Staff Memo

Forecasts and narratives for the policy rate in a macroeconomic model with a real interest rate trend

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Table of contents

Staff Memos

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Summary

Real interest rates, as well as central bank policy rates, trended downwards in many countries for several decades prior to the rise in inflation and interest rates in recent years. This has made it difficult to assess the normal level for the policy rate, and central bankers' and other analysts' forecasts for the policy rate have often been too high. Macroeconomic business cycle models often make the simplifying assumption that the central bank sets the policy rate on the basis of the level of resource utilisation and inflation (a so-called Taylor rule). In the absence of a clear trend in these variables, it is difficult for such models both to explain the trend in policy rates and to forecast them well. The interest rate trend is largely explained by various structural factors that are not usually included in the business cycle model, such as various demographic factors. But even if it is not explained in the model, it is important that trends are taken into account in the right way for the business cycle model's projections and policy analyses to be useful and credible.

In this Staff Memo, we discuss how a time-varying trend for the real interest rate can be built into the Riksbank's macroeconomic model MAJA in a simple and practically useful way, and how this trend can be estimated using macroeconomic data. Thus, instead of assuming that movements in the real interest rate must be cyclical in nature, we now recognise that structural factors can have persistent effects. We show that there is sufficient information to reliably estimate the real interest rate trend using MAJA and, in line with other research studies, we find that the trend level has fallen during the inflation targeting period. We also show that the model's interpretations of movements in the policy rate become more plausible, and that policy rate forecasts are more accurate compared with a model without a time-varying trend. Our approach implies that we can use different types of information about the trend in the real interest rate when we make forecasts of the policy rate with the model: the model's own estimated trend based on data on, for example, resource utilisation and inflation, as well as information about the structural drivers of the real interest rate and market expectations of future interest rates summarised in a long-term level for the policy rate. This is an advantage over other common approaches that use more limited information about the trend or assume that the trend level is constant.

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1 Introduction

The objective of monetary policy in Sweden is to maintain sustainably low and stable inflation; in concrete terms a CPIF inflation rate of 2 per cent. As it takes time for monetary policy to fully affect the real economy and inflation, monetary policy is guided by forecasts of economic developments. The forecast of the Riksbank's policy rate is an assessment of the policy rate required for inflation to reach the inflation target within a reasonable time, also giving consideration to real economic developments.[2] To make this assessment, one needs to consider what level of the policy rate is normal in the sense that it is roughly compatible with a normal resource utilization and inflation on target, which can be interpreted as the level of the policy rate, say, 3-10 years ahead. This long-term level of the policy rate is determined by various structural factors that are beyond the control of central banks, and it can vary over time. Distinguishing which economic fluctuations in the policy rate and other variables are cyclical and which are of a more structural nature is a key element in understanding the driving forces behind economic developments and thus also the design of monetary policy.

Before the rise in inflation and interest rates in recent years, real interest rates in Sweden as well as in many other countries had been trending downwards for several decades, and the literature discussing the causes of the decline has by now become extensive.[3] Since inflation expectations (and inflation) in many countries have been relatively stationary over this period, the declines in nominal and real interest rates have been of roughly the same magnitude.[4] The downward trend in interest rates has undoubtedly complicated the assessment of what is a normal level for the policy rate, and central banks and other analysts have revised their view of this downwards over time.[5] This has also meant that it has been difficult to make accurate policy rate forecasts, and instead, in the period following the global financial crisis of 2007-2009, forecasts have typically been too high.[6] The biggest part of these systematic forecasting errors are probably related to misjudgements of the trend level of real interest rates.[7]

[2] See Nyman and Söderström (2016) for a discussion of how the Riksbank's inflation target affects the forecasts for inflation and the policy rate.

[3] See Lundvall (2023) and Flodberg (2024) for a review of different explanations and for references to this literature. Structural explanations for lower real interest rates highlighted in the literature include various demographic factors, lower productivity growth, higher demand for safe assets, high savings in China, increased inequality and lower investment demand.

[4] See, for example, Bean et al. (2015).

[5] Flodberg (2024) shows how the Riksbank, the Federal Reserve, the Bank of Canada and Norges bank have revised down their views on the long-term level of the policy rate in their respective countries over the past 20 years. See also Sveriges Riksbank (2024).

[6] See Alsterlind (2017), who shows that all forecasters have made too high forecasts of the policy rate in Sweden during the period 2007-2016 and that the forecast errors have been similar in other countries where the central bank publishes a forecast for the policy rate.

[7] Another possible contributory explanation is that negative shocks to the economy have been more common than positive ones in the period following the global financial crisis of 2007-09. The exception is the rise in inflation in recent years, where positive and large shocks to inflation have instead implied that interest rate forecasts have been too low. Here, however, the size of the shock and the large errors in forecasting inflation appear to have been the dominant reason for the interest rate forecasts being too low, rather than misjudgements about the trend level of real interest rates.

In this Staff Memo, we show how to incorporate and estimate a time-varying trend for the real interest rate in the Riksbank's macroeconomic model MAJA (Model for General Equilibrium Analysis) in a simple and practically useful way.[8] We discuss how this can help the Riksbank to make more accurate policy rate forecasts and to understand the driving forces behind economic developments. In this Staff Memo, we do not go through the different building blocks of the model but focus on the implications of the assumption of a time-varying interest rate trend for the properties of the model and how the model can be used in practice.[9] Our approach is broadly in line with the research on estimating the trend in real interest rates (or the neutral real interest rate trend) in so-called semi-structural macroeconomic models.[10] More generally, our paper is related to the literature on more realistic modelling of trends in general equilibrium models aimed at making these models more empirically relevant.[11]

The semi-structural approach is *one* useful way to get an idea of what the real interest rate trend has been historically and its level today. However, when forecasting the policy rate, it is beneficial to be able to use as much information as possible to assess its long-term level. An advantage of modelling the real interest rate trend in MAJA is that we can use several common sources of information on the trend level of the real interest rate when we make forecasts with the model: the model's own estimated trend level for the real interest rate, which is based on macroeconomic data for Sweden and abroad, and an assumption of the normal level of the real interest rate in the somewhat longer term. The longer-term assumption is based on data on the (mainly global) structural factors that are assumed to affect the real interest rate in the long term, the judgements of other central banks and market expectations of future interest rates. Our analysis shows that using different types of information on the trend level of real interest rates can help to make better forecasts of the policy rate.

Our main conclusions are as follows. 1) MAJA with a time-varying real interest rate trend is preferable to a model without such a trend according to standard model evaluation criteria. The former can capture the downward trend in the real interest rate and typically makes better forecasts of the policy rate. 2) We also show that our estimate of the trend is robust to different assumptions and that we have enough information in the data to estimate it.[12] Furthermore, the model with a time-varying real

[8] It is a common assumption in general equilibrium (or DSGE) models – which is the class of models to which MAJA belongs, as we discuss in more detail below – that the real interest rate is assumed to move around a long-run equilibrium that does not vary over time. See, for example, Smets and Wouters (2003), Adolfson et al. (2007) and Christiano et al. (2011), for examples of models in the DSGE literature that have been influential in the field and have also had a bearing on the Riksbank's monetary policy analysis.

[9] See Corbo and Strid (2020) for a presentation of MAJA.

[10] See, for example, Laubach and Williams (2016), Holston et al. (2017) and Berger and Kempa (2014). We choose to use the concept of "trend real rate" instead of "trend component of the neutral rate" here because we do not focus on the metric’s potential usefulness as a measure of the monetary policy stance, i.e. whether it is expansionary or contractionary. Holston et al. (2017), for example, state that they estimate the "highly persistent component", or "lower frequency component", of the natural rate. These descriptions also fit our measure. See also Kiley (2020) for a clarifying discussion of the concept of "neutral interest rate".

[11] See, for example, Lafourcade et al. (2012), Canova (2014 and 2019) and Coletti (2023). In general equilibrium models, it has been common practice to detrend variables before analysing them with the model, rather than modelling the trends explicitly within the model.

[12] We show that our estimate fulfils the basic requirement of recoverability highlighted in recent research on the estimation of unobservables in unobserved component (UC) models, see Buncic et al. (2024).

interest rate trend better captures the systematic component of monetary policy, while the model without such a trend attributes a larger share of the variations in the policy rate to monetary policy shocks. 4) Finally, our model of the trend component of the policy rate is well suited to practical forecasting and policy work. It is simple and flexible and could be used to forecast the policy rate even with simpler time series models than MAJA. In other words, it can serve as a more general, and very simple, framework for forecasting the policy rate and its trend component.

2 A trend for the real interest rate in a macroeconomic model

In this chapter we show how to introduce a time-varying trend in the real interest rate into a so-called dynamic stochastic general equilibrium (DSGE) model. We focus on the Riksbank's macroeconomic model MAJA, which is an estimated DSGE model for Sweden and its main trading partners, the euro area and the United States.

It is common to divide macroeconomic variables into two components, trend and cycle (or gap). Some variables, such as interest rates, are usually assumed to move around a constant equilibrium level, or *steady state*, meaning that all variation in the variable is captured by the cyclical component.[13] Other variables, such as GDP, are assumed to grow over time along an equilibrium trend. DSGE models are primarily designed to study cyclical variations, i.e. the relationships between the cyclical components of different variables. However, since the assumptions made about trends interact with the business cycle analysis, it has become increasingly common to integrate trend assumptions into DSGE models and estimate the two components simultaneously.[14]

The purpose of introducing a time-varying trend for the real interest rate in MAJA is to be able to capture the (downward) trend in the real interest rate since the 1990s, and thereby also improve the model's policy rate forecasts and interpretations of cyclical fluctuations. A longer and more detailed presentation of both the model as a whole and the modelling of the trend in the real interest rate is given in Corbo and Strid (2020). Here, we provide a brief and somewhat simplified presentation to highlight the main ideas.

In the model, various economic decisions, such as households' decisions on how much to consume and save, are influenced by the real interest rate (r), which is the difference between the policy rate (R) and expected inflation (π),

[13] In the model, which is based on economic theory, the equilibrium level of the real interest rate is determined by the average growth rate of the economy and the discount factor (which is intended to capture how much higher we value the present compared to what we expect at different points in the future) – both constant, so that the interest rate trend is stationary. Over very long periods of time, real interest rates have also been effectively stationary; see Del Negro et al. (2019), which looks at how global interest rate trends have developed from the 1870s onwards. However, over shorter samples, interest rates may exhibit a trend, such as during the inflation-targeting period, which is the period we focus on.

[14] This means that the DSGE model can be regarded as an advanced tool for a trend-cycle decomposition. See, for example, Lafourcade et al. (2012) for a discussion on modelling trends in DSGE models.

$$r_t = R_t - E_t \pi_{t+1}, \tag{1}$$

in relation to what is perceived to be a normal level for it – a real interest rate gap.[15] If the normal level of the real interest rate is assumed to be constant, decisions are thus affected by the following real interest rate gap

$$r_t^g = r_t - r, \tag{2}$$

where r is the steady state of the real interest rate. For example, a positive (negative) real interest rate gap is associated with a lower (higher) consumption gap and a higher (lower) expected consumption growth (via the Euler equation).[16] We now instead let the normal level be time-varying so that the real interest rate gap is

$$r_t^g = r_t - r_t^{tr}, \tag{3}$$

where r_t^{tr} is the trend of the real interest rate. Since real interest rates have fallen globally and since Sweden is a small open economy with free capital movement and extensive international trade, it is reasonable to assume that the trend in the real interest rate is largely driven by global factors.[17] Here we make the simplifying assumption that the trend in the Swedish real interest rate is equal to the trend in the real interest rate abroad:

$$r_t^{tr} = r_t^{tr,f}. \tag{4}$$

It is common to attribute the trend in real interest rates to various structural factors, such as productivity growth or demographic factors.[18] To further simplify the presentation, we choose here to model the trend in the real interest rate as an exogenous process (an AR(1) process), which is then assumed to capture all structural factors that affect the trend:

$$r_t^{tr,f} = r + z_t; \;\; z_t = \rho_z z_{t-1} + \sigma_z \, \varepsilon_{z,t}, \tag{5}$$

where $\varepsilon_{z,t}$ is an innovation to the trend that is assumed to be standard normal distributed. Our modelling of the real interest rate trend is therefore reminiscent of how the

[15] In a simple model, there is usually only one interest rate in the economy. This is the central bank's policy rate and also the rate on which all economic agents base their decisions. In reality, of course, economic agents face a range of different interest rates, depending on the degree of risk, whether they are savings or borrowing rates, etc. Even in a more complex model, such as MAJA, it is assumed that different agents face different interest rates. Moreover, the model includes two different economies (Sweden and the trade-weighted rest-of-the-world), and interest rates differ between the two. However, all interest rates co-vary over time with the central bank's policy rate and are driven by the same trend. In MAJA, it is also assumed that the interest rate trend is global, i.e. common to both economies.

[16] The consumption gap is the deviation of consumption from its trend.

[17] See Del Negro et al. (2019) for a long-term and global perspective on interest rate trends. One of its conclusions is that increasingly integrated international capital markets have led to global factors being an increasingly dominant driver of real interest rate trends across countries from the 1980s onwards. In the shorter term, however, it is reasonable to assume that there are other, and sometimes country- or region-specific, driving forces behind more transitory movements in interest rate trends; see, for example, Platzer et al. (2022) and Flodberg (2024) for a discussion.

[18] A discussion of the driving forces behind trends in the real interest rate and the associated academic literature can be found in, for example, Lundvall (2023).

real interest rate trend is usually modelled in semi-structural models.[19] Allowing the trend to be exogenous means that we will not be able to use the model to say anything about the driving forces behind the trend (which is not our purpose either) and that it is not affected by other shocks or variables in the model. We also note that the usual assumption of a constant trend rate is obtained by letting $\rho_z = 0$ and $\sigma_z = 0$ (so that $z_t = 0$), which also means that it is easy to test whether there is statistical support for the time-varying real interest rate trend when the model is estimated on data.[20]

We further assume that the trend in real interest rates is stationary, i.e. that $\rho_z < 1$.[21,22] With this assumption, we need to distinguish between the trend level of the real interest rate, r_t^{tr}, and its long-term equilibrium level (or steady state), r. We argue later that it allows us to, in practice, weigh different sources of information on the trend level of real interest rates when making forecasts with the model (see further discussion in Section 4 below).

Our central assumption above is thus that the economic decisions made by different agents in the economy are influenced by the real interest rate in relation to a trend level that is allowed to vary over time (instead of a constant level). This means, for example, that a given level of the real interest rate has different implications for households' consumption and savings decisions at different points in time historically, as the reference point for what is a normal level of the real interest rate has changed over time. It also means that the impact of a given policy rate level on the economy has varied over time.[23]

The central bank in the model sets the policy rate based on what is perceived to be a normal level for the policy rate and the deviations of unemployment and inflation from their normal levels, a so-called reaction function or Taylor rule. We assume that the central bank, like households and firms, takes the trend in real interest rates into

[19] See, for example, Laubach and Williams (2003), Laubach and Williams (2016), and Holston, Laubach and Williams (2017). Like us, Kiley (2020) chooses to model the trend interest rate as an exogenous process, while Pescatori and Turunen (2016) allow the trend to be affected by a larger number of explanatory variables. Corbo and Strid (2020) also allow productivity growth and the difference between a corporate borrowing rate and the policy rate (a so-called risk premium) to affect the trend in the real interest rate, which also means that there is some difference between the trends for Sweden and abroad. However, they find that productivity growth has no important impact on the real interest rate trend; see also Hamilton et al. (2015) for a discussion of the weak relationship between real interest rates and GDP growth in cross-sectional data for a large number of countries. As these differences in the specification of the real interest rate trend have no important bearing on the analysis and conclusions of this Staff Memo, we disregard them here.

[20] The model without a real interest rate trend is thus nested in the model with a real interest rate trend.

[21] In the econometric literature, the term "trend" is generally used for stochastic processes that are non-stationary, see for example Harvey (1989). With an augmented Dickey-Fuller (ADF) unit root test, we cannot reject the zero hypothesis that the real interest rate has a unit root. However, on the other hand the unit root is not structural. See, for example, Mosconi and Paruolos (2022) interview with Katarina Juselius for reasoning on the choice of modelling a process as I(0) or close to I(1).

[22] For example, Laubach and Williams (2003) assume that the neutral rate is a sum of two I(1) components of productivity growth and a residual (the "z term"), respectively, and is thus non-stationary. Lewis and Vazquez-Grande (2019) investigate how different assumptions about the neutral rate in Laubach and Wiliams' model affect the estimation and find that a stationary specification of the process for z is preferable to a non-stationary one on statistical grounds.

[23] There are, of course, other reasons why the effects of a policy rate change may change over time than those explicitly modelled in MAJA, such as increased interest rate sensitivity as a result of increased indebtedness. See, for example, Berggren et al. (2024) and references therein.

account when making its policy rate decisions. We do this by letting the normal level of the policy rate (the intercept in the Taylor rule) be given by

$$R_t^{tr} = r_t^{tr} + \pi \quad (6)$$

where $\pi = 2\%$ is the central bank's inflation target. This is thus the level of the policy rate that the central bank sets when resource utilisation and inflation are close to their normal levels, what we call the trend level of the policy rate.[24] More generally, we can interpret the estimated level of r_t^{tr} as the level that best fits the observed data and the model of the economy. The trend is mainly identified by the variables included in the reaction functions for central banks abroad and Sweden in the model, i.e. data on the policy rate, inflation and unemployment for the euro area, the United States and Sweden, respectively.[25] Since the real interest rate trend, like all other trends such as potential GDP, is unobservable, it is assumed that the agents in the model estimate it based on their understanding of how the economy works and on the data. Since agents are assumed to have rational, i.e. model-consistent, expectations, the agents' view of the functioning of the economy is the same as that of the model.

An important consequence of our assumption about monetary policy is that a shock to the trend of real interest rates ($\varepsilon_{z,t}$) has no effect on variables other than interest rates in the model – since the interest rate trend R_t^{tr} is the intercept of the Taylor rule, monetary policy is assumed to adjust to neutralise the effects of these shocks. If the trend level of the real interest rate falls and the central bank, on the other hand, *does not* fully take this into account when setting the policy rate, the real interest rate gap will be higher. This will have contractionary effects on resource utilisation and inflation (a negative demand shock), which in turn, and with some delay, leads to a reduction in the policy rate. But if, as we assume, the central bank adjusts the policy rate in line with the fall in the trend level of the real interest rate, the real interest rate gap is not affected and thus the shock has no impact on other variables.[26] The fact that the real interest rate trend in Sweden is assumed to follow that in the rest of the world also means that it does not affect the real exchange rate.[27] The responses to a shock to the real interest rate trend ($\varepsilon_{z,t}$,) under these two assumptions about the behaviour of monetary policy are shown in Section A of the Appendix. As regards

[24] This also implies that the trend level of the real interest rate can be interpreted as *a neutral level in the longer run* in the sense that it is the level consistent with normal resource utilisation and inflation on target, corresponding to a situation where the effects of cyclical shocks on the economy have dissipated. This interpretation is in line with that of Kiley (2020), for example.

[25] The identification of the trend can be described as "indirect" in the sense that we do not use direct data on the structural factors that determine the trend level of real interest rates. See, for example, Taylor and Wieland (2016) for an intuitive discussion of trend rate identification in semi-structural models. Thus, even if the trend in real interest rates is assumed in our model to be determined globally, data for Sweden can provide us with information about its level.

[26] There is no doubt that central banks have adapted to structurally lower real interest rates. However, it is of course debatable how quickly this happens in practice and our assumption should be seen as a simplification.

[27] A shock to the real interest rate trend affects real interest rates in Sweden and abroad in the same way and, according to the real interest rate parity condition in the model, the real exchange rate is then not affected.

other shocks in the model, the reverse is true – they are assumed to affect the real interest rate gap but not the trend level of the real interest rate. These shorter-term shocks are then assumed to influence monetary policy via their effects on resource utilisation and inflation.

3 Forecasts and interpretations of economic fluctuations

3.1 Calibration and estimation of the model's parameters

We estimate MAJA using two different assumptions about the real interest rate trend (with and without a time-varying trend) and then compare the forecasting performance of the two models. In the latter case, we therefore assume $\rho_z = 0$ and $\sigma_z = 0$ so that $z_t = 0$, which implies that the trend component of the real interest rate is constant, $r_t^{tr,f} = r$. The estimation method essentially follows that of Corbo and Strid (2020), with the most significant difference being that here we extend the sample period to Q4 2023 (instead of Q4 2018 as in the previous estimation). We do not present the estimated parameters in detail here but focus entirely on the parts that concern the real interest rate trend. In Section B of the appendix, we provide more information on the estimation and, in Section C of the appendix, we also present an analysis of how sensitive the estimation of the real interest rate trend is to alternative assumptions about its specification.

We assume that the constant steady state level of the real policy rate is $r = 0.5$ per cent and that the normal level of inflation is 2 per cent, in line with the inflation target, so that the steady state level of the policy rate is 2.5 per cent. We choose this value for the policy rate's steady state as it is roughly in line with the Riksbank's assessment of the long-term level of the policy rate over the past five years.[28] Our estimation of the real interest rate trend yields a very persistent process – we have $\rho_z = 0.995$, which means that the process for the real interest rate trend is a near unit root. Of course, this also means that the model with a real interest rate trend is preferred on statistical grounds.[29] Furthermore, an important consequence of this parameter estimate is that the forecast of the trend level of the real interest rate will be close to a random walk.

[28] In 2017, the Riksbank communicated a range for the long-term policy rate between 2.5 and 4.0 per cent and, in 2019 and 2022, it communicated that the level is likely to be at the lower end, or slightly below, the range from 2017; see Sveriges Riksbank (2017, 2019 and 2022). At the end of 2024, the Riksbank communicated a range for the long-term policy rate of between 1.5 and 3.0 per cent; see Seim (2024) and Sveriges Riksbank (2024). Our assumption is also in line with other central banks' assumptions about the long-term level of the policy rate over the past decade; see Flodberg (2024) and Sveriges Riksbank (2024).

[29] A standard model comparison of the log marginal likelihood of the two models yields a log Bayes factor in the magnitude of 54, which means that the model with a real interest rate trend is strongly preferred. This result is also in line with Cúrdia et al. (2015), who show that, for a New Keynesian model estimated using US data, a specification in which monetary policy is assumed to follow the neutral interest rate is preferred.

3.2 The estimated real interest rate trend

Recent research has shown that the ability to reliably estimate the trend in real interest rates (or latent variables more generally) varies considerably across models. This can be investigated using statistical measures of recoverability that measure the population correlation between the true latent variable and the smoothed estimate of it. A value close to 0 means that the model is unable to estimate the latent variable, while a value closer to 1 means that it is possible to recover the variable. For the change in the real interest rate trend in MAJA, the correlation is 0.94, implying a good ability to estimate this variable with the model.[30]

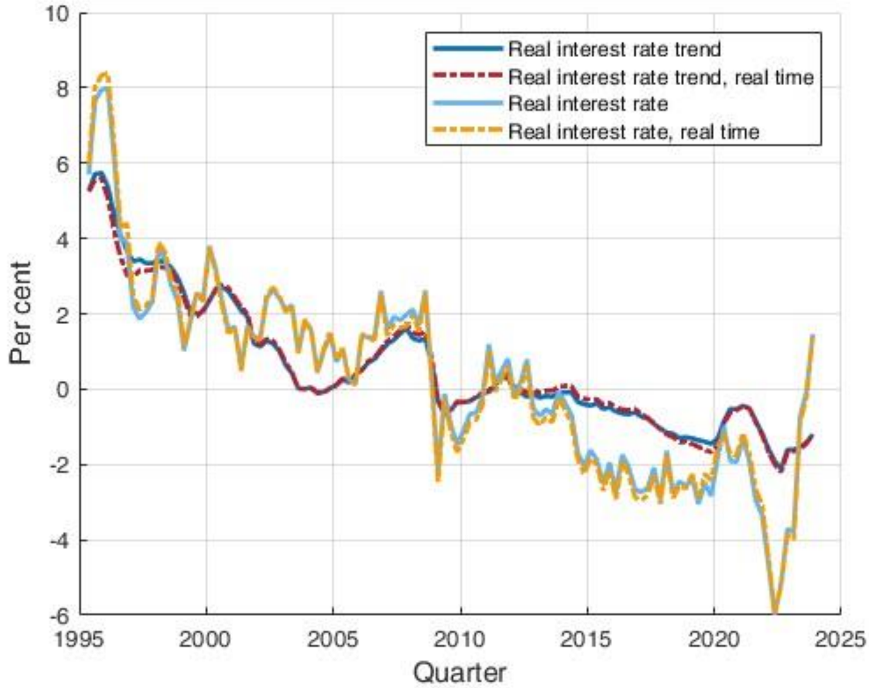
Figure 10 shows the real policy rate (see Equation 1) and the estimated real interest rate trend. We show an estimate using data for the entire sample period and an estimate based on data available at a specific point in time (labelled "real time").[31] We see that the trend level of the real interest rate has moved from a level of around 2 per cent in the early 2000s to negative levels over the past decade. We also see that the real-time estimate is in line with the estimate based on data for the entire sample period, which can be interpreted as meaning that it is possible for economic agents to detect changes in the trend level of the real interest rate when they occur. Our estimated trend for the real interest rate is also broadly in line with other estimates for Sweden and other countries using similar methods.[32]

[30] See Buncic et al. (2024). For example, they show that this correlation is 0.1-0.2 for different variants of the Laubach and Williams model, which means that there is insufficient information to estimate the trend rate reliably with this model. We simulate a sample of length 10,000 observations from MAJA for the posterior mode parameter vector. We then estimate the model's latent variables (using the state smoother and the innovation smoother) and calculate the correlation between the true (i.e. simulated) and the estimated change in the real interest rate trend.

[31] We show an estimate based on data for the entire sample period 1995Q2-2023Q4, $r_{t|T}^{tr,f} = E\left(r_t^{tr,f}|D_{1:T}\right)$, where D denotes data in the model and T=2023Q4, a so-called "smoothed estimate", and a so-called "filtered estimate" (or real-time estimate), $r_{t|t}^{tr,f} = E\left(r_t^{tr,f}|D_{1:t}\right)$, based on data at the current time. These are estimated using the Kalman filter and the state smoother respectively.

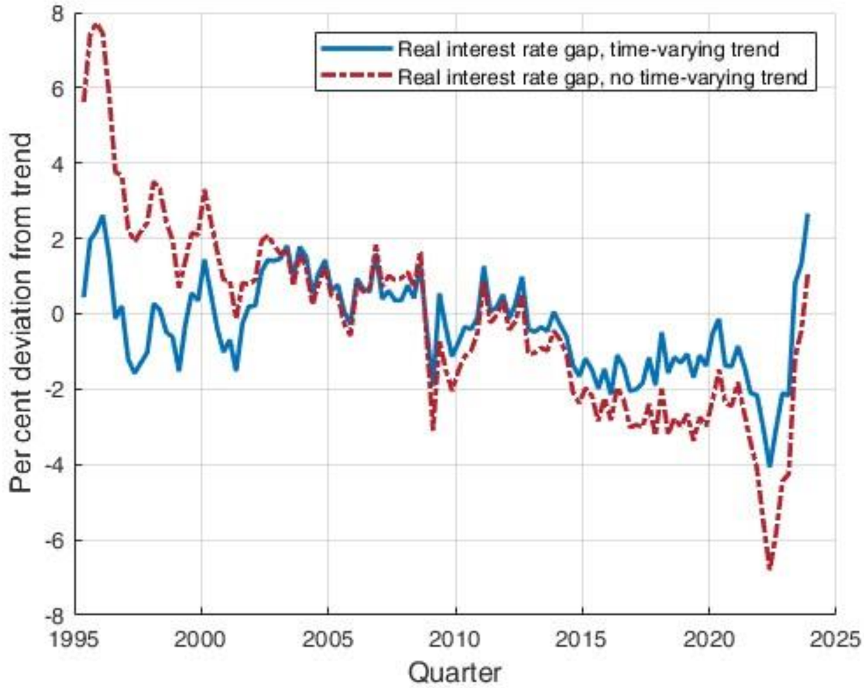
[32] See, for example, Armelius et al. (2018) and Armelius et al. (2024) for Sweden and Meyer et al. (2022) for Norway.

Figure 1. Real interest rate trend in MAJA, 1995-2023



In Figure 20, the real interest rate gap, the difference between the real interest rate and its trend level, is shown in the models with and without a time-varying real interest rate trend. In the model without a time-varying trend, the real interest rate gap evolves in line with the real interest rate because the trend level is assumed to be constant (see red line). In the model with a time-varying trend, the trend captures a larger part of the variation in the real interest rate so that the gap becomes smaller (in absolute terms) and looks more stationary (see blue line). The time-varying trend in the real interest rate therefore makes it easier to rationalise, for example, that the GDP gap and inflation have been stationary despite the downward trend in real interest rates.

Figure 2. Real interest rate gap in MAJA with and without a time-varying real interest rate trend



3.3 Forecast evaluation

In this section, we compare the forecasts from the models with and without a time-varying trend for the real interest rate. We choose to start the forecast evaluation in the mid-2010s, as the issue of a downward trend in interest rates received more attention then.[33]

We make forecasts with the first forecast quarter Q1 2015-Q1 2022 and thus two years ahead for the period Q4 2016-Q4 2023. The forecasts differ from real-time forecasts in two respects and can therefore be labelled pseudo out-of-sample forecasts. First, the model's parameters are estimated using data up to Q4 2023 and, second, we do not use real-time data – i.e. the data available at the time of each forecast – to generate the forecasts but instead use a vintage of data available in 2024. Our judgement is that these simplifications are unlikely to have a major impact on our results or conclusions.[34]

To understand the impact of the real interest rate trend on the policy rate forecast, we can express the forecast for the trend h quarters ahead, $r^{tr}_{t+h|t}$, as a weighted

[33] One article that was highly influential at this time was Rachel and Smith (2015). See also, for example, Armelius et al. (2018) for a discussion of the neutral interest rate in Sweden at that time and Yellen (2015, 2017) for discussions of the neutral interest rate in the United States.

[34] When we estimate MAJA for samples ending with the quarters Q4 2019 and Q4 2023, we see no major differences in the parameter estimates. Furthermore, both the policy rate, i.e. the variable we focus on here, and CPIF inflation (the variable that is most important for the level of the policy rate) are variables that are not revised over time.

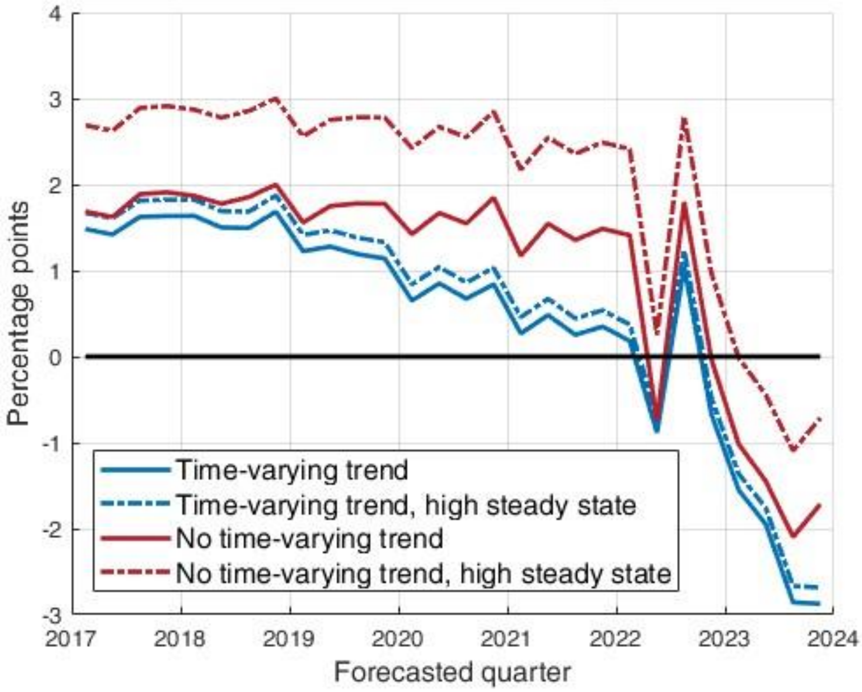
mean value of the estimated trend level at the time of the forecast, $r_{t|t}^{tr}$, and the steady state level, r:

$$r_{t+h|t}^{tr} = \rho^h r_{t|t}^{tr} + (1 - \rho^h) r \quad (7)$$

where $\rho = \rho_z$ is the persistence in the real interest rate trend since we assume it is given by the AR(1) process in Equation 5. In the model without a time-varying real interest rate trend, we have $r_{t+h|t}^{tr} = r_{t|t}^{tr} = r$ because the trend level is assumed to be constant. In the model with a time-varying real interest rate trend, the weights, and hence the forecast of the real interest rate trend, will depend on the estimated persistence. With a very high estimated persistence, close to 1, we then have $r_{t+h|t}^{tr} \approx r_{t|t}^{tr}$ for the forecast horizons we are interested in. The forecasts for the real interest rate trend with $\rho \ll 1$ and $\rho \approx 1$ could be described as mean reverting and random walk forecasts respectively, where the latter case is what we obtain when the model is estimated on data.[35] The forecast for the real policy rate, in turn, moves towards the forecast for the trend in real interest rates. In the model without a time-varying real interest rate trend, the forecast for the real policy rate will typically approach the constant steady state level relatively quickly.

[35] One way to describe the speed of the return to steady state is in terms of the half-life, $-\frac{ln(2)}{\ln(\rho)}$. . For example, if ρ =0.84, half the distance between the current level, $r_{t|t}^{tr}$, and the steady-state level, r, will have closed after about four quarters.

Figure 3. Forecast errors for policy rate forecasts two years ahead with different assumptions of the real interest rate trend in MAJA



In Figure 30, we show the forecast errors (forecast minus outcome) for the two-years-ahead policy rate forecasts using the two models.[36] The models make relatively similar forecasts for unemployment (our measure of resource utilisation) and CPIF inflation, and the differences in the policy rate forecasts are therefore largely due to the differences in the forecasts for the trend level of the real interest rate. We see that the model with a time-varying real interest rate trend (solid blue line) has a smaller forecast error than the model without a time-varying trend (solid red line) during the period when the policy rate was persistently low, up to and including 2022. The estimation of a negative level for the trend level of the real interest rate during this period (see Figure 10) and the random walk component of the trend component of the policy rate forecast (R_t^{tr}) thus benefited the accuracy of the forecasts during the period when the policy rate was relatively unchanged.[37]

In six of the seven years that we study, the model with a time-varying real interest rate trend thus makes more accurate forecasts of the policy rate. But in the last year of our evaluation, 2023, the reverse is true – the forecast errors of the model with a time-varying real interest rate trend (solid blue line) are then larger than the forecast errors of the model without a time-varying trend (solid red line). However, the main explanation for this is not linked to the trend in real interest rates but to the interest rate gap in the model. In 2021, when the forecasts for 2023 shown in Figure 3 were

[36] Forecasts are shown in section D of the appendix. We get a similar picture of the relative accuracy of the models if we study the forecasts one year ahead, for example.

[37] A similar conclusion is drawn by Alsterlind (2017), who examines the forecasting performance of a persistent AR(1) model for the policy rate and finds that it has made relatively good forecasts during the period of falling interest rates.

made, inflation in many countries rose rapidly to high levels, surprising most forecasters, and many central banks raised their policy rates as a result.[38] We see that both models have large negative forecast errors, which means that the outcomes for the policy rate in 2023 were significantly higher than the forecasts made by the models two years earlier. In the model without a time-varying trend, the forecast error for this particular episode was smaller. This occurs since using this approach the interest rate is expected to quickly return to its steady state level, which has long been higher than the estimated trend.

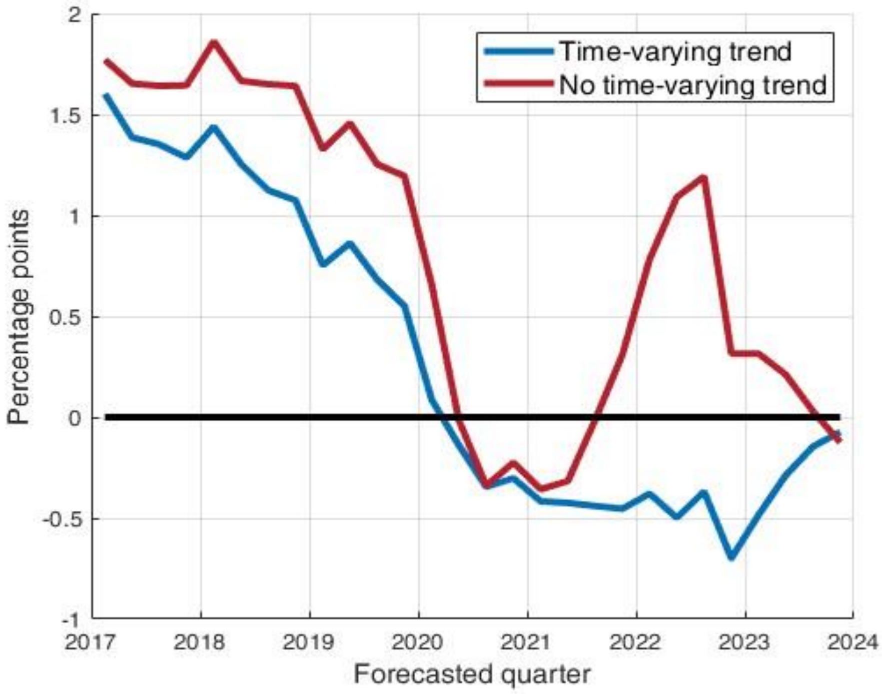
For 2023, the forecast errors for the policy rate thus primarily reflect the forecast errors for inflation. One way of illustrating the importance of forecast errors in other variables for the forecast errors for the policy rate is with so-called conditional forecasts.[39] In Figure 40, we show the forecast errors for the policy rate when we give the model perfect information about future inflation developments in Sweden and abroad. We see that the forecast errors for both models are, on average, smaller than the forecast errors shown in Figure 30, which is not surprising as they are now conditioned on outcomes for inflation. We also see that the forecast errors for the model with a time-varying trend are smaller than those for the model without a time-varying trend for most forecast dates.[40] Overall, this reinforces the view that the model with a time-varying trend for the real interest rate generally makes better forecasts of the policy rate.

[38] Håkanson and Laséen (2024) show that neither central banks nor other forecasters anticipated the rapid rise in inflation and that the forecast errors were therefore large.

[39] A conditional model forecast involves making assumptions about the forecast paths of a number of variables in the model and treating these as data. Our analysis is conditional on outcomes for a selection of variables, which generally improves forecasting performance. See Ringqvist et al. (2020) for a discussion on conditional forecasting with MAJA.

[40] We choose here to use the development of inflation abroad and in Sweden and, in addition, a number of international variables as conditioning variables. We have studied different assumptions for the set of conditioning variables and conclude that the model with a time-varying trend for the real interest rate generally makes better policy rate forecasts.

Figure 4. Forecast errors for conditional policy rate forecasts two years ahead with different assumptions about the real interest rate trend in MAJA



In Figure 30 we also show the forecast errors when we assume a higher steady state level for the policy rate in both models. This exercise is interesting because central banks long assumed that the steady state level of the interest rate is relatively high and because a higher level, according to standard theory, is more consistent with our assumptions about normal productivity growth and the level of inflation. We assume here that the steady state level of the policy rate is 3.8 per cent instead of 2.5 per cent.[41] We see that the assumption of the steady state level is important for the forecasting performance of the model without a time-varying real interest rate trend. Assuming a higher steady state, the forecast errors were larger during the period when the policy rate was low (dashed red line). In the model with a time-varying real interest rate trend, the assumption of the steady state level of the interest rate plays a smaller role (dashed blue line). This is due to the high persistence of the real interest rate trend (close to a unit root), which means that the importance of the steady-state level of the policy rate for two-year-ahead forecasts is very limited (with our estimated persistence, the weight on the steady-state level in Equation 7 is about 4 per cent for the two-year forecast).

Finally, we also examine the forecasting performance of three other key variables – GDP growth, CPIF inflation and the change in the real exchange rate – by comparing the root mean square errors of the forecasts of these variables in the two models. We find that the forecasting performance of these variables is broadly similar for the

[41] This is the theoretical steady state value of the policy rate in MAJA when we assume an inflation target of 2 per cent, productivity growth of 1.4 per cent and a discount factor of β=0.999 so that 400ln(β)=-0.4. To obtain a steady state of 2.5 per cent, we have added a so-called excess trend for the policy rate; see Corbo and Strid (2020).

models with and without a time-varying real interest rate trend (see Table 1 in the appendix).

3.4 Decomposition of the policy rate

DSGE models are well suited as tools not only for forecasting but also for interpreting developments in the economy. The variables in the model can be decomposed in different ways so that it becomes clear which driving forces are behind the economic events we observe. How much importance is attached to different driving forces will depend partly on the data used in the model and partly on how the model is specified. Thus, two different model specifications – in our case with or without a time-varying real interest rate trend – will result in two different interpretations of economic developments, even if they use the same data.

In the model, the central bank is assumed to set the policy rate based on what is perceived to be a normal level for the policy rate and the deviations of unemployment and inflation from their normal levels. This kind of reaction function provides a simplified description of how monetary policy is conducted but should explain the vast majority of variations in the policy rate. Of course, deviations from this so-called systematic monetary policy do occur and are referred to in the model as monetary policy shocks. However, provided that monetary policy is conducted in a predictable and credible manner – as the model assumes – monetary policy shocks should not be a dominant driver of policy rate movements if the model is well specified in this respect.

Figures 5 and 6 show decompositions of the policy rate based on the reaction function, in MAJA with and without a time-varying real interest rate trend. The level of the policy rate is then broken down into contributions from inflation, unemployment, the real interest rate trend and monetary policy shocks.[42] We first see that the contributions of inflation and unemployment in the two models are similar, which follows from the fact that the estimated parameters in front of these two variables in the two models are reasonably similar (blue and red bars in Figures 5 and 600).[43] In the model without a time-varying trend, we also see that the contribution from monetary policy shocks is significant – at the end of the 2010s, for example, the contribution is greater than two percentage points (purple bars in Figure 6).[44] The systematic part of the central bank's reaction function simply does not provide a good description of how monetary policy has been conducted in practice. In the model with a time-varying trend, a larger part of the level of the policy rate is instead explained by the trend component and thus, by extension, by the structural factors affecting the real interest rate (yellow

[42] We have interest rate smoothing in the reaction function. We solve the reaction function backwards in time so that the policy rate can be expressed in terms of the contributions from an initial state, a trend component, inflation, unemployment and monetary policy shocks.

[43] The coefficient in front of inflation in the reaction function is estimated to be slightly higher in the model without a time-varying trend (1.6) compared with the model with a time-varying trend (1.4).

[44] The monetary policy shock is modelled as white noise, i.e. without autocorrelation. However, the smoothed estimates in the model without a time-varying trend are negative and highly correlated for long periods, implying that the reaction function is mis-specified.

bars in Figure~~s~~ 5~~ and 6~~0). The contribution of monetary policy shocks is much smaller here.

To summarise, this shows how the interpretation of the monetary policy conducted is affected by trend behaviour. In the model without a time-varying trend, the interpretation is that the policy rate has been at a much lower level for a longer period of time than given by the (systematic part of the) reaction function, which could be interpreted as monetary policy having been much more expansionary than usual.[45] However, in the light of the time-varying trend model, this can rather be seen as an expression of omitted variable bias – the monetary policy shock simply captures variation in the policy rate that should instead be attributed to the structural factors affecting the real interest rate.

[45] It is not only the interpretation of the interest rate that is affected – the drivers that are interpreted also have an effect on all (domestic) variables in the model. For CPIF inflation, for example, monetary policy shocks also become important as drivers – mainly inflationary ones in the latter half of the sample. In order to explain, for example, why inflation was still so low in the second half of the 2010s, the model instead takes into account other shocks that had a restraining effect on inflation. Taken together, the two different models provide different pictures or interpretations of what was going on in the economy as a whole. These interpretations, in turn, have a bearing on how monetary policy should best be designed to meet the inflation target.

Figure 5. Decomposition of the policy rate into the different components of the reaction function in MAJA with time-varying real interest rate trend

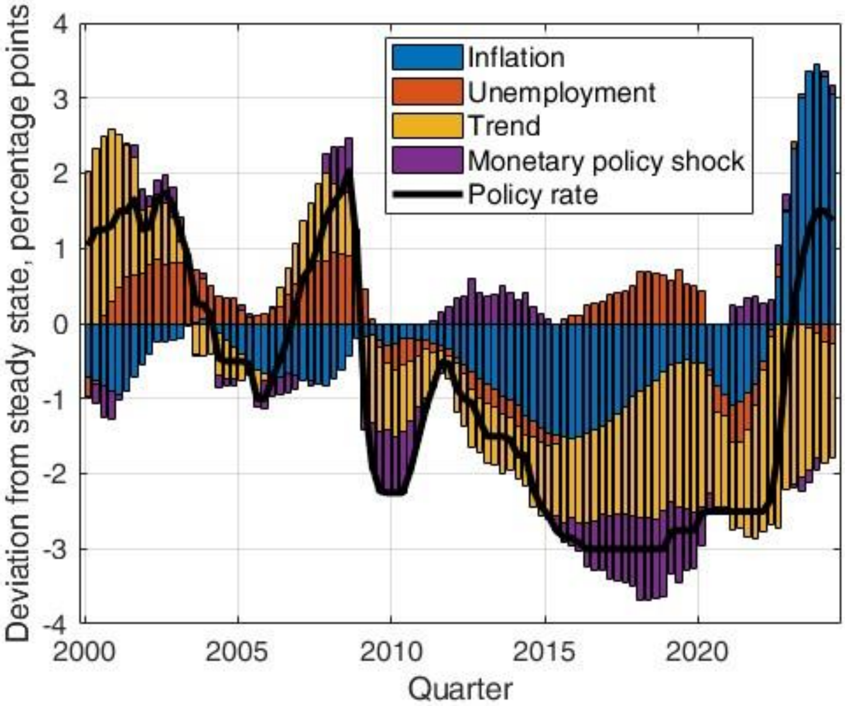
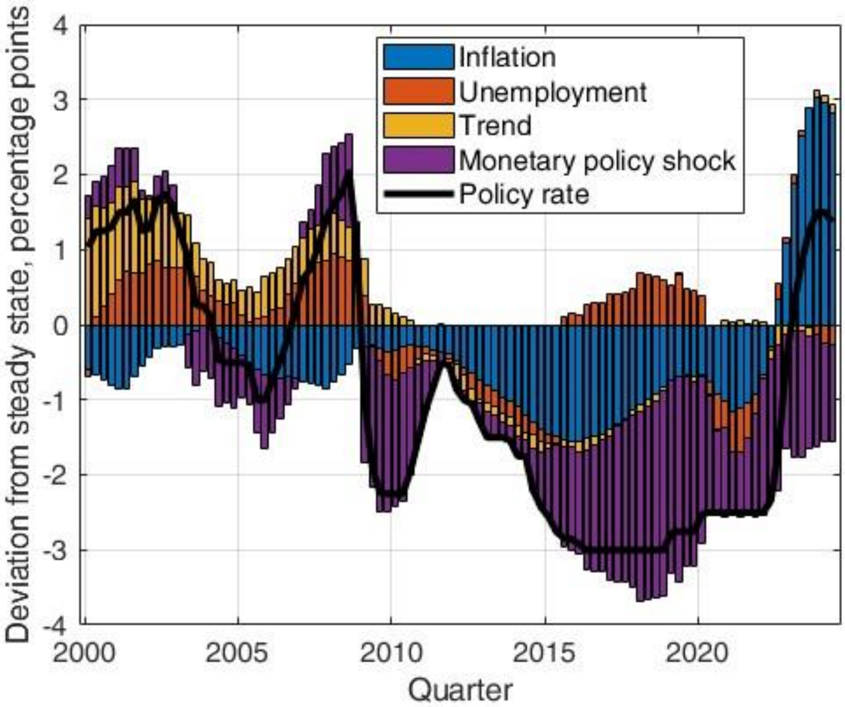


Figure 6. Decomposition of the policy rate into the different components of the reaction function in MAJA without time-varying real interest rate trend



4 How *should* we forecast the trend level of the policy rate with MAJA?

Above, we have compared policy rate forecasts from two estimated versions of MAJA, with and without a time-varying real interest rate trend. The two models can be said to give rise to two extreme forecasts for the real interest rate in the longer term: $r^{tr}_{t+h|t} = r$ (with no time-varying trend) and $r^{tr}_{t+h|t} \approx r^{tr}_{t|t}$ (with a very persistent trend, ρ close to 1). We now propose a forecasting method that involves using the model with a time-varying trend but allowing the persistence of the trend over the forecast period to be lower than the estimated persistence. For example, if we make the assessment that it is likely that the variation and persistence in the real interest rate will be less in the future compared with the situation in recent decades, it may be more reasonable to assume a lower persistence.

One starting point is that central banks, including the Riksbank, make assessments of the long-term equilibrium level of the real interest rate, r, and that it is therefore reasonable to assume that we should have $r^{tr}_{t+h|t} \approx r$ on a medium-term horizon, say 3−10 years. At the same time, the history of systematic over-predictions of policy rates and recurrent downward revisions of the long-term level of the real interest rate, r, in recent decades may argue in favour of allowing the estimation of the real interest rate trend with a macroeconomic model (in our case MAJA), $r^{tr}_{t|t}$, to have some impact on the shorter-term forecast. An important advantage of estimates based on macroeconomic models is that they are likely to be much more nimble than direct estimates based on structural factors.[46] Overall, this favours forecasts in which the level of $r^{tr}_{t|t}$ influences the forecast but the real interest rate trend returns more quickly to the long-term level, r, in the forecasts, meaning one in which the value of the persistence parameter ρ is set lower than the estimated value of the parameter (which is close to 1). This is a pragmatic way of combining multiple sources of information on the long-term level of the policy rate and it is particularly interesting when $r^{tr}_{t|t}$ differs from r.

In Figure 70, we illustrate how the forecast for the real interest rate trend and the policy rate is affected when we vary the persistence, ρ, of the real interest rate trend. For all forecasts, we assume that the estimated trend level of the real interest rate in Q4 2023 is $r^{tr}_{23kv4|23kv4} = -1.2$ per cent, in line with the model's estimate shown in Figure 10, meaning that the trend level of the policy rate (see Equation 6) in Q4 2023 is $R^{tr}_{23kv4|23kv4} = (-1.2 + 2) = 0.8$ per cent. We further assume that the real interest rate in the steady state is $r = 0.5$ per cent, so that the steady state level of the policy rate is $R = 2.5$ per cent. We thus have a relatively large deviation between the (time-varying) trend level and the assumed steady state level in the long run. We then make forecasts using the first forecast quarter of Q1 2024 and 5 years ahead. The forecasts from the model without a time-varying trend for the real interest rate are shown in

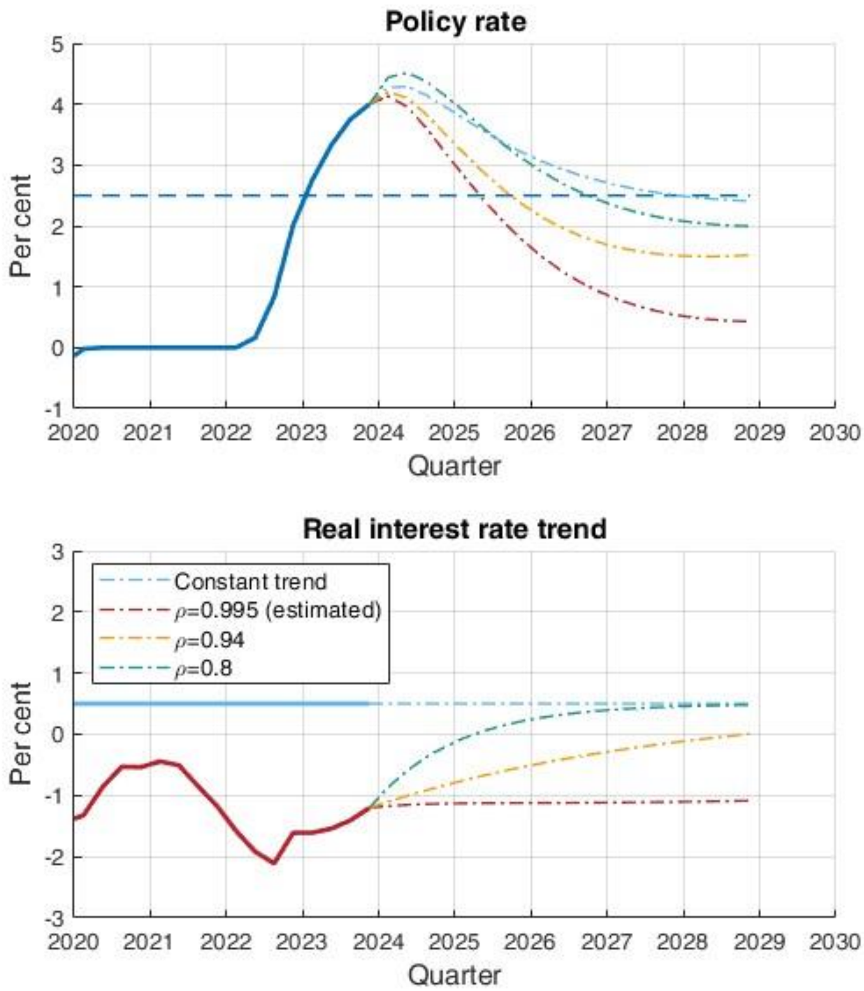
[46] In Figure 1, for example, we see that MAJA's estimate of the trend level of the real policy rate was around 0 during the period 2010-2015, while the Riksbank's assessment of the long-term real policy rate was 1.5–2.5 per cent during this period. As we saw in Section 3.2 above, the model's estimation indicated that it is possible to detect changes in the trend level of real interest rates when they occur.

light blue and we see that the forecast for the policy rate with this assumption reaches the steady state level of 2.5 per cent after 3–4 years. The forecasts from the model with a real interest rate trend and with the estimated persistence parameter are shown in red. Here we see that the forecast for the trend level of the real interest rate is close to a random walk and thus lies close to –1 per cent all the way, which means that the forecast for the policy rate is moving towards around 1 per cent in 5–10 years' time. This forecast can be said to assume that the trend level of real interest rates has, in practice, become permanently negative.

We also show two forecasts in which we lower the persistence of the real interest rate trend in the forecast period. For example, if we let the persistence be $\rho = 0.8$, we see that the trend level of the real interest rate has converged to the steady state level after about three years (green line). The medium-term policy rate forecast then shifts upwards to a similar extent, by around 1.5 percentage points over the 3–5-year horizon compared with the random walk forecast. If we instead assume $\rho = 0.94$, we obtain a forecast that is roughly midway between the two extreme forecasts after 5 years (yellow line). None of the forecasts for the trend in the real interest rate shown in the chart can be said to be manifestly implausible.[47] The different policy rate paths shown can therefore be said to reflect the uncertainty that naturally follows from the uncertainty about the future trend development of real interest rates. In practice, a forecast of the real interest rate trend somewhere between the yellow and green options could be a good starting point for MAJA's forecast, as these forecasts imply that the steady state trend level will be reached in 3-10 years' time.

[47] For example, the IMF (2023) finds that the long-term level of real interest rates in developed countries in 2022 was between –0.7 and –0.7 per cent and that roughly these levels will persist in the coming decades. The range of forecasts for the trend in real interest rates shown in Figure 7 is broadly in line with this assessment. The IMF uses a version of the model in Platzer and Peruffo (2022) in which the trend level of the real interest rate is determined by a large number of structural factors.

Figure 7. Model forecasts for the policy rate in Q4 2023 with different assumptions about the trend level of the real interest rate



Overall, an important advantage of our forecasting method in MAJA is that we weigh together several sources of information on the level of real interest rates in the longer term, summarised in $r_{t|t}^{tr}$ and r respectively. The former is estimated here using MAJA and data on key macroeconomic time series (indirect inference), while estimates of the latter are based on data on the structural factors assumed to affect real interest rates in the longer term and data on market expectations of future interest rates (direct inference). As for the assessment of r, this is naturally based on several different approaches and a large amount of data.[48] However, the estimate of the trend interest rate at present, $r_{t|t}^{tr}$, could also be based on estimates with several different models instead of only MAJA in order to reduce the model uncertainty of the estimate.[49] Being able to make alternative assumptions about the trend interest rate in practical

[48] See Lundvall (2023) and Flodberg (2024) for estimates and further references to the literature.

[49] See, for example, Meyer et al. (2022), who use several semi-structural models and produce an average estimate of the neutral interest rate for Norway. An alternative to using the real interest rate trend estimated in MAJA is to use such an approach to produce an 'external estimate' that can then be used in MAJA for forecasting and policy work in practice. The trend in the real interest rate is then used as data in MAJA, instead of being estimated by the model.

policy work may also be relevant in periods when the economic correlations do not look like usual.[50] A clear example of this was the pandemic, when temporary changes in behaviour and measures such as shutdowns of parts or all of the economy resulted in the usual correlations not holding. In the years when the economy was most affected by the pandemic, 2020–2022, we see that the model estimates a temporary increase in the trend level of the real interest rate (see Figure 10). Specifically, the model sees that the interest rate moved abnormally little given the large decline in economic activity, relative to how it usually moves. To explain this, the interpretation is that the trend level of real interest rates must have risen. However, given the obvious change in the functioning of the economy, there are reasons to make a different assessment of how the trend rate developed in such situations.[51]

Finally, we briefly discuss two practical alternatives to the forecasting model for the trend component of the policy rate presented above. A first option is to make a (near) random walk forecast based on the model's own estimate of the trend level of the real interest rate (see red lines in Figure 7). This is the usual approach in semi-structural models and is based on the assumption that the trend in real interest rates is non-stationary and thus lacks a constant long-run equilibrium level.[52] An obvious drawback of this approach is that it is difficult to condition on external information about the longer-term level of the real policy rate.

A second option is to start from the model without a time-varying trend in real interest rates but to update more frequently the view of the steady-state level of real interest rates in order to avoid large and persistent deviations between the actual level of real interest rates and the assumed steady-state level. In practice, this means using a steady state assumption that puts more weight on more recent data, what we might call a 'forward-looking steady state'. A drawback of this approach remains that the downward trend in the real interest rate during the data period cannot be handled and that the model's interpretation of history is therefore less reliable. Such an approach may also be problematic if it is used in estimating the parameters of the model.

[50] The estimation of macroeconomic models such as MAJA assumes that the fundamental relationships in the economy are persistent over time, including how monetary policy responds to movements in inflation and resource utilisation or economic activity. The relationship between different variables in the economy is constantly changing as the economy is affected by different types of economic shocks at different times. What is constant is how the different actors in the economy make their decisions and shape their expectations, i.e. that households optimise their utility, firms maximise their profits and the central bank adjusts monetary policy to meet the inflation target and preserve its credibility – so-called micro-fundamentals.

[51] In special situations where the basic correlations of the model do not apply, the interpretation is thus misleading. This is not specific to MAJA but applies to all models using indirect inference. For example, the New York Fed has regularly published estimates of the trend interest rate using the Laubach and Williams model but temporarily stopped doing so during the pandemic because the estimates were no longer deemed reliable. Given the way the real interest rate trend in MAJA is constructed, it is easy in practice to use other measures for the trend than the model's own, for sensitivity analyses or when the model's basic assumptions are not deemed to hold.

[52] This means that the trend level today is defined as the long-term (infinite horizon) forecast of the real interest rate, which is consistent with Beveridge and Nelson's (1981) decomposition. Even if we assume that the real interest rate trend is stationary, the forecast with our estimated, very high, persistence becomes, in practice, very similar to a random walk forecast.

5 Concluding discussion

Assumptions that the real interest rate would return to a relatively high level contributed to the long period in which many central banks and other analysts over-predicted policy rates. Estimating the trend level of the real interest rate and using it as a starting point for policy rate forecasts has been one way to reduce forecast errors and improve our understanding of economic developments. In this Staff Memo, we have discussed how to incorporate a time-varying trend for the real interest rate into the Riksbank's macroeconomic model MAJA. We have shown that there is sufficient information to estimate the trend reliably with the model, that the model's forecasts of the policy rate are improved and that a larger part of the movements in the policy rate can be explained by the Taylor rule, compared with a model without such a trend.

The practical usefulness of measures of the real interest rate trend level of (or the neutral level of the interest rate) is widely discussed both at central banks and by researchers. The discussion covers both economic-theoretical and econometric issues. The theoretical discussion focuses on different concepts of the neutral interest rate and their usefulness as measures of the stance of monetary policy.[53] The ability of central banks to influence interest rate trends through their monetary policy is also a topic that has been discussed in recent years.[54] However, these discussions primarily revolve around the world's largest economies – for a small, open economy like Sweden, the long-term movements in the real interest rate trend are a largely exogenously given condition to relate to.[55] The econometric discussion includes model specification, estimation methods, information/identification issues and uncertainty in the estimates. Some analysts have concluded that trend measures, such as those derived from semi-structural models, are not useful for practical monetary policy. Recent research highlights that some of the most frequently cited estimates of real interest rate trends are based on too limited information to be reliable.[56] We have shown that estimates using the Riksbank's macroeconomic model MAJA are not sensitive to this criticism. The model uses more information than smaller semi-structural models and the estimates are also robust as regards alternative assumptions about the specification of the trend interest rate. However, as different models are based on different assumptions, the MAJA estimates should be compared with other approaches to provide a broader picture of model uncertainty. Central banks have also emphasised the uncertainty of the measures and taken a cautious stance regarding their usefulness for policy purposes.[57]

[53] See, for example, Taylor and Wieland (2016) for a critical perspective on the usefulness of the neutral rate for practical policy work. See also Lundvall et al. (2025) for further discussions on the Swedish neutral interest rate.

[54] See Borio et al. (2022) for a discussion of how global long-term real interest rates can be affected by the monetary policies of major central banks.

[55] Armelius et al. (2018) show that the interest rate trend in Sweden can largely be explained by movements in international interest rates, which is also discussed further in Armelius et al. (2024).

[56] See Buncic et al. (2024).

[57] See, for example, Sveriges Riksbank (2024), Meyer et al. (2022) and Brand et al. (2018).

Our practical starting point is that central banks need to have an idea of the normal level of the real interest rate, despite the many difficulties associated with estimating it. For example, the Riksbank's policy rate path will always, explicitly or not, be based on an assumption of the normal level of the policy rate. In practical policy work, a wider range of information on economic developments is usually used than can be captured by a single model. However, having a clear framework or model to depart from allows analyses and assessments to be made in a structured and continually consistent way. Our model for the real interest rate trend is simple and flexible and allows for the incorporation of many different sources of information on the trend level. This creates favourable conditions for it to be useful in assessing interest rate trends and in discussions on macroeconomic developments and monetary policy in practice.

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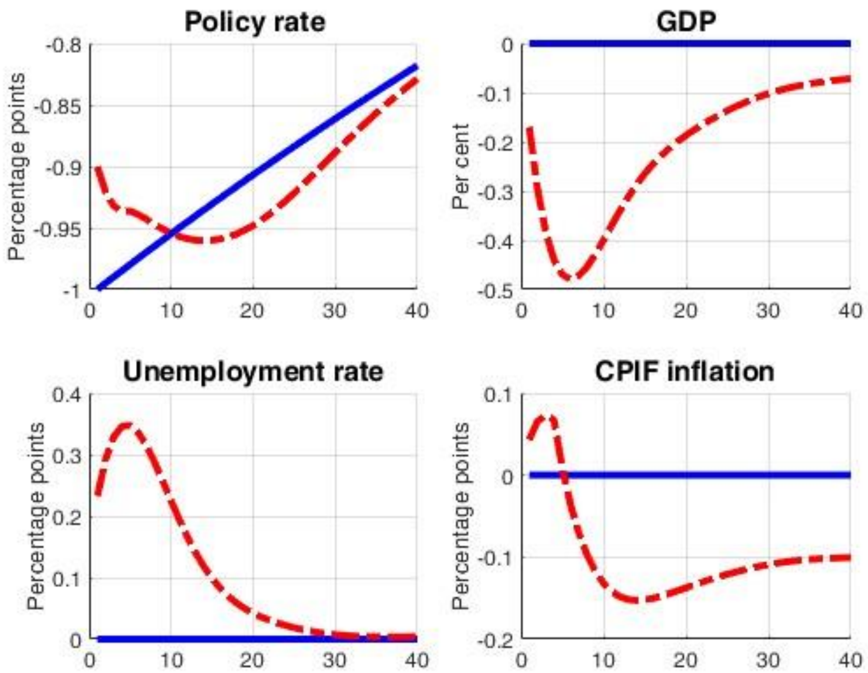
APPENDIX

A. Effects of a shock to the trend level of the real interest rate

In Figure 80, we show the responses of a few key macroeconomic variables to a negative shock to the trend level of the real interest rate, $\varepsilon_{z,t}$, under two different assumptions about how monetary policy responds to the shock. In the model with a time-varying real interest rate trend as described in the main text, we assume that the central bank fully neutralises the effects of a shock to the trend by cutting the policy rate in line with the decline in the trend level (blue lines). We normalise the effect so that the shock gives rise to an initial reduction in the policy rate of 1 percentage point. We then assume instead that the central bank cuts the policy rate by only 0.9 percentage points initially so that the shock is not completely neutralised. This makes the real interest rate gap positive, and GDP falls and unemployment rises (red lines). Inflation initially rises but then falls. Consequently, if the central bank's response is 'too weak', the shock takes on the character of a negative demand shock. As resource utilisation and inflation fall, the policy rate, in this case, needs to be lower for a longer period of time compared with the case in which monetary policy initially reacts more strongly to the shock.

Figure 8. Responses to a shock to the real interest rate trend under two different assumptions about how monetary policy reacts



B. Estimation of the model

Here, we briefly describe the Bayesian estimation of the model. We follow the methodology of Corbo and Strid (2020) (hereinafter CS) closely and the reader is referred to the quoted article for a more detailed description. Here, we focus on the main differences in our updated estimation of the model. We do not report calibrated values or prior and posterior distributions for all the parameters of the model here, but these are available from us on request.

We estimate MAJA using data for the period Q2 1995-Q4 2023. We use the same 25 data series as CS for the estimation. We estimate 87 parameters, while CS estimated 91 parameters. We have chosen to calibrate two indexation parameters (κ_d=1, κ_f=1) and the share of consumer goods in the export demand function ($\omega_c^x = 1/4$) based on preliminary estimates of these parameters, as part of simplifying the estimation of the model. We have also chosen to model the shock to the trend real interest rate, z_t, as an AR(1) process instead of an ARMA(1.1) process as in CS ($\theta_{\varepsilon_z} = 0$).

Among the estimated parameters, we note mainly that the variation in inflation trends (modelled as exogenous AR(1) processes) and monetary policy shocks both abroad and in Sweden are greater in the model without a time-varying real interest rate trend compared with the model with such a trend. These shocks thus act as 'substitutes' for the shock to the real interest rate trend.

With regard to the calibrated parameters in the model, we note, in particular, that the steady state level for policy rates abroad and in Sweden has been calibrated to 2.5 per cent (compared with 3 per cent in CS).

C. Sensitivity analysis – alternative real interest rate trend assumptions

Here we estimate some different variants of MAJA and show how the estimation of the real interest rate trend looks for these. We first estimate an alternative specification in which the trend of the real interest rate is assumed to depend on the annual growth of permanent technology (in deviation from its steady state).[58]

$$r_t^{tr} = r + c\mu_{z,t}^4 + z_t$$

We then examine how the estimation is affected if we use the Riksbank's assessment of the GDP gap as data when estimating the model. Finally, we examine how the estimation of the standard deviation of the shock to the real interest rate trend, σ_z, is affected when we change its prior. In the baseline estimation, the prior distribution for this parameter is assumed to be inverse gamma with a mode value of 0.002 (which is a common prior for the standard deviation of innovations in DSGE models).

The models estimated are then:

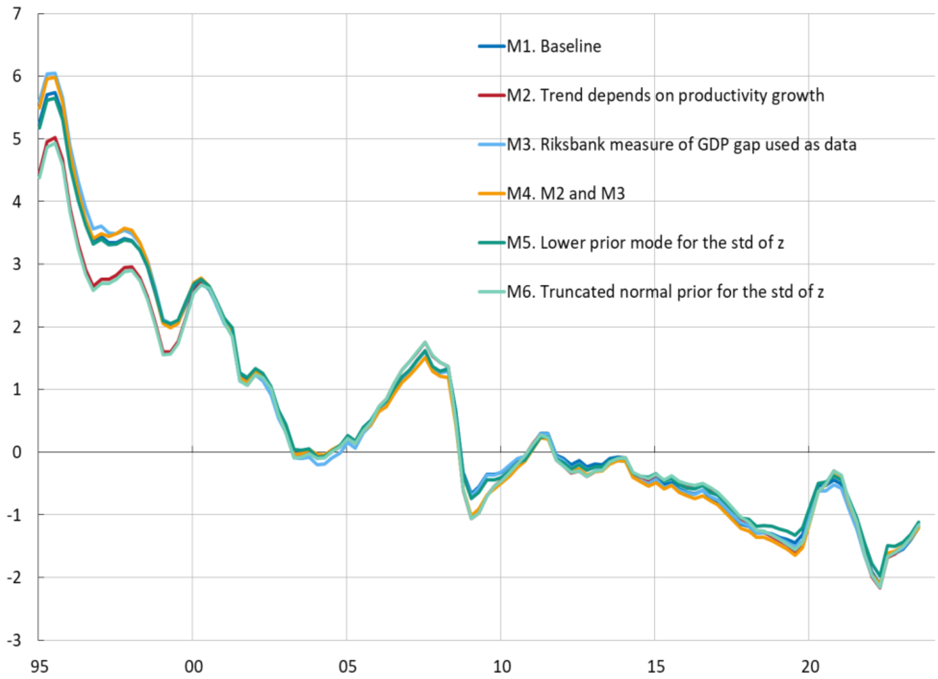
- M1. Baseline: $\rho_z = 0.995$, σ_z =0.00059.
- M2. The neutral interest rate depends on the growth in permanent technology: $c = 1.04$, $\rho_z = 0.994$, σ_z =0.00035.
- M3. The Riksbank's measure of the GDP gap is used as data in the estimation: $\rho_z = 0.995$, σ_z =0.00060.
- M4. M2 and M3 at the same time: $c = 1.79$, $\rho_z = 0.989$, σ_z =0.00037.
- M5. Less variation in real interest rate trends. The prior for σ_z is assumed to have a mode value of 0.0002 (a factor of 10 smaller than in the baseline): $\rho_z = 0.995, \sigma_z$ =0.00058.
- M6. The neutral interest rate depends on the growth in permanent technology: The prior for σ_z is assumed to be a truncated normal distribution that allows the estimate to come arbitrarily close to 0: $c = 1.08$, $\rho_z = 0.994$, σ_z =0.00033.

We note that the estimation of σ_z is insensitive to the choice of prior distribution (as seen, for example, by comparing M1, M3 and M5, which have the same specification for the real interest rate trend, alternatively we can compare M2, M4 and M6.). In Figure 90, the estimated real interest rate trend is shown for the different variants of the

[58] We choose to relate the trend in the real interest rate to the annual percentage change in permanent technology because the quarterly change is relatively volatile and therefore provides a low estimated value for the parameter c.

model. We see there that the estimated trend is relatively robust to a range of alternative assumptions about its specification, the prior distribution of key parameters and the data used in the estimation.

Figure 9. Estimates of the real interest rate trend in MAJA with different assumptions



D. Forecasts

Figure 10. Policy rate forecasts in MAJA with and without a time-varying trend for the real interest rate and a long-term level for the policy rate equal to 2.5 per cent

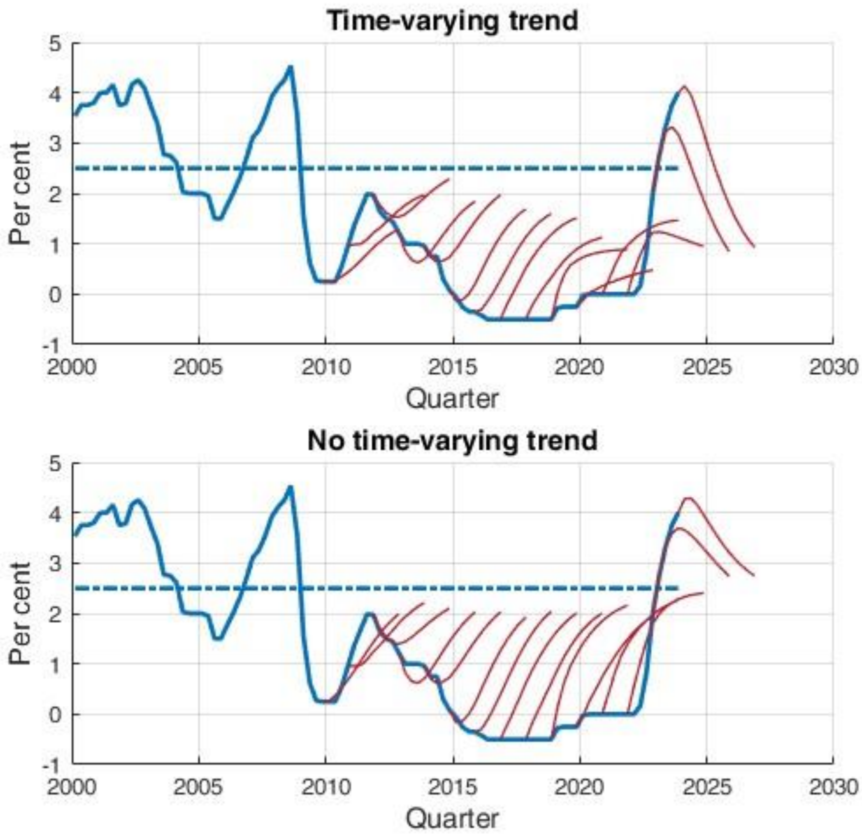


Table 1. Root mean squared forecast errors (RMSFE)

			Time-varying real interest rate trend		No time-varying real interest rate trend				
		Horizon	Low steady state	High steady state	Low steady state	High steady state		Relative RMSE	
			A	B	C	D		C/A	D/B
Policy rate		1 year	0,9	1,0	1,0	1,4		1,1	1,5
		2 years	1,4	1,5	1,6	2,4		1,2	1,6
CPIF		1 year	2,2	2,2	2,2	2,2		1,0	1,0
		2 years	2,5	2,5	2,5	2,5		1,0	1,0
GDP		1 year	3,4	3,4	3,8	4,0		1,1	1,2
		2 years	3,0	3,0	3,0	3,0		1,0	1,0
Real exch. rate		1 year	7,4	7,7	6,4	6,6		0,9	0,9
		2 years	6,5	6,7	5,9	5,8		0,9	0,9

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