STAFF MEMO

The neutral real interest rate

AN UPDATED VIEW OF R*

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The neutral real interest rate: An updated view of r*

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The neutral real rate of interest (r*) is a key variable for assessing the tightness of monetary policy. *The neutral real interest rate has by all accounts fallen substantially over the past three decades, amid slowing productivity growth, an ageing population, increased inequality and increased demand for safe and liquid assets along with lower investment demand. Updated model estimates and long-term market rates support Norges Bank's assessment that the neutral real money market rate lays between -0.5 and 0.5 percent. Going forward, a further rise in life expectancy might suggest a continued very low r*, while increased public investment in defence and the climate transition, as well as the phasing out of asset purchase programmes by the large central banks may pull up on r*.*

Key words: monetary policy, neutral real rate of interest, r*.

1. Introduction

The neutral real rate of interest (r*) is a key variable for assessing the tightness of monetary policy. We define the neutral real interest rate as the risk-free rate consistent with balanced developments in the economy in the medium term, when the impact of transitory short-term shocks has unwound (normally within five to ten years). Balanced economic developments refer to output in line with potential output and inflation at target. The difference between the actual real interest rate and the neutral real interest rate provides an indication of whether the monetary policy stance is expansionary or contractionary. A real interest rate that is below the neutral interest rate stimulates economic activity, while a higher real interest rate has a dampening effect.

The neutral real interest rate has by all accounts fallen substantially over the past three decades. Long-term nominal interest rates have shown a pronounced downward trend across countries since the mid-1980s (Chart 1). The fall in the first part of the period reflects lower actual and expected inflation. In recent decades, the decline in nominal interest rates has coincided with lower real rates. Monetary policy is often assumed to have limited influence on the real interest rate in the long run. These developments are therefore usually interpreted as a fall in the

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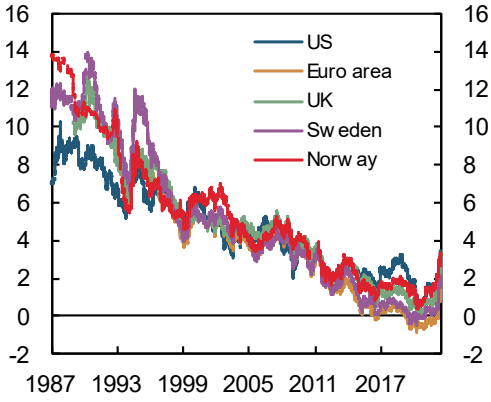
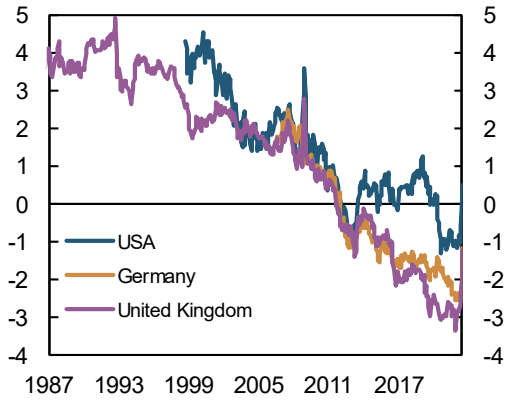
neutral real interest rate, which is primarily determined by structural factors.

Chart 1a: *Ten-year sovereign yields in selected countries. Percent*



Source: Thomson Reuters

Chart 1b: *Ten-year synthetic real sovereign yields in selected countries.[1)] Percent*



1) Nominal yields adjusted for the 10-year inflation swap.
Sources: Bank of England and Bloomberg

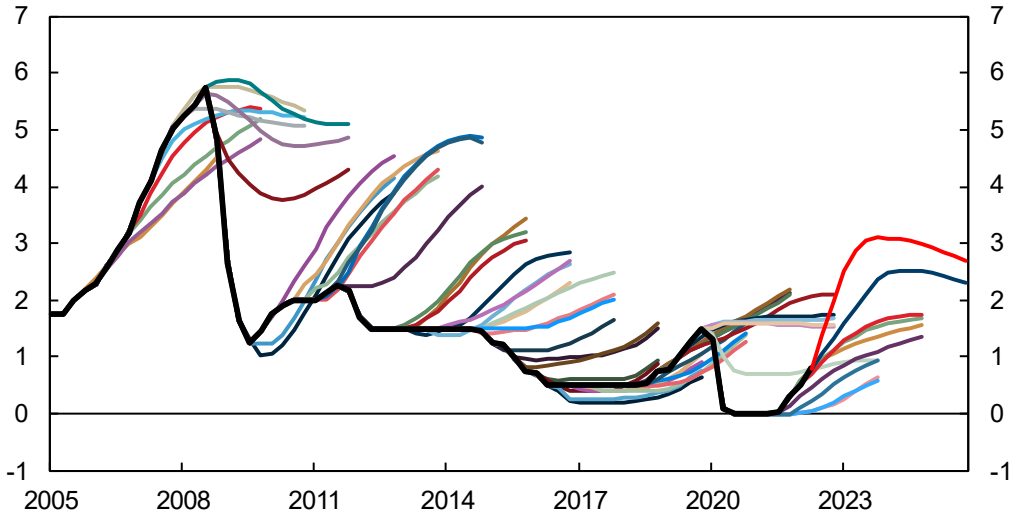
Because the level of the neutral real interest rate determines how expansionary or contractionary an interest rate level is, it is important for a central bank to have a notion of the level of r* in order to correctly calibrate the monetary policy stance. However, the neutral real interest rate cannot be observed and is difficult to estimate. Over time, erroneous estimates of the level of the neutral real interest rate may result in policy rate forecasts that are systematically off the mark. This is probably one of the reasons why the policy rate forecasts in Norges Bank's Monetary Policy Report (MPR) have from time to time overestimated the level of the policy rate further out in time (Chart 2).

To avoid large policy errors, Norges Bank regularly assesses its estimate of r*. When r* was last assessed, in MPR 2/21, the interest rate level was estimated to be neutral when the real money market rate is close to 0 percent.[2] This estimate is in line with estimates for other countries and is consistent with the model estimate of r* for Norway in Brubakk, Ellingsen and Robstad (2018).

In connection with MPR PPR 2/22, we have updated the model estimates of r* and assessed developments in long-term market interest rates.

[2] No change was made to the estimate of the neutral real interest rate when it was previously assessed in connection with PPR 2/21.

Chart 2: *Norges Bank's policy rate with projections over time. Percent*



Source: Norges Bank

In a small open economy like Norway, underlying conditions are largely influenced by international developments. This means that the neutral real interest rate in Norway will over time be close to the global neutral real interest rate. In the assessments of r* in Norway, we therefore give weight to global developments in structural drivers of the neutral real interest rate.

In this *Staff Memo*, we first review the structural drivers that have contributed to reducing r* in recent decades. We then assess developments in long-term market interest rates and provide updated model estimates of r*. To conclude, we discuss the direction in which structural drivers might conceivably influence the evolution of r* in the period ahead.

2. Structural drivers behind the decline in long-term interest rates

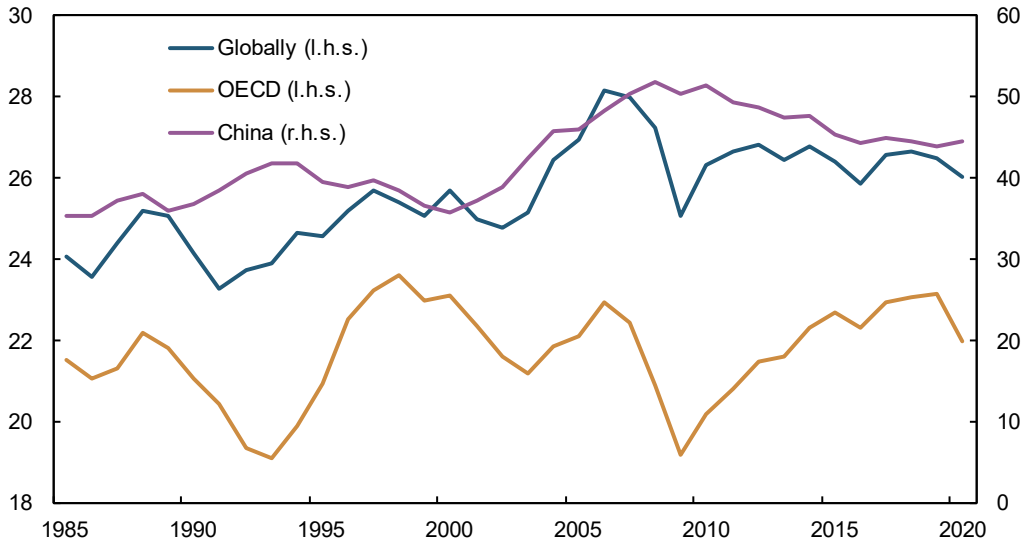
2.1. The interest rate that brings saving and investment into equilibrium

The neutral real interest rate is the rate that brings saving and investment into equilibrium. Structural factors that influence the supply of saving and demand for investment in the medium term therefore influence the neutral real interest rate.

Since the beginning of the 2000s, a number of structural developments have contributed to an increase in global saving (Chart 3). Following the Asian crisis at the end of the 1990s, saving rose in many emerging economies. China's entrance into the global market in the early 2000s

led to an increase in prosperity and saving in that country, which has pushed up total global savings.

Chart 3: *Gross saving as a share of GDP. Percent*



Source: World Bank

The world as a whole can only save through real investment, ie investment in machinery and other equipment that can be used to produce goods and services. The price at which the market for the supply of savings and demand for investment clears equals the return savers can earn on their (next) real investment. Therefore, in a simple model with one representative firm and one representative household (see eg Ramsey, 1928), the real interest rate is determined by potential growth (productivity growth (*g*), intertemporal substitution elasticity (σ) [3] and population growth (*n*)), as well as households' time discount rate (ρ)[4]: ($r^* = \sigma g + n + \rho$).

The real world consists of many different kinds of households with more complex saving motives than the household in the Ramsey model. Moreover, savers can invest in a number of asset classes with different maturities, liquidity, risk and hence, expected returns. The return on real capital serves as an anchor for all other interest rates in the economy, like risk-free rates. Nevertheless, changes in how savers value characteristics of various asset classes may result in changes in real interest rates not attributable to changes in the return on real capital.

In the following sections, we review explanations for the fall in r* that have often been cited in the literature.

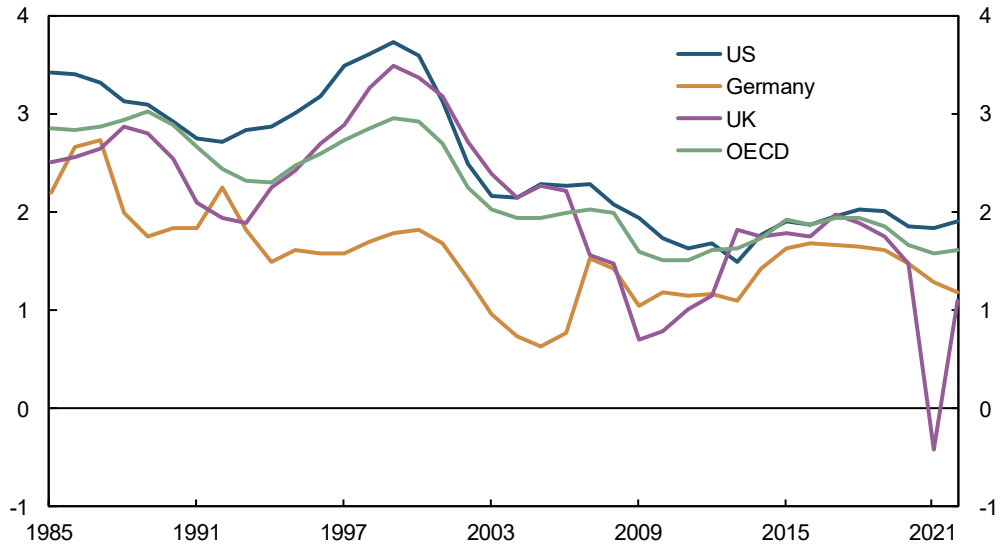
[3] σ represents the inverse intertemporal substitution elasticity. It is common to assume that σ is equal to 1.
[4] Some would relate structural factors, as discussed below in this article, to households' time discount rate. In our view, it is more reasonable to think about these factors outside of the Ramsey model.

2.2. Neutral real interest rate and potential growth

Expected productivity growth influences household saving behaviour. When we expect to earn more in a year's time, our need to save from income for future consumption is smaller. But if growth expectations decline and we believe that we will earn less, saving may increase, contributing to a lower neutral real interest rate. At the same time, lower growth expectations will reduce the expected return on real capital, and firms will invest less, which pulls in the same direction. Similarly, lower employment growth will reduce the need for capital and thus reduce investment.

One can observe some decline in both productivity growth and employment growth in many advanced economies since the 1990s (Chart 4). It follows from the Ramsey model from the previous section that such a decline in potential growth will also lead to a lower r*.

Chart 4: *Potential growth in selected countries. Annual growth. Percent*



Source: OECD

However, many have shown that potential growth has fallen less than long-term interest rates. Hamilton, Harris, Hatzius and West (2016), among others, show that empirically there is a weak correlation between trend GDP growth and the trend in real interest rates. They argue that other factors may be more important for explaining the fall in the neutral real interest rate. Also the model frameworks of Laubach and Williams (2003) and Holston, Laubach and Williams (2017), which are widely used for estimating r*, indicate that a substantial portion of the decline in r* is explained by factors other than the growth outlook.

2.3. Demographic changes and the impact on saving and investment

In lifecycle models, pension saving is an important driver behind the supply of capital. Thus, the share of the population that are savers together with developments in life expectancy are important factors for developments in the real interest rate.

Developments in western countries and other advanced economies have long trended towards lower birth rates, lower mortality and higher life expectancy (Lee, 2016). These developments are expected to continue. The fall in birth rates have led to lower growth in the labour force, pulling down potential growth. [5] Besides the effect on the labour force, demographic changes affect saving behaviour, primarily through two channels (Brand, Bielecki, Penalver et al, 2018):

1. **Lower r*:** An increase in life expectancy results in higher pension saving, resulting in turn, all else equal, in *increased saving* and an *increased supply of capital*.[6]
2. **Higher r*:** More pensioners reduce total saving, since pensioners *reduce* savings, reducing the supply of capital.

Empirical studies based on overlapping generational models indicate that the former channel has been stronger than the latter and suggest that demographic changes have reduced r* by between 0.8 and 1.0 percentage point since 1980 (see eg Bielecki, Brzoza-Brzezina and Kolasa (2018) and Papetti (2018)).

2.4. Growing income inequality

Empirical studies find a higher propensity to consume among the poor. In models that take into account income inequality, the distribution of income between rich and poor will affect the saving rate.

The importance of increased income inequality as a reason for a lower r* has drawn greater attention in recent years (see eg Straub (2019) and Eggertsson and Mehrotra (2017)). Wealthy households often have a higher propensity to save than others.[7] At a given increase in income, the wealthy will tend to use their income growth more on saving, while poorer

[5] At the same time, today's elderly are also healthier longer. In Norges Bank's analyses of microdata, we find that the increased life expectancy in recent years has, all else equal, *sustained* the employment trend, because healthier elderly can work more than previously (MPR 3/21). In this analysis, we take into account the composition effects of age, sex and educational attainment on the employment trend.
[6] At the same time, the dependency ratio has risen and is expected to rise further, which may make it more challenging for those of working age to support pensioners. This may further amplify the need to save for retirement.
[7] This assumes that wealthy households also have ample liquid assets. Many households can have substantial wealth, but little in the way of liquid assets. The literature shows that such "wealthy hand-to-mouth" agents may also have a lower propensity to save (see eg Kaplan, Violante and Weidner, 2016).

households will tend to use their income growth more on consumption. Thus, the supply of savings rises, while the demand for goods and services falls, which in turn may lead to a reduction in investment demand. Both suggest a lower r*.

In a more recent study of US microdata, Mian, Straub and Sufi (2021) find that the saving ratio of the top 10 percent of the income distribution is 10-20 percentage points higher than the saving ratio of the remaining 90 percent. The difference in the saving ratio across income groups holds for the income distribution within all age cohorts. According to the study, the 10 percent wealthiest households in each age group increased their share of income by 15 percentage points since the 1980s. The authors find that increased income inequality has been more important for the fall in r* than demographic changes.

Estimates of the effect of higher income inequality on r* in recent decades vary widely between -1 and -4 percentage points, depending on methodology and assumptions (see Straub (2019) and Rannenberg (2019)).

2.5. Increased demand for safe and liquid assets

In models where agents' risk appetite differs, the share of risk-averse agents relative to risk-neutral ones will be an important factor for determining the yield on safe assets.

While the real yield on safe and liquid securities has fallen over the past three decades, the real return on corporate capital has remained relatively stable (Marx, Mojon and Velde, 2021). This indicates that it has not only been total saving that has risen in recent decades, but that a larger share of savers has preferred to save in safe and liquid assets. Krishnamurthy and Vissing-Jørgensen (2012) point out that investors pay a premium for holding safe and liquid assets. This premium is estimated to have increased and has been one of the drivers of the downward pressure on yields on such securities in recent years.

When saving increased in a number of emerging economies, following the Asian crisis, saving primarily increased in the form of US Treasury securities and other safe assets. The supply of assets of this kind rose much less than demand, and the yield on safe and liquid assets fell considerably (Bernanke, Bertaut, Demarco and Kamin, 2011). Stricter financial sector regulation after the financial crisis in 2007-2008, with requirements to hold a certain quantity of such assets, may have helped to reinforce these developments (Caballero, Farhi and Gourinchas, 2017).

Del Negro, Giannone, Giannoni and Tambalotti (2017) estimate that the shift towards safe and liquid assets has contributed to pulling down the neutral real interest rate by just under 1 percentage point in the period 1998 – 2016.

2.6. Lower investment demand

At the same time as changes in saving behaviour have contributed to an increase in the supply of savings in recent decades, a fall in investment demand is also likely to explain some of the decline in r*. Rachel and Smith (2017) find that a reduction in the relative price of investment goods has led to a reduction in desired investments, which pulls down on r* by 0.5 percentage point. They also find that lower public investment has contributed to a further reduction of 0.2 percentage point.

2.7. Possible effects of monetary policy

The consensus view has been that monetary policy is neutral in the long run and therefore does not influence the level of r*. However, many have recently challenged this assumption, in the light of a period of unconventional monetary policies in the period after the financial crisis of 2007-2008.

During the past decade, policy rates among many of Norway's trading partners have been historically low. Many central banks have used unconventional monetary tools, such as quantitative easing and forward guidance on policy rates far out in time, in order to reduce long-term interest rates and interest rate expectations. This has reduced the effective supply of safe and liquid assets with long maturities and have helped to reduce the premiums on assets of this kind.

Monetary policy further influences household debt accumulation, thereby also affecting households' response to interest rate changes.[8] Following a period of very low interest rates and rapid debt growth, interest rate sensitivity may have increased and the level of real interest rate that is consistent with normal capacity utilisation may have changed. This may lead to a transitory change in r*.

According to Mian et al (2021), increased debt growth fuelled by monetary accommodation can also influence r* through distribution effects. Higher debt levels owing to low interest rates will eventually lead to households having to spend a larger share of income on interest and principal payments. In theory, this entails a greater transfer of resources from borrowers to savers, ie from poor to wealthy households. Thus, households with a high propensity to consume (low propensity to save) transfer resources to households with a low propensity to consume (high propensity to save). An increase in debt service payments results in a "savings glut" that weighs on r*. In their model, this takes place when the interest rate is reduced so that equilibrium is achieved.

[8] See the box "How do interest rates influence disposable income and consumption?" in *Monetary Policy Report* 2/22.

On the other hand, da Silva, Kharroubi, Kohlscheen, Lombardi and Mojon (2022) argue that economic downturns result in persistently higher income inequality, an inequality hysteresis. The hysteresis follows from low-income households' exposure to higher unemployment and lower wage growth through the downturn. Thus, by counteracting business cycle fluctuations, monetary policy may dampen adverse effects on inequality and reductions in r*.

Potential growth, lower investment demand, demographics, income inequality and stronger preferences for safe and liquid assets are drivers that are primarily cited when the decline in r* has been discussed in the literature. None of these factors can explain the full decline in r*, but in the aggregate they can probably explain much of the decline in global neutral interest rates in recent decades.

3. Estimates of r*

Norges Bank bases its assessments of the level of the neutral real interest rate both on estimates from economic models and on market rates. Long-term market rates are used as an indication of market expectations of the risk-free medium-term real interest rate when the effect of economic shocks has unwound. Economic models use correlations between economic variable to estimate the level of the interest rate that would be consistent with a closed output gap in the absence of economic shocks.

When we here estimate the neutral real interest rate, we estimate the real money market rate, as measured by the Norwegian three-month money market rate, Nibor. A neutral policy rate will lie somewhat below this, depending on the money market premium. In MPR 2/22, the premium in three-month Nibor was estimated to lie close to 0.35 percentage point in the coming years.

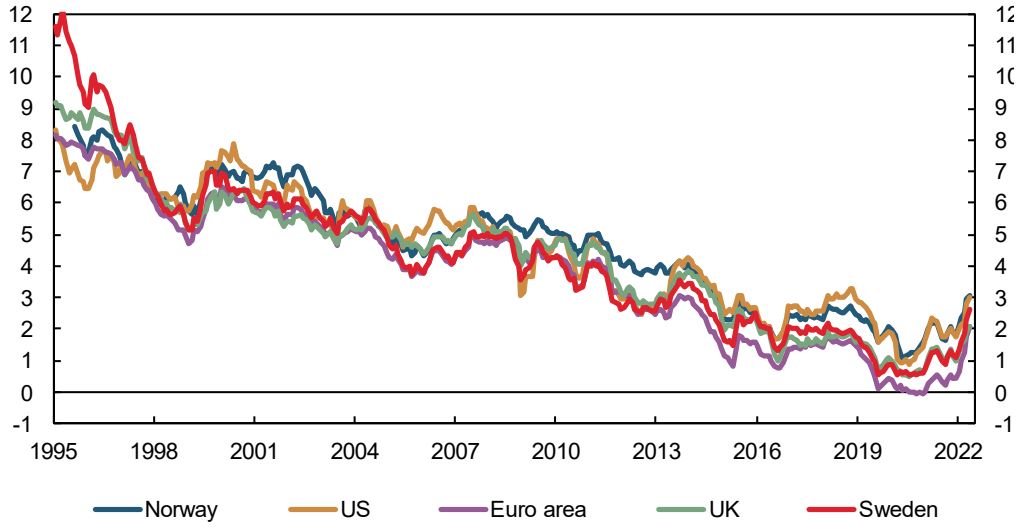
3.1. Long-term market rates

A large number of agents who manage substantial assets trade in various fixed income securities on a daily basis. While trading, the agents base their trades on their own expectations of what short-term money market rates will be in the future. The yields on such financial instruments can therefore provide us with information about what a large set of agents expect short rates will be further out in time.

Interest rate expectations for the coming years largely reflect expectations regarding the monetary stance. At the five-to-ten-year horizon, however, it is reasonable to expect that the effects of economic shocks have unwound and that in anticipation, output is broadly equal to potential output and inflation approximately at target. We interpret interest rate expectations at this horizon as the market's view of the neutral real interest rate.

Like the model-based estimates of r*, implied five-year yields five years forward have shown a declining trend in recent decades (Chart 5). However, in recent months, we have observed a marked rise in these yields in many countries (Chart 5). A relevant question for central banks is whether this rise can be interpreted as expectations of an increase in the neutral real interest rate or whether other factors explain the rise.

***Chart 5**: Implied five-year yields five years forward in selected countries. Swap rates. Percent*



Source: Refinitiv Datastream

Estimating expected short-term real interest rates based on financial instruments with longer maturities is not a trivial exercise. First, it may be a challenge to estimate the market's inflation expectations. Particularly in countries such as Norway, where there are no inflation-linked financial instruments, inflation expectations can be difficult to measure. Second, these rates will not only depend on the expected short-term rate but also on what is called the term premium. The term premium is the extra return an investor receives for holding long bonds rather than a series short bonds. Term premiums can be either positive or negative, depending on the supply of and demand for bonds with certain maturities. Term premiums are not observable and are difficult to estimate.

Norges Bank has usually applied the assumption that the market's inflation expectations are at the 2 percent inflation target further out, and it has been usual practice to subtract the 2 percent inflation target from the implied five-year yield five years forward as an indicator of the market's expectations for real short-term rates at the five-to-ten-year horizon, and thus interpreted as the market's estimate of r*.[9] In the calculations we assume that the term premium is close to zero.

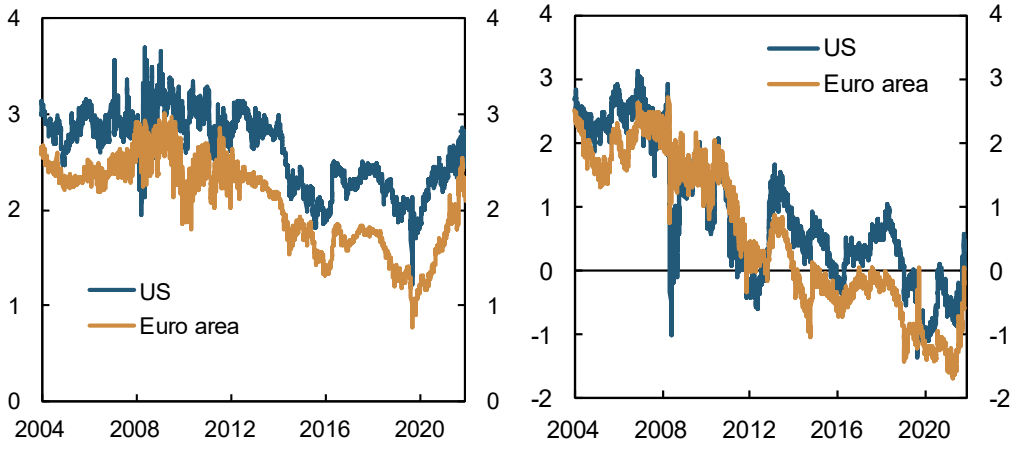
[9] See eg box "Neutral real interest rate estimate still close to zero" in *Monetary Policy Report* 2/21.

Since we do not have knowledge of market expectations of inflation in Norway and since our estimates of term premiums are uncertain, it is difficult to evaluate the accuracy of such a market indicator. As a cross-check it may be useful to see how market-based inflation expectations and term premiums have evolved in other countries, in order to assess the drivers of nominal long-term rates there. Long-term rates are highly correlated across countries. In a world of free capital flows it seems reasonable that many of the same drivers influence developments in Norway and abroad.

Market-based inflation expectations at the five-to-ten-year horizon have risen considerably in both the US and euro area in the first half of 2022 and are now higher than the inflation objectives in both monetary jurisdictions (Chart 6.a). This does not necessarily mean that market participants believe that the most probable outcome is above-target inflation in five to ten years, but it may indicate that higher inflation five to ten years out is being priced in. Thus, some of the rise in nominal five-year yields five years forward is probably ascribable to increased inflation expectations. Nominal yields have nevertheless risen considerably *more* than inflation expectations: estimated real interest rates have increased by about 1 percentage point in both the US and the euro area since the beginning of 2022 (Chart 6.b). If the market is pricing in a risk of high inflation in five to ten years' time, it is also conceivable that it sees a risk that monetary policy will be contractionary in the longer term, so that the real interest rate being priced in for the US and euro area is also somewhat higher than r*. Just as market expectations at the five-to-ten-year horizon appear to be somewhat higher than US and euro area inflation objectives, it may be reasonable to assume that the same will also be the case in Norway.

6.a: *Market-based inflation expectations. Five-year five years forward. Percent*

6.b: *Market-based real yields. Five-year five years forward. Percent*



Sources: Refinitiv Datastream and Bloomberg

Estimates of term premiums in US five-year yields five years forward indicate that the term premium varies considerably over time (Adrian, Crump, Moench, 2013). The estimated term premium was positive in 2015 but has been fairly close to zero since.[10] Such estimates of term premiums are highly uncertain and are method-dependent. If the same applies to the term premium in Norwegian five-year yields five years forward, it is currently not unreasonable to disregard the term premium when estimating market expectations of short-term interest rates at the five-to-ten-year horizon. Now that many central banks are tightening monetary policy and scaling back or phasing out their asset purchase programmes, this may mean an increase in the term premium in the period ahead. It may also imply that long-term market interest rates overestimate r*.

On balance, it is our assessment that Norwegian five-year yields five years forward less the inflation target now likely overestimate somewhat the level of r* that is consistent with market expectations.

3.2. Updated model estimates

Other estimates of the neutral real interest rate can be calculated by economic models that help us to estimate the real interest rate that is consistent with output in line with its potential in the absence of shocks. All models are simplifications of reality and will therefore have their weaknesses and misspecifications. Since there is not one model that is superior, Norges Bank consider estimates of r* from a number of models. We focus on the average model estimate, and consecutively evaluate which ones we believe to be best equipped given current economic circumstances.

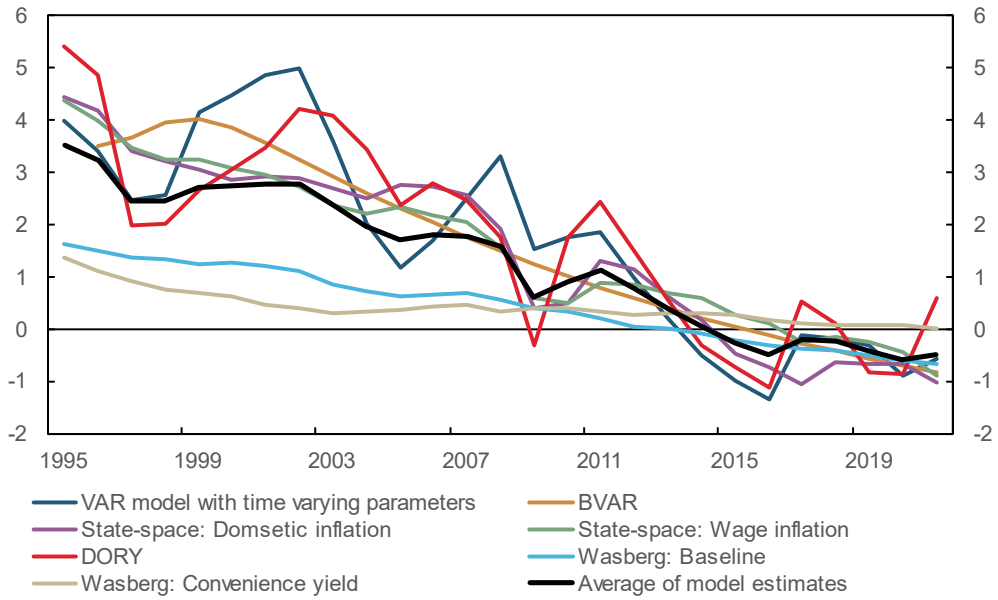
Some of the models used are time series models that can estimate what the real interest rate would be when the effects of economic shocks have unwound. Other models to a larger extent impose correlations between variables on the basis of economic theory. Most of the models in our model portfolio are estimated on annual data through 2021. The Covid-19 pandemic led to an abnormal fall in GDP, which creates challenges for some of the models. Adjustments were therefore made to the models in order for the pandemic years to be interpreted in a reasonable manner. See Appendix A for a detailed description of the models. The models we use are also documented in Brubakk et al (2018), Landsem, Njølstad, Paulsen, Robstad and Åstebøl (2022) and Wasberg (2022, forthcoming).

All models in the model portfolio indicate that the neutral real interest rate has fallen in recent decades. The average of the model estimates fell from 3.5 percent in 1995 to -0.5 percent in 2016 and has since remained relatively stable (Chart 7). Such model estimates are highly uncertain, and the model estimates for 2021 range between -1.0 percent and 0.6

[10] The term premiums are estimated by the Federal Reserve Bank of New York with the aid of a method developed by Adrian et al (2013).

percent. We have also conditioned the models on projections for 2022 from MPR 2/22 as a cross-check of the marked rise in market yields at the five-to-ten-year horizon. The estimates of r* do not change substantially.

Chart 7: *Model estimates of the neutral real interest rate. Percent*



Sources: Wasberg (2022) and Norges Bank

3.3. Overall assessment of r*

Neither market-based measures nor model estimates of the neutral real interest rate provide definitive answers as to the level of the neutral real interest rate. Model estimates are highly uncertain, and the estimates depend on model specifications. Market-based measures may be influenced by term premiums, and it is difficult to apply correct inflation expectations – and market participants may have wrong expectations about future short-term interest rates. Chart 8 summarises the estimate from our model portfolio together with the market-based measure, given that inflation expectations lie at the inflation target. In the chart we have also included Norges Bank's official estimate of r* from previous monetary policy reports.[11] Norges Bank regularly evaluates its estimate of r*.

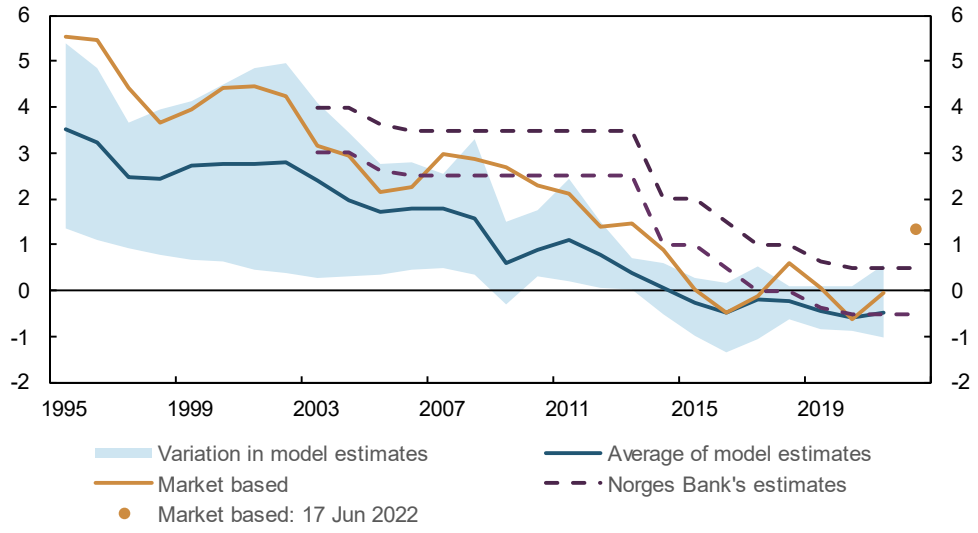
In the past, the market-based measure was higher than the preponderance of model estimates, and Norges Bank's estimate has periodically been above the market-based measure. In recent years,

[11] Norges Bank's estimate of the neutral real interest rate has either been stated as a range or "close to" a point estimate. In cases where a point estimate has been stated, we have added and subtracted 0.5 percentage point to obtain a range.

however, there has been a closer alignment of the models, the market-based measure and Norges Bank's estimate.

Norges Bank estimates that the neutral real money market rate ranges between -0.5 percent and 0.5 percent (see MPR 2/22). This appears to be well in line with the sum of information from the models and the market.

Chart 8: *Estimates of the neutral real interest rate. Percent*



Sources: Refinitiv Datastream and Norges Bank

4. Structural drivers of developments in long rates ahead

We started by discussing various structural drivers that the literature cites as important for explaining the decline in the level of r*. In this section, we will briefly discuss how structural drivers will evolve ahead and in what direction they may pull r* in the future. An attempt to quantify the level of r* further out is a demanding task. It may nevertheless be useful to discuss the developments that may pull r* in different directions.

4.1. Productivity and inequality

Norges Bank regularly evaluates its estimate of trend productivity growth. In MPR 2/22, underlying productivity growth was assumed to remain close to 0.75 percent to the end of the projection horizon, ie to 2025. This will have a neutral effect on r*. Many factors can influence the evolution of productivity growth ahead, but there are no specific grounds for claiming that it will be higher or lower than it has been recently.

Income inequality has increased gradually over a long period in many advanced economies and thereby contributed to a drop in r*. Future developments in income inequality will depend on technological, political and social factors.

4.2. An ageing population

Both in Norway and globally, the tendency is towards longer life expectancy and relatively low birth rates. These trends are expected to continue.

As described above, the effect of an ageing population on the neutral real interest rate is not obvious.

Based on population projections, Bielecki et al (2018) find that demographic trends will pull down on r* by an additional 0.25 to 0.5 percentage point by 2030 (see Brand et al (2018)).

On the other hand, Goodhart and Pradhan (2020) argue that the number of persons approaching retirement age is increasing, which will lead to a surge in debt accumulation to finance a growing share of persons in need of care. This may suggest an increase in r* ahead.

The design of the pension system and how long people choose to remain at work will naturally have a considerable influence over which of these effects will predominate in the coming years.

4.3. Higher investment demand

A number of trends point to higher demand for real investment in the period ahead.

In the Paris Agreement, the global community has set ambitious goals to reduce global greenhouse gas emissions. It requires a gradual phase-out of fossil fuels. The transition necessary to reach these goals will demand substantial investment in new low-emission technology, in the electrification of society and in renewable energy production. This may contribute to a considerable increase in total investment demand and thus suggest a higher r*.

Similarly, the ongoing war in Ukraine has led to major changes in many countries' security policy, including Norway and its trading partners. A number of countries are planning to increase defence spending in the years ahead, Rearmament and substantial investment in defence may also influence investment demand and point to a higher r*.

4.4. Increased supply of safe and liquid assets

If parts of the increase in public spending amid climate transition and increased investment in defence are financed by government debt, this

will increase the effective supply of safe and liquid assets. This may reduce the extra premium investors are willing to pay to hold such assets, which will also pull in the direction of a higher r*.

A number of central banks have recently announced tighter monetary policies in response to high inflation and capacity utilisation. Substantial changes in major central banks' asset purchase programmes have also been announced. For instance, government debt held on central bank balance sheets will mature without being reinvested. A reduction in central bank balance sheets will also result in an increase in the effective supply of safe and liquid assets, pulling up r*.

On balance, the drivers of r* pull in different directions ahead, and it is difficult to conclude about whether the total effect is negative or positive. The uncertainty is high, and we consider it to be reasonable to assume the current estimate of r* also for the coming years.

5. Conclusion

Structural drivers such as slowing productivity growth, an ageing population, increased inequality and increased demand for safe and liquid assets along with lower investment demand have likely contributed to the decline in recent decades in the neutral real rate of interest r* and led to a smaller monetary space. It is difficult to estimate r*, but with a broad modelling system that uses various estimation methods and takes into account different economic correlations, we can get an idea of the level of the risk-free neutral interest rate. Updated model estimates of the neutral real money market rate in Norway ranges between -1.0 percent and 0.6 percent. Long-term market rates can also be a useful indicator for the neutral interest rate. The yield on five-year rates five years forward has risen through the first half of 2022 and are currently traded at slightly above 3%. If market participants' inflation expectations at the five-to-ten-year horizon lie somewhat above the inflation target, current market rates are compatible with a level of r* slightly below 1%. Taken together, the estimates are well in line with Norges Bank's updated estimate of the neutral real money market rate of between -0.5 and 0.5%.Looking ahead, a further rise in life expectancy might suggest a continued very low r*, while increased public investment in defence and the climate transition, as well as the phasing out of asset purchase programmes by the large central banks may pull up on r*.

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Appendix: Models for estimating r*

Here is a brief presentation of the seven models used to estimate r* in this *Staff Memo*.

A. State space models with wages and domestic inflation

State space models with wages and domestic inflation are documented in Brubakk et al (2018) and are based on Laubach and Williams (2003). Two modifications have been made to the models from Brubakk et al (2018). First, an equation has been added that links the real interest rate gap, ie the difference between the real interest rate and r*, to developments in the inflation gap and output. This increases the stability of the estimates of r* over time. Second, a correlation has been added between potential output and an indicator of the scope of containment measures through the Covid-19 pandemic, the "Covid stringency index"[12]. We do this to explain the peculiar path of output during the pandemic.

The revised models can be summarised as follows:

$$\widehat{y_t} = \lambda_{\hat{y}}\hat{y}_{t-1} - \frac{1}{\sigma}(r_{t-1} - r^*_{t-1}) + \gamma_{y,\Delta op}\Delta op_t + e_{\hat{y},t}$$
$$\pi_t = \lambda_\pi \pi_{t-1} + \gamma_{\pi,y}\hat{y}_{t-1} + e_{\pi,t}$$
$$\Delta y^*_t = g_t + \gamma_{y^*,\Delta si}\Delta si_t + e_{\Delta y^*,t}$$
$$\Delta y_t = \Delta\widehat{y_t} + \Delta y^*_t$$
$$r^*_t = \sigma g_t + z_t$$
$$(r_t - r^*_t) = \lambda_r(r_{t-1} - r^*_{t-1}) + \gamma_{r,\hat{y}}\widehat{y_t} + \gamma_{r,\pi}\pi_t + e_{\hat{r},t}$$
$$g_t = g_{t-1} + e_{g,t}$$
$$z_t = z_{t-1} + e_{z,t}$$

where π_t is measured as domestic inflation in the model with domestic inflation and as wage growth in the wage model. Δsi_t is the change in the "Covid stringency index", while the remainder of the notation follows Brubakk et al (2018).

B. DORY

DORY is a large state space model that decomposes a number of variables into a noise component, a trend component and a cyclical component. In the model, r* is linked to potential output growth and to an idiosyncratic component. See Landsem et al (2022) for a further description of the model.

C. VAR model with time-varying parameters

The VAR model with time-varying parameters permits the parameters in the model to vary over time and thus takes account of the fact that economic correlations can change. In addition, the model permits

[12] See https://www.theglobaleconomy.com/rankings/covid_stringency_index/.

stochastic volatility, which is particularly important for explaining developments in GDP through 2020. The estimate of r* reported by the model is the model's forecast of what the real interest rate (the difference between the nominal money market rate and inflation) will be at the five-year horizon.

The model is estimated on data for GDP for mainland Norway, the CPI-ATE and the three-month money market rate (Nibor) The method follows Lubik and Matthes (2015), and the model is documented in Brubakk et al (2018).

D. BVAR

This is a Bayesian VAR model, estimated on Norwegian data from 1994 Q1 to 2022 Q1. The variables entered are GDP for mainland Norway per potential employee (log level), the CPI-ATE (log level), registered unemployment rate, real wages (log level), the three-month money market rate (Nibor) and the import-weighted exchange rate index (I-44). The number of lags is set to five, and the estimation follows Giannone, Lenza and Primiceri (2019) in its prior selection. The priors assume that real compensation rises in pace with output per employee. To correct for the peculiar shocks during the pandemic years, the model proposed by Lenza and Primiceri (2020) is used to correct for increased volatility in the period.

All variables in the model can be decomposed into a deterministic component and a stochastic component. The deterministic component is the level the variable would be in the absence of shocks. These levels of the money market rate and inflation are used to estimate what the real interest rate would be in the absence of shocks, an estimate of r*.

E. Wasberg: Baseline and convenience yield

Wasberg (2022, forthcoming) uses the same theoretical and empirical approach as Del Negro, Giannone, Giannoni and Tambalotti (2019) to estimate the natural real interest rate in Norway by using data from Norway and other advanced economies. In this study, the neutral interest rate depends on a global interest rate and an idiosyncratic (country-specific) component. Short and long sovereign yields and inflation are entered into the main ("baseline") model. The "convenience yield" model also includes the spread between high-yield and investment grade bonds as a measure of the extra premium investors are willing to pay for holding safe and liquid assets. The models thus allow such premiums to influence r*. The models applied in this *Staff Memo* are estimated on annual data from the period 1975 to 2021.