The neutral interest rate is estimated for two key reasons. First, an estimate of the neutral rate allows for an assessment of the monetary policy stance and, second, it indicates the level to which policy rates should converge in the long run. In this way, the neutral interest rate plays a significant role in a central bank's communication with the public and can help anchor inflation expectations around the inflation target. As a government typically services its obligations on loans and bond issuances over a longer horizon, the concept of the neutral rate is also important for fiscal policy, as it can assist in determining the government's total financing costs and in assessing public debt sustainability.

The concept of the neutral interest rate was introduced into economic theory by Wicksell (1936), who defined it as the rate consistent with a stable price level, while it was incorporated into modern macroeconomic theory by Woodford (2003), who linked it to the monetary policy rule within the New Keynesian paradigm.

According to one of the most commonly used definitions, the neutral interest rate represents the rate that would prevail in the long run in the absence of business cycle fluctuations – i.e. the interest rate that is consistent with stable inflation at target and output growth equal to potential growth [Borio, 2021]. Practically, it is the rate at which monetary policy is neither restrictive nor expansionary. Underestimating the neutral interest rate leads to an overheating of the economy and rising inflation because monetary policy is more expansionary than it should be, while overestimating it results in higher unemployment and a slowdown in economic growth. An alternative definition describes it as the rate that balances the level of investment and savings.

The neutral rate is often equated with the long-run equilibrium interest rate and with the natural rate of interest (r*), although differences exist depending on the definition. The neutral interest rate is more oriented towards the medium term, where the effects of economic shocks that cannot be fully isolated still persist, whereas the long-run interest rate (the natural rate) depends solely on structural factors. In the long run, the neutral interest rate converges to the natural rate of interest.

The neutral interest rate is an analytical concept; it is not an interest rate for which data are available and which can be observed, but is instead estimated based on the movements of the economic fundamentals that determine it. These include potential output, productivity, demographic factors, the saving-investment balance, risk premia, fiscal indicators etc. Generally, factors that lead to increased saving and decreased investment contribute to a lower neutral interest rate. Thus, lower potential output leads to lower investment by affecting a lower marginal return on capital, which in turn increases saving. Similarly, longer life expectancy increases saving, whereas a growing working-age population works in the opposite direction. Financial factors, such as a higher country risk premium, as well as a persistently larger fiscal deficit and public debt that necessitate fiscal consolidation, also act to increase saving. Greater income inequality operates in the same direction, due to a higher propensity to save among higher-income groups. Lower productivity also contributes to a lower neutral interest rate by reducing potential output and, consequently, the propensity to invest.

Due to the variety of estimation methods, which often yield significantly different results, it is challenging to precisely assess the true level of the neutral interest rate. Furthermore, as it depends on multiple factors, it is not constant but evolves over time, albeit at a considerably slower pace than the policy rate set by the central bank. Moreover, the neutral interest rate is generally independent of monetary policy decisions, as monetary policy is neutral in the long run and does not affect real macroeconomic variables.

The first group of models for estimating the neutral interest rate comprises structural and econometric models. One of the most commonly used methods within this group is the approach by Laubach and Williams (2003), and subsequently Holston, Laubach and Williams (2017), based on a small New Keynesian structural model. According to this model, the neutral interest rate is derived by combining the real interest rate and the output gap via an IS curve for a closed economy, as well as the output gap and inflation via a Phillips curve. This method separates trend and cyclical component, with the neutral interest rate and potential output representing the trend of the component of the interest rate and economic activity. This approach has been used to estimate the neutral rate for the Federal Reserve System and many other central banks, including those of small, open economies. The second group of models is based on financial market perceptions, where the neutral rate is interpreted as the expected real interest rate derived from the term structure of nominal and real interest rates, i.e. adjusted for the term premium. The third group consists of survey-based methods, where professional forecasters are directly asked about their long-term expectations for central bank policy rates and inflation; the median difference between these estimates provides an assessment of the neutral rate.

Economists agree that the neutral interest rate had a declining trend in previous decades and was at a historically lowest level immediately prior to the coronavirus pandemic. In developed and some emerging economies, the fall in the neutral rate over the past three–four decades was primarily influenced by demographic factors and declining total factor productivity, with specific factors accounting for differences in levels. Consequently, central bank policy rates also reached their lowest levels in the pre-pandemic period. However, following the tightening of monetary policy by central banks in response to heightened global inflationary pressures, the question arises as to whether the neutral rate in these countries has also increased and what level can be expected in the period ahead. There is no consensus among economists on these questions. Most analysts agree that it is unlikely the neutral rate will fall below its pre-pandemic level in the coming period, with some even suggesting it could rise. Factors cited as potentially driving an increase in the neutral rate include the supply of safe assets, the weakening of some drivers of income inequality, and rising investment necessary for the transition to a green economy.

Given the importance of this concept for the conduct of monetary policy, this paper estimates the level of the neutral interest rate for Serbia over the past 17 years. Our estimation is based on several models. The first is a QPM used by the NBS for its medium-term inflation projection, adapted to estimate the real interest rate trend in a manner similar to Hlédik and Vlček (2018). The second follows the approach and model proposed by Bulíř and Vlček (2024), and the third is based on the approach of Holston, Laubach and Williams (2017). Finally, we also estimated the neutral interest rate using a TVP-VAR model.

The working paper is structured as follows. The section following this introduction provides a literature review concerning estimates of the neutral interest rate for other countries. The third section presents different conceptual approaches to estimating the neutral rate, some of which we employed for our own estimate. The fourth section contains an analysis of the results obtained for Serbia. Concluding remarks are provided at the end.

2 Overview of literature

Many central banks estimate the neutral interest rate. As previously noted, interest in this topic has increased markedly over the past three years, a period during which inflationary pressures intensified significantly in almost all countries worldwide, prompting central banks to respond by tightening monetary policy. The structural models used to estimate the neutral interest rate can be divided into two main groups: general equilibrium models, which include DSGE models, which estimate the neutral rate as the return on capital when savings and investments are in equilibrium; and semi-structural models, typically New Keynesian models, which are based on relationships between core macroeconomic variables estimated using econometric techniques. The Holston Laubach and Williams (HLW) model falls into the latter category.

As mentioned earlier, the majority of empirical analyses are based on the Laubach-Williams (LW) model, which was initially used to estimate the neutral interest rate and potential output for the United States for the 1960–2000 period. Application of the Kalman filter determined that the neutral rate fluctuated considerably over that period. Subsequently, Holston, Laubach and Williams (2017) re-estimated this model and extended the analysis to Canada, the euro area and the United Kingdom. Their results indicated a decline in the neutral interest rate during 1990–2016 and highlighted the significant role of global factors in its movements.

The HLW method has also been applied in numerous other empirical analyses [for example, Berger and Kempa (2014); Armelius et al. (2018)]. According to an IMF assessment (WEO 2023), which is based on the HLW and the Platzer and Peruffo (2022) methods, the neutral interest rate has declined substantially over the past four decades in most major economies (the United States, the United Kingdom, Japan, Germany, France, Brazil, China and India). Furthermore, projections suggest that in advanced economies, the neutral rate will converge towards its pre-pandemic levels, but how close it gets to those levels will depend on the trajectory of fiscal policy. This is because a high level of public debt and fiscal expenditure leads to higher interest rates and simultaneously increases the need for fiscal consolidation. The IMF projects that population ageing will contribute to a decline in the neutral interest rate in emerging economies, and that over the next 30 years, China's neutral rate will fall by 1.5 pp, hovering around zero by 2050. Brand, Lisack and Mazelis (2025) estimated the ECB's real neutral interest rate using various methods, including three variants of the HLW approach, and found that estimates vary significantly depending on the estimation method used. According to these estimates, the real neutral interest rate is in a range of -0.5% to 0.5%, implying a nominal neutral rate of 1.75% to 2.25%. This is lower than a previous estimate, which placed it in a range of 1.75% to 3%. Carvalho (2023) also estimated the neutral interest rate for the euro area over the last 50 years using an HLW method adapted for the pandemic period and modified to incorporate inflation expectations into the neutral rate estimate. The results of this analysis indicate that the neutral rate declined from around 3% in the early 1970s to approximately 0.5% in 2022. The neutral rate fell particularly sharply following the 2008 global financial crisis, influenced by a decline in potential output and reduced total factor productivity, as well as adverse demographic factors and increased risk aversion, especially after the public debt crisis in some euro area countries.

Several empirical studies have employed VAR models to estimate the neutral interest rate. For instance, Del Negro et al. (2017) estimated the neutral rate for the United States from the 1960s to the 2010s and found that its decline was driven by a slowdown in economic activity and increased convergence in the returns on safe and liquid assets. Subsequently, the analysis by Del Negro et al. (2019) was extended to seven advanced economies, concluding that since the 1970s, interest rates in these countries followed a similar trend to those in the US. Cesa-Bianchi et al. (2022) further expanded the analysis to a panel of 31 countries for the 1950–2015 period. They estimated that the average equilibrium real interest rate rose from 1.25% in the mid-1950s to 2.75% in the mid-1970s, and has since declined significantly, to 0.25% by 2015.

Regarding analyses of the neutral interest rate that include CSEE countries, the study by Bulíř and Vlček (2024) on twelve open economies is particularly noteworthy. For this estimation, the authors adjusted the HLW model by incorporating the equilibrium real exchange rate into their assessment of the real neutral interest rate (the so-called Penn effect, which indicates a positive correlation between economic growth and real exchange rate appreciation). Their premise was that in small open economies, the economic structure changes significantly under the influence of capital inflows from abroad, resulting in real appreciation. Generally, countries experiencing real appreciation will have a lower neutral interest rate, as investors require lower yields since they gain part of their yields from real appreciation. Conversely, in countries with real depreciation, investors demand a higher yields, leading to a higher neutral interest rate. The authors compared their results for the sample countries with those obtained using the HLW approach and concluded that their model estimates the neutral rate to be approximately 1 pp higher. In other words, according to their assessment, real interest rates were below neutral in many of the analysed countries, suggesting that excessively expansionary monetary policy also contributed to inflation in these economies during the 2021–2023 period. Serbia was included in this analysis, and the results indicated that Serbia's real interest rate was at or above the level of the neutral rate in the pre-pandemic period under review.

Previously, Hlédik and Vlček (2018) estimated the neutral interest rate for the Czech Republic for the period 2000–2017 using a small structural model with rational expectations. In their model, the neutral rate is a function of potential output adjusted for the equilibrium real exchange rate (the real exchange rate trend). According to their estimates, the neutral interest rate in the Czech Republic was around 1% in 2017, and its decline relative to 2015 was largely a result of real exchange rate appreciation amid strong economic growth.

Stefanski (2018) estimated the neutral interest rate for the Czech Republic, Poland, Hungary and the euro area for 1996–2017 using both a New Keynesian model, as recommended by Gali and Monacelli (2005), and a version of the HLW method. It was found that the neutral rate in the observed countries declined significantly following the global financial crisis, recovered somewhat after 2012, but remained substantially lower in 2017 than it was before 2008.

Bielecki et al. (2023), applying the methodology used by Del Negro et al. (2017), followed by Brand and Mazelis (2019) and Holston, Laubach and Williams (2017), estimated the neutral interest rate for Poland and compared it to the estimate for the euro area. The conclusion of this analysis was that the neutral rate had declined significantly over the past two decades in both Poland and the euro area, driven by demographic factors and declining productivity. The neutral interest rate in Poland was consistently higher than in the euro area by an average of about 2–3 pp. The future trend of the neutral rate is less clear-cut – demographic factors will exert downward pressure, but artificial intelligence could boost productivity and act in the opposite direction.

3 Methodology of neutral interest rate estimate

3.1 Estimate of the neutral interest rate using the HLW approach

One of the most commonly used methods for estimating the neutral interest rate is the Laubach and Williams (LW), or Holston, Laubach and Williams (HLW) approach, based on a small structural New Keynesian model, which posits a relationship between aggregate supply, demand, interest rates and inflation. According to this concept, the neutral interest rate is defined as the interest rate that returns GDP to the level of potential output once the effects of short-term supply- and demand-side shocks have dissipated, and which also returns inflation to its target level over the medium term.

The authors begin with a version of the New Keynesian model for open economies, where the relationship between inflation and GDP is represented by a Phillips curve:

$$\pi_{H,t} = \beta E_t[\pi_{H,t+1}] + k\widetilde{y}_t, \quad (1)$$

where $\pi_{H,t}$ is inflation, and a $\widetilde{y}_t$ is the output gap, $\widetilde{y}_t = 100(y_t - y_t^*)$, and where cy y_t and y_t^* are the logarithms of real GDP and estimated potential output, respectively.

The IS curve is given in the following form:

$$\tilde{y}_t = E_t[\tilde{y}_{t+1}] - \sigma^{-1}\left(i_t - E_t\left[\pi_{H,t+1}\right] - r_t^n\right). \quad (2)$$

In the previous equation, i_t is the nominal risk-free interest rate, and r_t^n is the equilibrium real interest rate, which depends not only on expected domestic economic growth but also on global economic growth. The parameters k and σ denote consumption preferences and the technological factor, respectively. When the real interest rate gap $(i_t - E_t\left[\pi_{H,t+1}\right] - r_t^n)$ closes, inflation and the level of output stabilise.

In addition to these equilibrium equations, further equations are defined to estimate the neutral interest rate:

$$\pi_t = b_\pi \pi_{t-1} + (1 - b_\pi)\pi_{t-2,4} + b_y \tilde{y}_{t-1} + \varepsilon_{\pi,t}, \quad (3)$$

$$\tilde{y}_t = a_{y,1}\tilde{y}_{t-1} + a_{y,2}\tilde{y}_{t-2} + \frac{a_r}{2}\sum_{j=1}^{2}\left(r_{t-j} - r_{t-j}^*\right) + \epsilon_{y,t} \quad (4)$$

In equation (3), $\pi_{t-2,4}$ represents average inflation from the second to the fourth preceding period, r_t in equation (4) represents the real short-term interest rate, and r_t^* *ex-post* the natural interest rate. From the previous equations, it follows that shocks affecting inflation and the level of output need not affect the neutral interest rate, which reflects long-term changes in the relationship between the interest rate and the output gap.

The HLW model is estimated using the Kalman filter, where transition equations are defined as follows:

$$r_t^* = cg_t + z_t \quad (5)$$

$$y_t^* = y_{t-1}^* + g_{t-1} + \varepsilon_{y^*,t} \quad (6)$$

$$g_t = g_{t-1} + \varepsilon_{g,t} \quad (7)$$

$$z_t = z_{t-1} + \varepsilon_{z,t} \quad (8)$$

where g is the potential output growth rate, and z represents other determinants that may influence the natural interest rate, with these variables following a random walk process, while y_t^* denotes a random walk process with drift.

The authors of this concept propose that, for the pandemic period, the level of potential output should be adjusted by incorporating a stringency index, constructed by the University of Oxford for the period of the pandemic's most severe effects, such that:

$$y_t^{*\prime} = \begin{cases} y_t^* + \rho d_t & t \geq 2020T1 \\ y_t^* & \end{cases} \quad (9)$$

where d_t is the level of the stringency index, representing the three-month average of daily data for quarter t.

In this way, equation (4) can be expressed as:

$$(y_t - y_t^{*\prime}) = a_{y,1}(y_{t-1} - y_{t-1}^{*\prime}) + a_{y,2}(y_{t-2} - y_{t-2}^{*\prime}) + \frac{a_r}{2}\sum_{j=1}^{2}\left(r_{t-j} - r_{t-j}^*\right) + \epsilon_{y,t} \quad (10)$$

Equation (3) can be modified so that instead of adaptive expectations, future inflation expectations are incorporated, giving it the following form:

$$\pi_t = b_\pi \pi_{t-1} + (1 - b_\pi)\mathrm{E}_t[\pi_{t+H}] + b_y \tilde{y}_{t-1} + \varepsilon_{\pi,t}, \quad (11)$$

where *H* is the horizon to which expectations refer.

Under the assumption of anchored expectations around the target, the previous equation takes the form:

$$\pi_t = b_\pi \pi_{t-1} + (1 - b_\pi)\pi^* + b_y \tilde{y}_{t-1} + \varepsilon_{\pi,t}, \quad (12)$$

where π^* is inflation target.

Furthermore, equation (12) can also be presented as follows:

$$\tilde{\pi}_t = b_\pi \tilde{\pi}_{t-1} + b_y \tilde{y}_{t-1} + \varepsilon_{\pi,t}, \quad (13)$$

where $\tilde{\pi}_t = \pi_t - \pi^*$, which indicates that the neutral interest rate depends not only on the inflation level, but also on inflation's deviation from target.

3.2 Estimate of the neutral interest rate using the modified HLW approach (Bulíř and Vlček)

Bulíř and Vlček (2024) modified the HLW approach and incorporated the change in the equilibrium level of the real exchange rate (Δz_t^*) into the neutral interest rate equation, based on the assumption that the appreciation of the real exchange rate is associated with FDI inflows and productivity growth:

$$r_t^* = \rho r_{t-1}^* + (1 - \rho)[2c_1(c_2 g_t^* + (1 - c_2)\Delta z_t^*)] \quad (14)$$

Another key assumption of this model is that there is no stochastic component in the neutral interest rate equation and that the sum of the coefficients on potential output growth and the appreciation of the real exchange rate trend is equal to one.

Like any classic model used by central banks (so-called quarterly projection models), the model estimated by Bulíř and Vlček (2024) essentially consists of four key equations: a Phillips curve equation, an aggregate demand equation, an uncovered interest rate parity equation, and a monetary policy reaction equation.

The Phillips curve equation is expressed in the following form:

$$\pi_t = \mathrm{a}_1 \pi_{t-1} + (1 - \mathrm{a}_1)\pi_{t+1} + \mathrm{a}_2 RMC_t + \varepsilon_{\pi,t}, \quad (15)$$

where RMC denotes real marginal costs defining the output gap and the real exchange rate gap:

$$RMC_t = \mathrm{a}_3 \tilde{y}_t + (1 - \mathrm{a}_3)\tilde{z}_t \quad (16)$$

The aggregate demand equation takes the following form:

$$\tilde{y}_t = b_1 \tilde{y}_{t-1} - b_2 MCI_t + b_3 \tilde{y}_t^F + \varepsilon_{y,t}, \quad (17)$$

where $\tilde{y}_t$ is the output gap, and the Monetary Conditions Index MCI is the combination of the real interest rate gap ($\tilde{r}_t$) and the real exchange rate gap ($\tilde{z}_t$):

$$MCI_t = b_4 \tilde{r}_t - (1 - b_4)(\tilde{z}_t) \quad (18)$$

$\tilde{y}_t^F$ denotes foreign output gap.

The uncovered interest rate parity equation is defined as follows:

$$s_t = h_2(s_{t-1} + \Delta s^*) + (1 - h_2)[(1 - e_1)s_{t+1}^e + \pi_{t-1} + e_1(s_{t-1} + 2(\pi^* - \pi^{*,f} + \Delta z^*)) + (-i_t + i_t^f + prem_t)/4] + \varepsilon_{s,t} \quad (19)$$

where s_t is the nominal exchange rate, Δs^* is the targeted level of exchange rate change, which enables model's adaptation to various exchange rate regimes, and π^* is the targeted inflation rate.

The fourth, monetary policy reaction equation, takes the form:

$$i_t = h_1(4(s_{t+1} - s_t) + i_t^f + prem_t) + (1 - h_1)[g_1 i_t + (1 - g_1)((r_t^* + \Delta_4\pi_{t+3}) + g_2(\Delta_4\pi_{t+3} - \pi^*) + g_3\,\tilde{y}_t)] + \varepsilon_{i,t} \quad (20)$$

This model, as defined, can be applied both to countries that target inflation exclusively ($h_1 = 0$), and to those that combine inflation and exchange rate stability.

3.3 Estimate of the neutral interest rate using the Taylor rule

Some central banks (e.g. the Reserve Bank of New Zealand) estimate the neutral interest rate by applying the Taylor rule, which considers the relationship between the nominal interest rate and a time-varying neutral real interest rate, expected inflation, inflation's deviation from target, and the output gap. This relationship can be expressed by the following formula:

$$i_t = r_t^* + \pi_{t+1}^e + \beta_t(\pi_t - \pi^*) + \varphi_t\tilde{y}_t + \varepsilon_{1,t} \quad (21)$$

Under the assumption of no arbitrage, a relationship is established between short-term and long-term interest rates, such that the long-term nominal rate R_t is equal to the short-term nominal interest rate ($r_t^* + \pi_{t+1}^e$), plus a term premium, α:

$$R_t = r_t^* + \pi_{t+1}^e + \alpha + \varepsilon_{2,t} \quad (22)$$

The real neutral interest rate is obtained as:

$$r_t^* = r_{t-1}^* + g_{t-1} \quad (23)$$

where the potential output growth rate follows a random walk process:

$$g_t = g_{t-1} + \varepsilon_{g,t} \quad (24)$$

The parameters β_t and φ_t are time-varying. The implied neutral interest rate is derived under the assumption that the medium-term neutral rate serves as the basis for decision-making. By adjusting for inflation expectations, the short-term, medium-term, and long-term real neutral interest rates are obtained [Castaing et al. (2024)].

3.4 Modified uncovered interest rate parity rule

In open economies characterised by substantial capital inflows, domestic and foreign interest rates are linked by the rule of uncovered interest rate parity. The uncovered interest rate parity rule posits that the returns on two currencies, adjusted for risk premium, tend to equalise:

$$z_t = z_{t+1}^e + \frac{r_t - r_t^f + \rho_t^*}{4} + e_t^z \quad (25)$$

According to the previous equation, the real exchange rate will tend to depreciate ($z_t - z_{t+1}^e$) as the difference between domestic and foreign market returns ($r_t - r_t^f$) narrows. In this case, the domestic neutral real interest rate is obtained as the sum of the foreign neutral interest rate and the estimated risk premium.

4 Estimate of the neutral interest rate for Serbia

4.1 Description of the variables used in the analysis and the analysis period

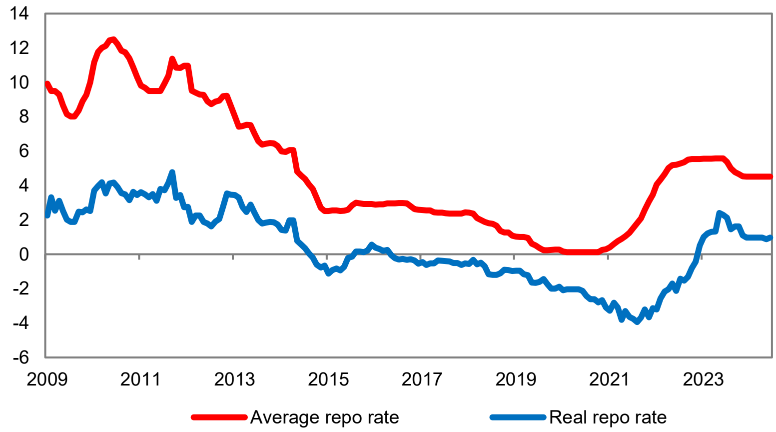
The analysis of the neutral interest rate estimate was conducted for the period from Q1 2008 to Q4 2024. Table 1 provides an overview of the variables used in the analysis.

In most part of the observed period, the NBS pursued an accommodative monetary policy. From late 2015, amid low and stable inflation, with inflation running below the target midpoint, the real interest rate was negative. Furthermore, since the end of 2012, the NBS has employed variable-rate auctions in its reverse repo transactions. This means that the key policy rate represents the maximum acceptable interest rate at auction. Due to the structural liquidity surplus, the average repo rate at which repo transactions are conducted becomes the benchmark for money market rates and trends below the key policy rate.

Table 1 **Overview of variables**

Designation	Description	Data source
π_t	quarterly inflation rate observed at annual level, s-a	SORS, authors' calculation
π^*	inflation target	NBS
$\tilde{y}_t$	output gap	NBS, authors' calculation
$\tilde{z}_t$	real exchange rate gap	NBS, authors' calculation
g_t^*	potential output growth rate	NBS, authors' calculation
Δz_t^*	change in real exhange rate trend	NBS, authors' calculation
$\widetilde{y_t^F}$	euro area output gap	NBS, authors' calculation
$\tilde{r}_t$	real interest rate gap	NBS, authors' calculation
r_t^*	neutral interest (real interest rate trend)	NBS, authors' calculation
s_t	nominal exchange rate	SORS, authors' calculation
π^{*f}	euro area inflation target	ECB
i_t	one-week nominal repo interest rate	NBS
i_t^n	neutral nominal interest rate	NBS, authors' calculation
i_t^f	ECB key interest rate	ECB
RMC_t	real marginal costs	NBS, authors' calculation
MCI_t	monetary restrictiveness index	NBS, authors' calculation
$prem_t$	risk premium	NBS, authors' calculation

Chart 1 **Average repo interest rate (nominal and real)**



Following the outbreak of the coronavirus pandemic, amid rising global inflationary pressures, a monetary policy tightening cycle was initiated – first with an increase in the amount of liquidity withdrawn through repo auctions, which contributed to a rise in the average repo rate from around 0.1% in October 2021 to nearly 1% in April 2022. The rate thus practically aligned with the key policy rate. The key policy rate was subsequently increased in a series of steps until August 2023, reaching a level of 6.75%. Thereafter, as inflationary pressures eased, the need for further monetary tightening diminished, supported by a decline in inflation expectations. This allowed the real interest rate to return to positive territory, resulting in restrictive monetary conditions without additional key policy rate hikes. Inflation peaked at 16.2% y-o-y in March 2023 during this period of heightened inflationary pressures, before moderating and returning within the target band in May 2024. This enabled the NBS to commence an easing cycle in June 2024, reducing the key policy rate by a cumulative 75 bp by September 2024. Since then and up to the time of writing this working paper, the rate has remained unchanged (standing at 5.75%). Over this period, the nominal average repo rate stabilised at 4.5%, with the one-week BELIBOR rate – the interbank money market rate – also settling at a similar level.

4.2 Estimate results

Our analysis, covering the period from Q1 2008 to the end of 2024, is based on the estimation of various models and estimation methods outlined in Section 3, drawing on the papers of Laubach and Williams (2003), Bulíř and Vlček (2024), and Hlédik and Vlček (2018).

4.2.1 QPM results

The estimation of the neutral interest rate for Serbia, or the real interest rate trend, based on the QPM was conducted using two versions of this model type. In the first step, we modified the model we typically use for medium-term inflation projections to some extent, implementing this adjustment specifically in the part estimating the neutral interest rate. Rather than calculating it based on the uncovered interest rate parity equation, we followed the approach presented in Hlédik and Vlček (2018), where the neutral interest rate is proportional to potential GDP growth adjusted for changes in the equilibrium real exchange rate (i.e. change in the real exchange rate trend). In the second step, we employed the small structural QPM proposed by Bulíř and Vlček (2024), where the neutral interest rate is also determined based on equilibrium economic growth and real appreciation. The results from both models are presented below.

As previously highlighted, in the model proposed by Laubach and Williams (2003), the neutral interest rate is estimated based on a constraint derived from the Euler equation. According to this constraint, the neutral interest rate, r_t^*, is a function of potential GDP growth, Δy_t^*:

$$r_t^* = c\Delta y_t^* + \varepsilon_t, \quad (26)$$

where coefficient $c > 0$.

However, this equation is not entirely appropriate for estimating the neutral interest rate in the case of a small open economy with free capital movement, as the process of rapid economic growth and convergence typically results in real appreciation. Potential GDP growth only captures the yield on capital, while foreign investors also earn yield from changes in the real exchange rate. Therefore, according to Hlédik and Vlček (2018) and Bulíř and Vlček (2024), the estimation of the neutral rate must also incorporate changes in the equilibrium real exchange rate:

$$r_t^* = c(\Delta y_t^* + \Delta z_t^*) + \varepsilon_t, \quad (27)$$

where $\Delta z_t^* > 0$ denotes real depreciation, and $\Delta z_t^* < 0$ real appreciation, and where $\Delta y_t^* = g_t^*$ and Δz_t^* denote changes in equilibrium levels (trends).

As a reminder, according to Laubach and Williams (2003), the scaling parameter c is equal to 1. The specification of these equations differs from Laubach and Williams (2003) in that the neutral interest rate is not defined as the sum of two non-stationary random walk processes, but rather as a combination of two stationary variables, Δy_t^* и Δz_t^*. Equations were specified in a similar manner by Mesonnier and Renne (2007).

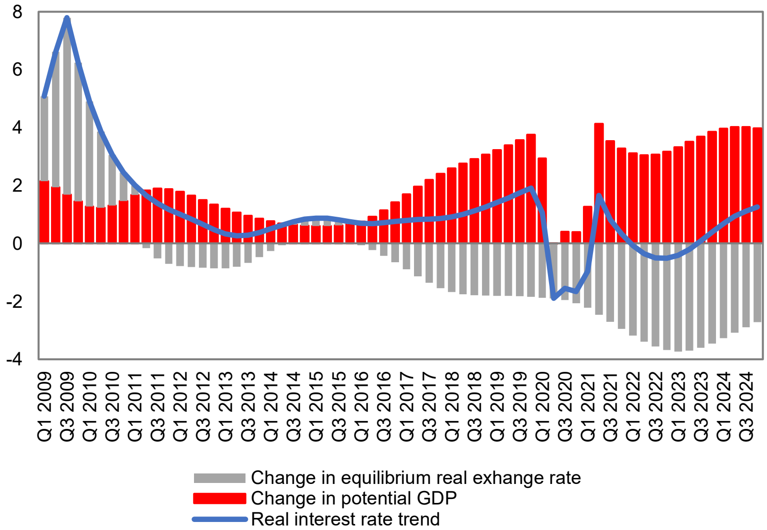
Chart 2 presents the contributions of potential GDP growth and real appreciation to the real interest rate trend in the absence of inertia in its movement, i.e. the estimate is based on equation (27). This Chart shows that the equilibrium real interest rate was relatively low and stable until the outbreak of the coronavirus pandemic, as relatively high potential GDP growth and an appreciating trend of the real exchange rate acted simultaneously. During the pandemic, the real interest rate trend decreased, primarily as a consequence of reduced potential output, but a gradual increase has been recorded thereafter, as the effect of higher potential GDP growth has outweighed that of real appreciation.

However, Hlédik and Vlček (2018) and Bulíř and Vlček (2024) in their empirical papers assumed that the neutral interest rate converges to potential GDP growth adjusted for the equilibrium real appreciation, with a certain degree of inertia in the movement of the neutral rate. They removed the stochastic component, as previously shown in equation 14, which we repeat here:

$$r_t^* = \rho r_{t-1}^* + (1-\rho)[2c_1(c_2 g_t^* + (1-c_2)\Delta z_t^*)], \quad (28)$$

where the change in potential GDP and the change in the equilibrium real exchange rate are defined as y-o-y changes.

Chart 2 **Decomposition of the real interest rate trend**



Furthermore, it can be noted that in the case where $c_2 = 0.5$, equation (28) is practically identical to equation (27).

Taking all of the above into account, we have incorporated equation (28) into the model used at the NBS for its medium-term inflation projection [for more details see Đukić, Momčilović and Trajčev (2011)], which was subsequently extended by including labour market equations [for details, see Momčilović and Miletić (2024)]. Previously, in these models, the real interest rate trend was estimated according to real uncovered interest parity:

$$r_t^* = \Delta z_t^* + prem_t^* + r\_ez_t^*, \qquad (29)$$

where the real interest rate trend, r_t^*, as an approximation of the neutral interest rate, was obtained as the sum of the change in the estimated trend of the real exchange rate (Δz_t^*), an estimated risk premium ($prem_t^*$), and the trend of the real interest rate of the euro area ($r\_ez_t^*$), which was estimated using the Hodrick-Prescott (HP) filter.

We note that the coefficients in the model were calibrated in line with estimates obtained from other models or papers for other countries, but also based on the standard error of the Kalman filter to achieve economically intuitive relationships consistent with economic movements in Serbia (for more on the values of individual coefficients for estimating the neutral rate, see the Table 2).

The results of the neutral interest rate estimate obtained via the Kalman filter (Model 1), as well as potential GDP growth and the change in the equilibrium real exchange rate based on equation (28), are shown in Chart 3. Estimates from the same model calculated on the basis of uncovered interest parity, i.e. equation (29), are given in Chart 3.1. The analysis indicates that the real interest rate trend, as in other countries, was on a strong downward trajectory in the period following the 2008 global financial crisis. This can be linked to a reduced potential output in the initial years of the post-crisis period, caused by both low growth in the euro area

– our most important trading partner – and, consequently, low investment into Serbia, as well as an increased risk premium due to the risk of a public debt crisis erupting in certain euro area countries. Subsequently, according to this estimate, from 2014 to 2019 the real interest rate trend was relatively stable and low, at around 1%. After the real interest rate trend was further reduced following the outbreak of the coronavirus pandemic, a gradual increase has been observed in the post-pandemic period, and it is currently, according to this estimate, slightly below 1%. When observing the movement of the real repo rate and comparing it to the estimate of the real interest rate trend, it is evident that monetary policy had a restrictive character until the beginning of 2015. Then, in an environment of low inflationary pressures and inflation moving below the midpoint, monetary policy was expansionary. Since late 2023, according to this estimate, monetary policy has again had a restrictive character, but this is diminishing as inflationary pressures ease. Similar estimates were obtained using the uncovered interest parity equation, although according to that estimate, the trend of our real interest rate is at a lower level, around 0.5%.

Chart 3 **Estimate of the real interest rate trend by equation (28)**

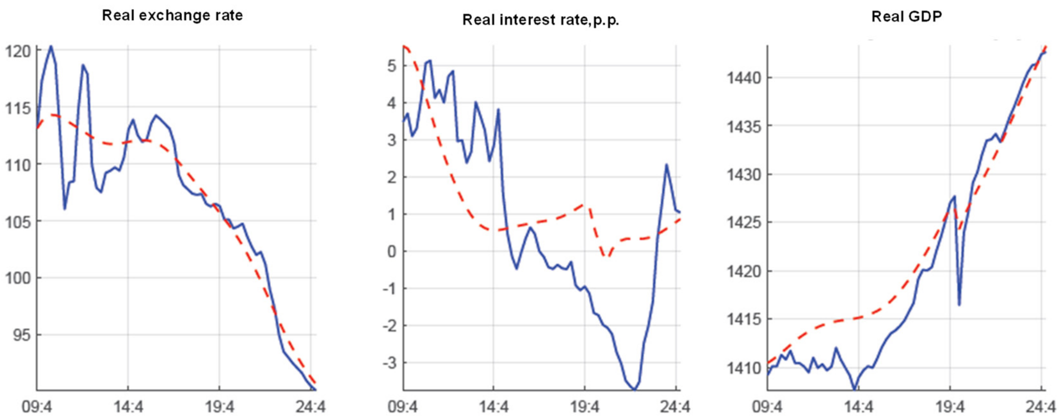
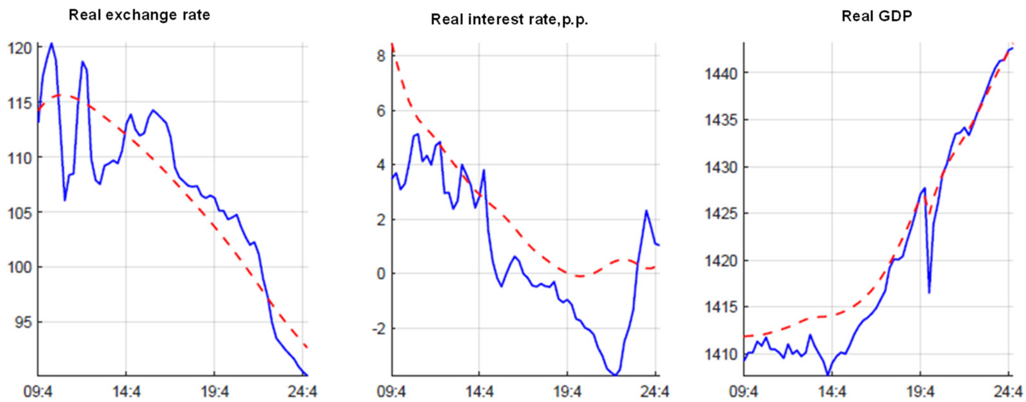


Chart 3.1 **Estimate of the real interest rate trend by UIP equation (27)**



The estimate of the neutral interest rate depends to a large extent on the estimates of potential GDP and the real exchange rate trend. The trends are based on the country's fundamentals and are not influenced by monetary policy. In contrast to the trend, the gap represents the cyclical component of a variable and is consistent with the country's business cycle. The estimate of the neutral interest rate also depends on the parameters in equation (28), namely on c_1, ρ and c_2. With this in mind, we conducted a sensitivity analysis of the obtained estimates to changes in the parameters of this equation, varying the values for the parameters: c_1 for $+0.25/-0.15, \rho$ for $\pm 0.17, c_2$ for ± 0.1 (see Charts 3.2, 3.3 and 3.4). The analysis shows that the resulting estimate of the real interest rate trend is most sensitive to changes in parameter c_2. The highest level of the interest rate is suggested by a coefficient value of $c_2 = 0.6$, as in this case the real interest rate trend is most dependent on potential output growth and less on real appreciation. In that scenario, the real interest rate trend is closer to a level of 2%.

Chart 3.2 **Estimate of the neutral interest rate depending on change in coefficient c_1**

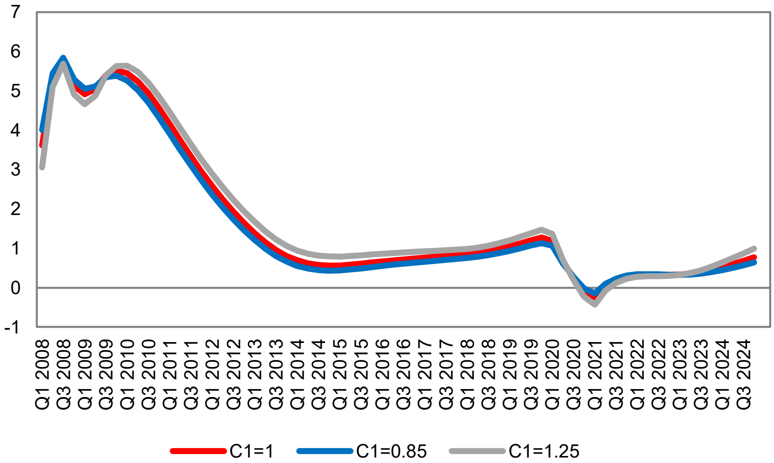


Chart 3.3 **Estimate of the neutral interest rate depending on change in coefficient ρ**

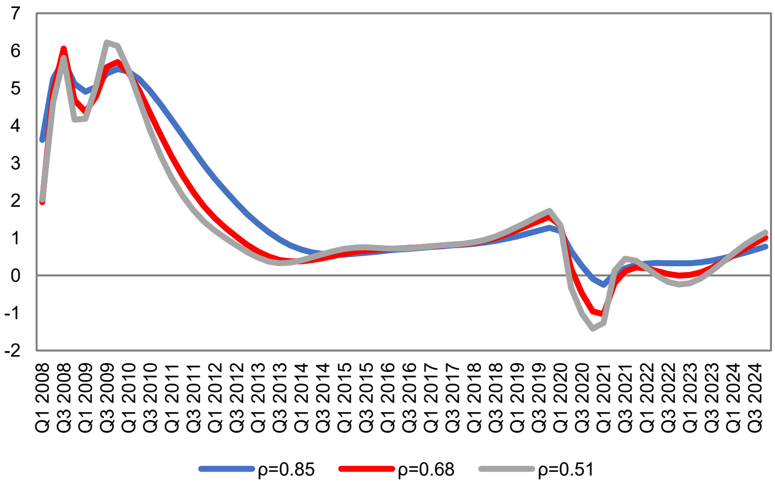
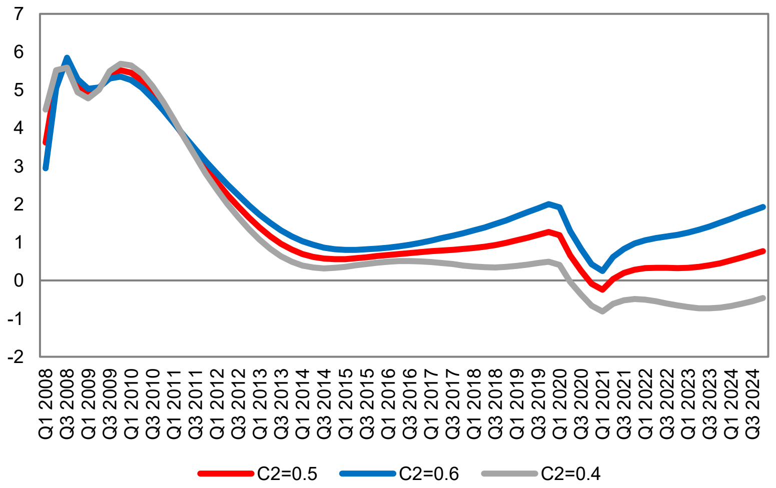


Chart 3.4 **Estimate of neutral interest rate depending on change in coefficient c_2** (in %)



The second model we estimated (Model 2) – QPM is proposed by Bulíř and Vlček (2024). The model is similar to the one we use for our medium-term inflation projection, with the difference that some equations are simplified (for instance, the Phillips curve for inflation) and the estimation was conducted using a Bayesian method. In addition to the Phillips curve, the model includes an IS curve, as well as a monetary policy rule. For further details, see Table 2, which provides an overview of all the equations in this model alongside the calibrated coefficients, as well as the prior distributions of the model's parameters.

Table 2 **Overview of equations, parameter values and standard deviations of estimated models**

Equations	Prior distribution		
	Type	Mean	Standard deviation
Phillips curve $\pi_t = \mathrm{a}_1\pi_{t-1} + (1-\mathrm{a}_1)\pi_{t+1} + \mathrm{a}_2 RMC_t + \varepsilon_{\pi,t}$ $RMC_t = \mathrm{a}_3\tilde{y}_t + (1-\mathrm{a}_3)\tilde{z}_t$			
a_1	-	0.4	
a_2	Inv. γ	0.3	0.3
a_3	β	0.5	½*0.5
$\varepsilon_{\pi,t}$	Inv. γ	$^1/_4\,\mathrm{std}(\tilde{\pi}^{\mathrm{obs}})$	Standard deviation during the coronavirus period (Q1 2021 – Q4 2022) was six times higher than in the pre-pandemic period.
IS curve $\tilde{y}_t = b_1\tilde{y}_{t-1} - b_2 MCI_t + b_3\tilde{y}_t^F + \varepsilon_{y,t}$ $MCI_t = b_4\tilde{r}_t - (1-b_4)(\tilde{z}_t)$			
b_1	β	0.4	¼*0.4
b_2	γ	0.2	¼*0.2
b_3	γ	0.6	¼*0.6
b_4	β	0.6	¼*0.6
$\varepsilon_{y,t}$	Inv. γ	$^1/_2\,\mathrm{std}(\widetilde{\Delta y}^{\mathrm{obs}})$	
Neutral interest $r_t^* = \rho r_{t-1}^* + (1-\rho)(2c_1(c_2 g_t^* + (1-c_2)\Delta z_t^*))$			

Equations	Prior distribution		
	Type	Mean	Standard deviation
ρ	-	0.85	
c_1	γ	1	1/15*1
c_2	β	0.5	1/15*0.5
UIP $s_t = h_2(s_{t-1} + \Delta s^*) + (1 - h_2)((1 - e_1)s^e_{t+1} + \pi_{t-1} + e_1(s_{t-1} + 2(\pi^* - \pi^{*,f} + \Delta z^*)) + (-i_t + i^f_t + prem_t)/4) + \varepsilon_{s,t}$			
h_2	-	0	-
e_1	-	0.6	-
$\varepsilon_{s,t}$	-	$\frac{1}{2}\,\mathrm{std}(\widetilde{\Delta s}^{\mathrm{obs}})$	-
Monetary policy reaction function $i_t = h_1(4(s_{t+1} - s_t) + i^f_t + prem_t) + (1 - h_1)[g_1 i_t + (1 - g_1)((r^*_t + \Delta_4\pi_{t+3}) + g_2(\Delta_4\pi_{t+3} - \pi^*)] + g_3\,\tilde{y}_t + \varepsilon_{i,t}$ $prem_t = \rho_{prem} prem_{t-1} + (1 - \rho_{prem})(-\Delta z^*_t + r^*_t + r^{*f}_t) + \varepsilon_{prem,t}$			
h_1	-	0	-
g_1	-	0.7	-
g_2	-	2	-
g_3	-	0.2	-
ρ_{prem}	-	0.85	-
$\varepsilon_{i,t}$	-	$2 * \mathrm{std}(\tilde{\imath}^{\mathrm{obs}})$	Standard deviation is twice higher after 2010 and four times higher during 2008–2010.

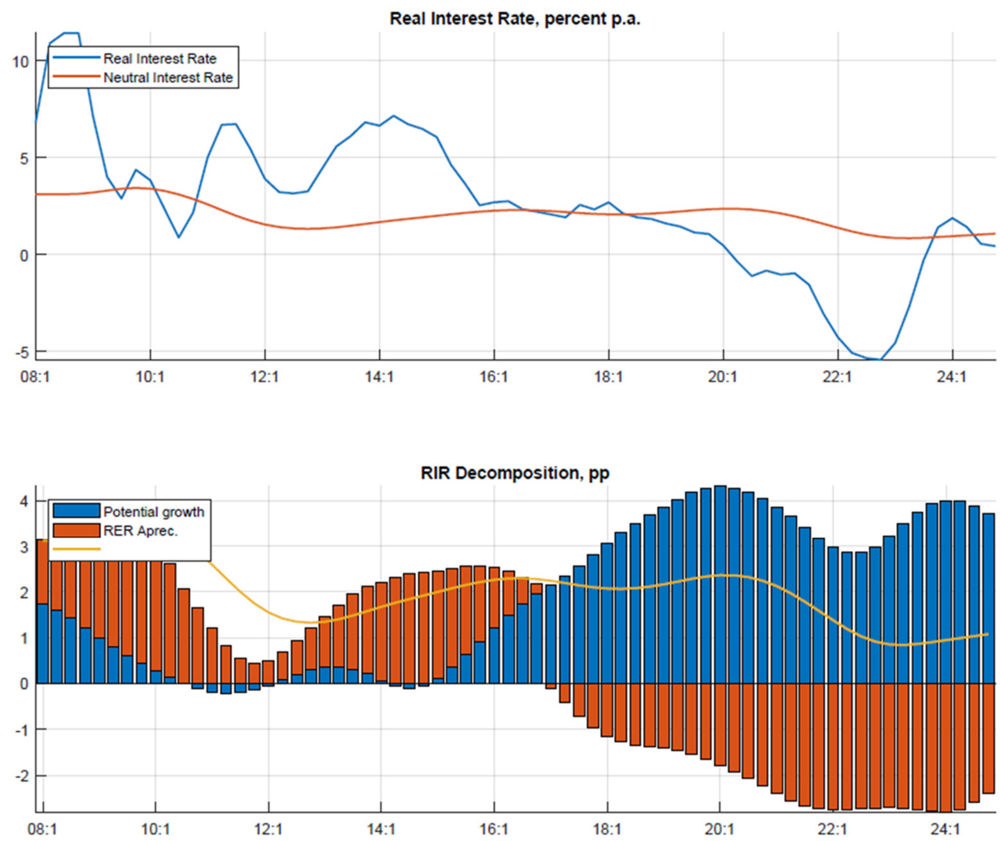
We adapted the model used by Bulíř and Vlček (2024) by calibrating its coefficients to match those from our medium-term inflation projection model and estimated it for the period Q1 2008 – Q4 2024. Specifically, the parameter denoting inflation inertia in the Phillips curve, a_1, was calibrated to 0.4, consistent with our medium-term inflation projection model, as opposed to the value of 0.5 used by Bulíř and Vlček (2024). This parameter reflects the assumed Calvo mechanism and is not estimated because it cannot be identified along with parameter a_2 due to their observational equivalence. The data for estimating the trend of real GDP of the euro area and the trend of the real interest rate of the euro area were obtained using an HP filter. Other trends and deviations, including the inflation target, are identified within the overall model framework using the Kalman filter, and the coefficients are estimated via the Bayesian method.

The prior distributions (priors) for parameters c_1 and c_2 were taken from the work of Bulíř and Vlček (2024) as 1 and 0.5, respectively, along with the standard deviations for these parameters suggested by the authors (provided in Table 2), given that these parameters are key for determining the neutral interest rate (r^*). In cases where a parameter was not estimated, only the mean of its calibrated value is shown. The prior distributions for the standard deviations of the supply shock, $std(\hat{\pi}\_obs)$, and demand shock, $std(\Delta\hat{y}\_obs)$, are set in line with the variability of the specific variable. Thus, $std(\hat{\pi}\_obs)$ denotes the standard deviation of the core inflation series from which the trend has been previously removed, and $std(\Delta\hat{y}\_obs)$ denotes the standard deviation of the real GDP growth rate series, from which the trend has also been removed (using an HP filter).

It is noteworthy that Bulíř and Vlček (2024), in their estimation for most countries, found the ratio of parameters c_1 and c_2 to be approximately ½, which together establish the proportional relationship between r* and potential growth g*, known as the HLW relationship.

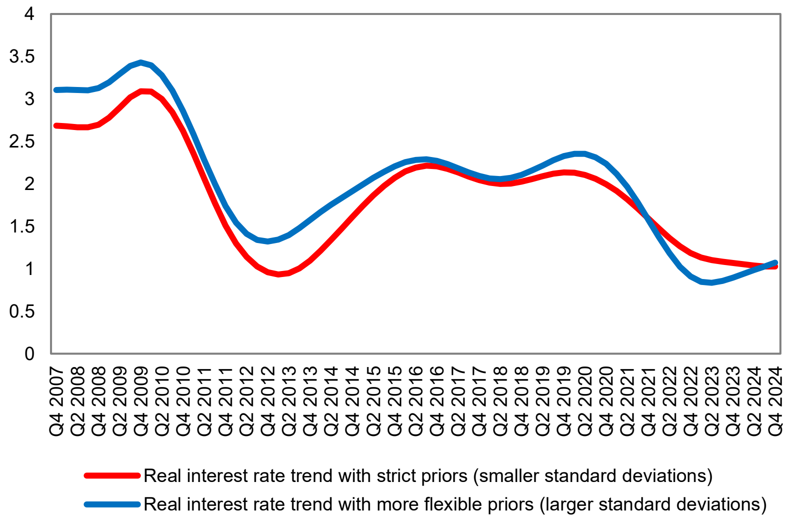
Chart 4 presents the estimate of the neutral rate, i.e. the real interest rate trend, and the estimates of its components derived from applying the QPM proposed by Bulíř and Vlček (2024). A decomposition of the neutral interest rate equation is also provided.

Chart 4 **Estimate of the neutral rate using the model proposed by Bulíř and Vlček (2024) and its decomposition**



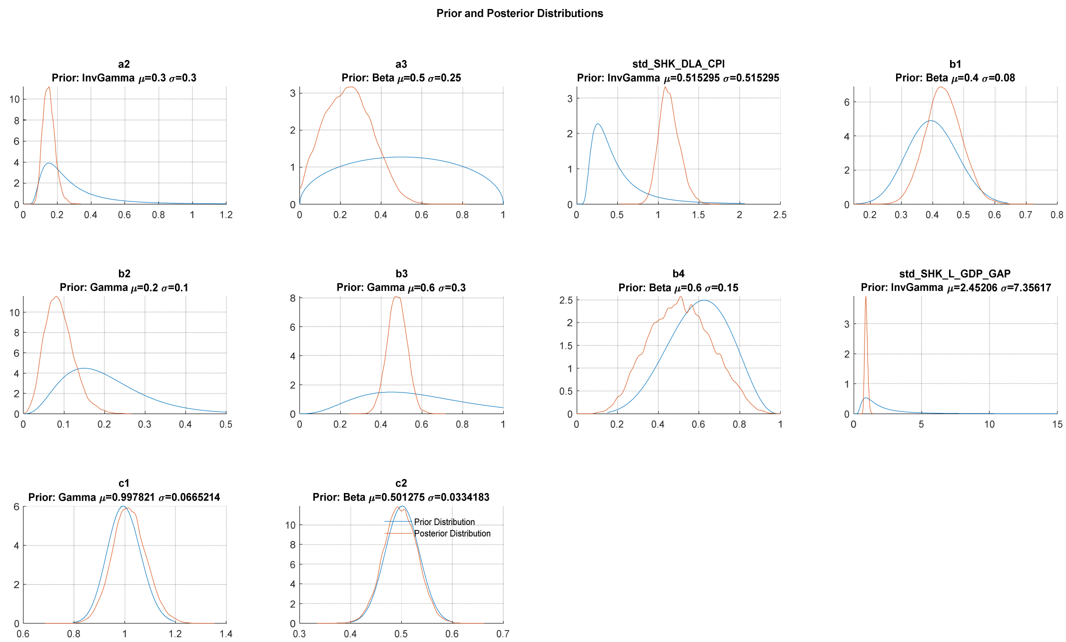
The authors analysed how changes in parameters c_1 and c_2 affect the estimate of the neutral interest rate (r*). The conclusion of the analysis is that, in the case of Serbia, the estimate of the neutral interest rate is sensitive to changes in the priors for c_1 and c_2. The estimate is conducted under an assumption of tight priors and less tight priors, by increasing the standard deviations of the estimated coefficients fivefold. In the case of Serbia, under the loosened priors, the estimate of the neutral interest rate was on average 30 bp lower over the period Q4 2007 – Q2 2021. When we extend the analysis period and incorporate the above model modifications, we find that for the period Q3 2021 – Q4 2024, the neutral rate estimate under the loosened priors is somewhat higher – by approximately 10 bp – but that the estimates nearly converge by the end of the analysed period (see Chart 5).

Chart 5 **Estimate of the neutral interest rate depending on changes in standard deviations used for estimating coefficients c_1 and c_2** (in %)



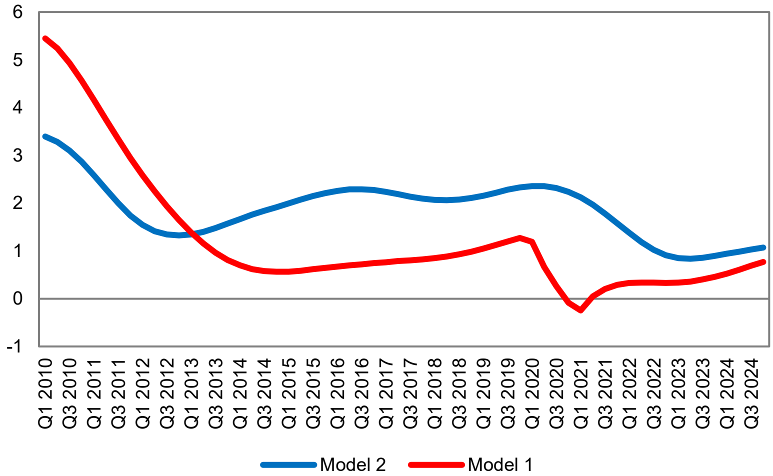
The posterior distribution of the model's estimated parameters was constructed using a Metropolis–Hastings simulation with 100,000 draws and is presented in Chart 6.

Chart 6 **Prior and posterior distributions of the coefficients estimated in Model 2**



In Chart 7, we present a comparison of neutral interest rate estimates derived from our medium-term projection model, where we replaced the UIP equation with a new equation incorporating potential GDP growth and the change in the real exchange rate trend for estimating the real interest rate trend (Model 1), and the QPM proposed by Bulíř and Vlček (2024), estimated via the Bayesian method (Model 2). A comparison of these models shows that the neutral interest rate estimate was lower for the majority of the observed periods according to Model 1. However, these differences are not significant, and by the end of the estimated period, the neutral rate estimates based on both models are very close.

Chart 7 **Comparison of neutral interest rate estimates based on Model 1 and Model 2** (in %)



Finally, bearing in mind that we adjusted the trend of potential GDP in our medium-term inflation projection model for the period Q1 2020 – Q4 2020 to account for a structural break, we also estimated Model 2 by incorporating this same break. The estimate of the neutral interest rate from a model that includes this break in the GDP growth trend – which is structurally identical to Model 2 and is estimated using the Bayesian method – is shown in Chart 8. The resulting estimate of the neutral interest rate is at a higher level than in the case of Model 1. This confirms findings from other countries that the estimate differs based on the underlying assumptions and analysis methods employed, and that estimates can vary significantly.

Chart 8 **Estimate of the neutral interest rate in Model 2 with a structural break**

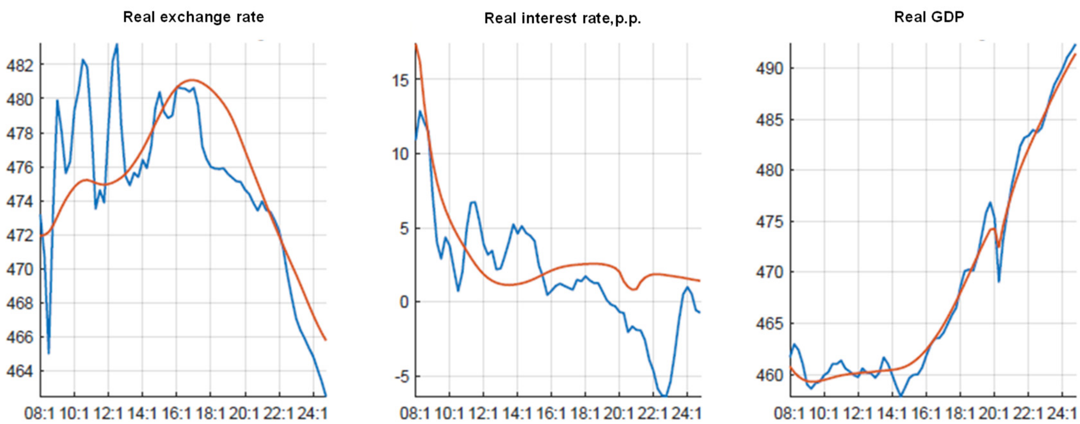


Chart 8.1 **Prior and posterior distributions of the parameters**

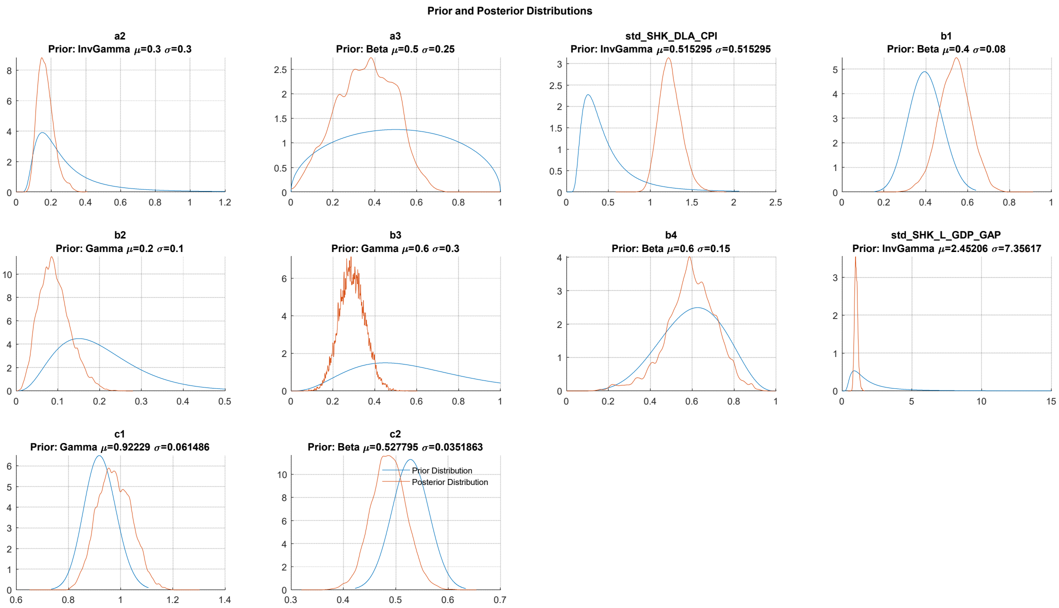
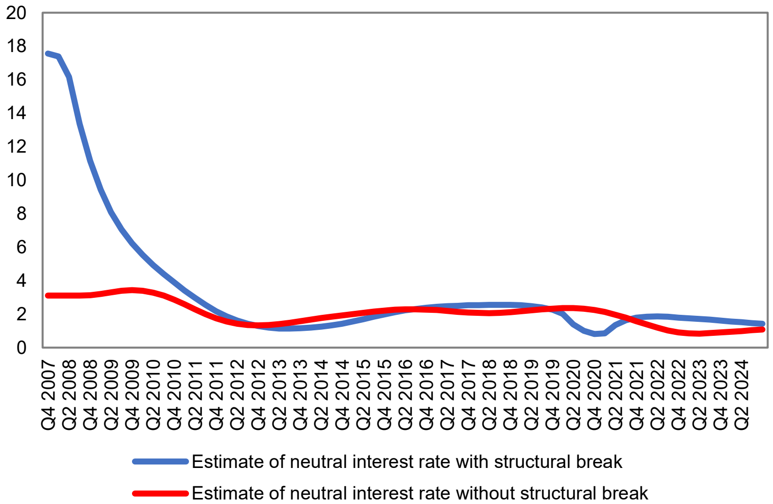


Chart 9 **Comparison of neutral interest rate estimates in Model 2 with and without a structural break** (in %)

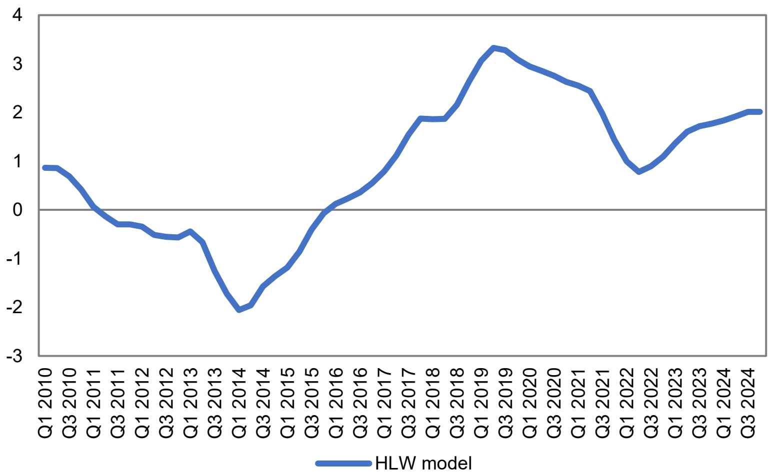


4.2.2 Results of the HLW model

In the estimation of the HLW model, presented by the equations in Section 3.1, we used the following variables: real s-a GDP, y-o-y inflation, the real money market interest rate (one-week BELIBOR) calculated based on one-year-ahead inflation expectations of the financial sector, according to a Bloomberg survey, and a stringency index constructed by the University of Oxford, which is available up to end-2022. Given that its last available values were low, this index was approximated using a linear downward trend. This indicator was included to account for the effects of the coronavirus pandemic.

Chart 10 presents the estimate of the neutral interest rate for Serbia using the HLW model. The estimation employed the smoothed state estimate obtained from the Kalman filter.

Chart 10 **Estimate of the neutral interest rate obtained using the HLW model**



According to the results of this estimate, the neutral interest rate was on a downward trajectory in the period following the 2008 global financial crisis until the beginning of 2014. This can be linked to a reduced potential output in the initial post-crisis years, caused by both low growth in the euro area – our most important trading partner – and the consequently low investment into Serbia, as well as an increased risk premium due to the risk of a public debt crisis erupting in certain euro area countries, and the negative contribution of other determinants captured by the component z. Subsequently, according to this estimate, a trend of a rising neutral interest rate was present from 2014 to 2019, which can be associated with growth in potential output. By the period immediately preceding the outbreak of the coronavirus pandemic, it had approached a level of around 4%, only to enter a downward path again until mid-2022. In the most recent analysed period, the neutral rate, according to this estimate, is again on an upward trend and stood at close to 2% by the end of 2024. The estimate results obtained using the HLW model indicate considerable volatility in the neutral interest rate, with its movement ranging between -4% and 4% over the entire analysed period. For this reason, we consider an estimate that also accounts for the effects of real exchange rate changes when assessing the neutral interest rate to be more adequate for the case of Serbia.

4.2.3 Results of the TVP-VAR model

In the final step of the analysis, we estimated a time-varying parameter vector autoregression (TVP-VAR) model. Unlike the previously presented structural models, which have a theoretical foundation and assume strong economic relationships between variables, the TVP-VAR model represents a more flexible framework with fewer restrictions.

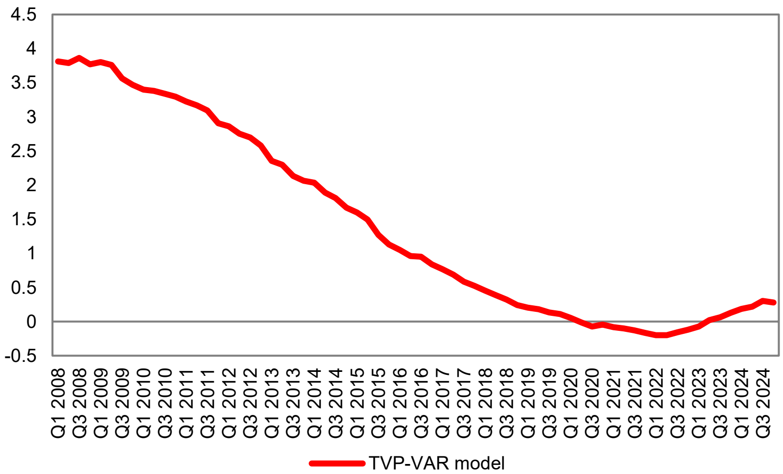
It should be noted that this is a specific class of VAR models, which differ from standard VAR models in that the model's parameters (the constant term, the coefficients on the lags of the variables included in the model, and the variances of economic shocks) are allowed to change over time. This accounts for the fact that the relationships between macroeconomic time series are characterised by a certain form of non-linearity, i.e. that the strength of their connection varies over time. All parameters follow a pure random walk process (first order), which allows for both temporary and permanent changes in parameter values, thereby enabling this class of models to adapt to changing economic relationships that occur over time. Estimating the TVP-VAR model involves the application of the Bayesian methodology, and the Gibbs sampler method was used, which is intended to simplify the computation of multi-dimensional probability densities (Lubik and Matthes, 2015). The priors for the model parameters, which are random variables, were determined based on the Primiceri (2005) procedure. This involves estimating a constant-parameter VAR model on a specific training dataset to obtain the mean and the variance matrix for the priors using a linear regression model.

Our model includes three variables: real GDP growth, quarterly s-a inflation (converted to an annual rate), and the real BELIBOR interest rate, calculated in the same manner as in the HLW model. The model was estimated for the period Q1 2004 – Q4 2024 with two lags, with the first four years (Q1 2004 – Q4 2007) used to establish the priors.

The neutral interest rate was obtained from a conditional forecast of the observed real interest rate. According to Lubik and Matthes (2015), the forecast horizon is set to five years ($r_t^* = r_{t+20}$) and is calculated for each period starting from Q1 2008. The assumption is that by forecasting over a longer period, the effect of temporary shocks is eliminated, allowing the short-term real interest rate to converge to its neutral level.

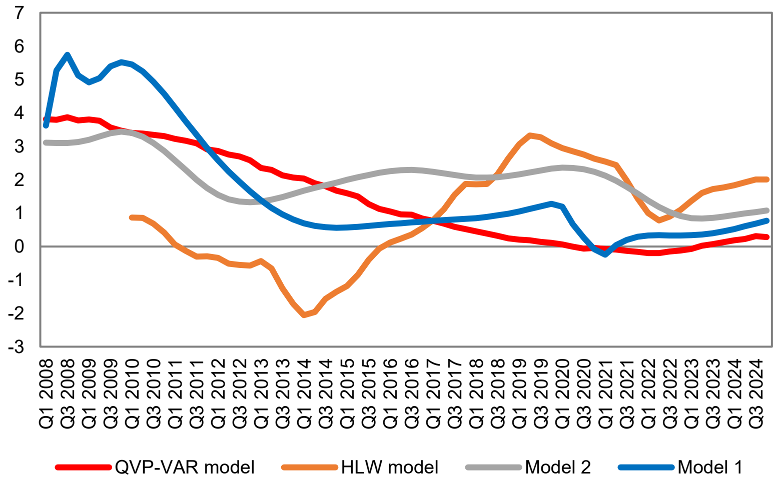
Chart 11 shows the estimate of the neutral interest rate obtained from the TVP-VAR model for the period Q1 2008 – Q4 2024. According to this estimate, the neutral interest rate was in decline for most of the observed period, though it began to rise towards the end. During 2008 and 2009, it moved in a range of 3.5–3.9%, then, following a downward path, reached around -0.2% by mid-2022. Thereafter, the neutral interest rate increased and stood at around 0.3% in 2024. The rise in the real interest rate is a consequence first of the increase in the nominal

Chart 11 **Estimate of the neutral interest rate obtained using the TVP-VAR model** (in %)



interest rate, and subsequently of lower inflation expectations, which the model identified as a likelihood that the neutral rate r* is rising.

Chart 12 **Comparison of different neutral interest rate estimates** (in %)



5 Conclusion

A crucial guide in assessing the monetary policy stance is the concept of the neutral interest rate, r*, which represents the equilibrium interest rate, i.e. the rate that will ensure the targeted level of inflation and a closed output gap in the medium term, and will thus exert neither inflationary nor disinflationary pressure.

Its future path depends on the influence of numerous factors, the direction and contribution of which cannot be predicted with certainty at this moment. Consequently, it is not possible to definitively determine the level at which real interest rates will settle in the medium term. The prevailing view among central bankers and analysts is that there is little probability that the neutral interest rate, r*, will fall below its pre-pandemic level in the coming period, although some factors that contributed to its decline in the previous period will continue to exert influence in the next decade, primarily demographic factors. The possibility that the real interest rate could rise in the future is not excluded; factors that could lead to this include growth in the supply of safe assets relative to demand, the weakening of some drivers of inequality, and increased investment necessary for the transition to a green economy.

Given the significance of the neutral interest rate for the monetary policy conduct process, we have estimated its level for Serbia using various methods: two versions of small structural models with quarterly data that account for the effect of real exchange rate appreciation on the level of the neutral interest rate, the HLW model, and a time-varying parameter vector autoregression (TVP-VAR) model. To our knowledge, this is the first paper to estimate the level of the neutral interest rate for Serbia using a TVP-VAR model.

Based on the estimated models, several key conclusions can be drawn:

– According to all estimated models, as has been the case for other countries, the neutral interest rate in Serbia had a downward trend in the initial years following the global economic crisis until the beginning of 2014. Thereafter, models that incorporate the real exchange rate for estimating the neutral interest rate, as well as the TVP-VAR model, indicate a relatively low neutral interest rate or even a continuation of its downward trajectory.
– The estimate obtained from the HLW model deviates the most from the other estimates and is the most volatile over the observed analysis period. As it does not account for the effects of real exchange rate appreciation, which characterised our economy in previous years, and given high FDI inflows, we consider this estimate to be the least relevant.
– As with other countries, the level of the estimated neutral interest rate changes depending on the model used, and assumptions about the priors of the model's parameters can also influence the level of the estimate.

A common characteristic of all the estimated models is that the neutral rate has had an upward trend in the last two years. However, for most models (except for the HLW model), the estimate of the neutral rate is below 1%, with the majority indicating that the monetary policy stance remains restrictive.

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