DANMARKS NATIONALBANK

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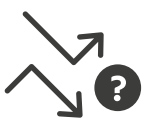
Real interest rates in the context of inflation and higher government debt

Since the 1980s, interest rates have declined gradually across the advanced economies

This decline partly reflects that inflation has also decreased. Another reason for the decline is that the neutral real interest rate has decreased over the same period. The neutral real interest rate was driven down by structural factors related to ageing populations and diminishing productivity growth, among other factors.

Since 2020, interest rates have risen significantly

This should be seen in the context of considerable increases in inflation across many countries. In addition, the state of the business cycle with high global demand and supply chain disruptions is pulling towards a higher neutral real interest rate.



At a longer horizon, there is considerable uncertainty about the level of real interest rates

There are indications that the structural conditions that contributed to the decrease in the neutral real interest rate are still present. However, new trends such as higher government debt, climate change, the green transition and changing trade patterns may potentially affect the neutral real interest rate.

Long period of falling interest rates has been followed by higher rates

Monetary policy interest rates as well as long-term market rates declined significantly from the early 1980s and until 2020, see chart 1.[1] The decline became particularly pronounced in the wake of the global financial crisis in 2008-2009, with interest rates reaching unprecedented low levels in the subsequent years. The period of very low interest rates ended during 2021, and interest rates have risen sharply since then. Against this background, this analysis discusses whether the higher interest rates are transitory or whether what we are seeing is a more fundamental shift.

There are several factors behind the gradual decline in interest rates since the 1980s. During the 1990s, a large number of central banks switched to inflation targeting. Also, central banks were typically mandated to conduct monetary policy independently of the political system, which also contributed to anchoring inflation expectations in the region of 2 per cent per year. As a result, monetary policy interest rates needed to be lower to ensure a desired level of real interest rates, i.e. interest rates adjusted for inflation.

In Denmark, Danmarks Nationalbank conducts a fixed exchange rate policy. This means that monetary policy is not conducted based on an inflation target, but that the objective is to maintain a fixed exchange rate of the Danish krone against the euro. As the European Central Bank (ECB) is tasked with keeping inflation in the euro area close to 2 per cent, this means that inflation in Denmark will also be at that level in the long term. The fixed exchange rate policy also means that interest rates in Denmark follow interest rates in the euro area.

Key interest rate concepts in the analysis

Box 1

Interest rate
The amount that a borrower pays to a lender on an ongoing basis in addition to amortisations on the debt and fees. The amount is typically stated as an annual amount as a percentage of the loan amount.

Monetary policy interest rates
The interest rates on commercial banks' deposits and loans at a central bank.

Short/long market rate
The interest rates on loans between central governments, companies and households issued in financial markets. The interest rates can be classified according to the maturity of the loans.

Real interest rate
The interest rate adjusted for inflation, which erodes the purchasing power of a deposit or loan over time.

Neutral real interest rate (r*)
The real interest rate which is compatible with a stable price and wage growth if the economy is at its structural level initially.

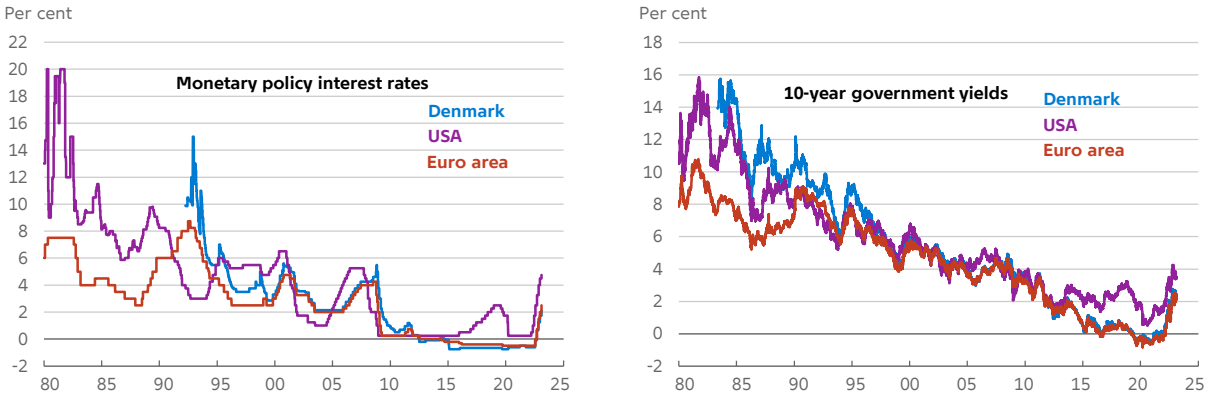
Natural real interest rate (r^n)
The long-term level of the neutral real interest rate, i.e. the neutral real interest rate excluding temporary, cyclical conditions. The natural real interest rate is driven solely by structural factors.

The neutral and natural real interest rates are stated in risk-free terms, i.e. adjusted for the risk of loss due to default.

1 See box 1 for an explanation of key interest rate concepts.

Significant decreases in short and long interest rates in the period 1980-2020 have been followed by increases

Chart 1

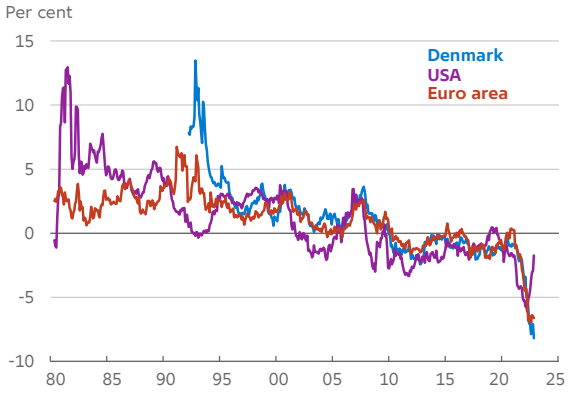


Note: The figure on the left shows monetary policy interest rates. For the United States, the Federal Funds Rate is shown. For the euro area, the Deutsche Bundesbank discount rate is shown until 1 January 1999, the ECB's interest rate for weekly market operations thereafter until 14 October 2008, and subsequently the ECB's deposit rate. For Denmark, Danmarks Nationalbank's interest rate for certificates of deposit is shown.
Source: Deutsche Bundesbank, Danmarks Nationalbank and Macrobond.

Like nominal interest rates, real interest rates have been declining for a number of years, see chart 2.[2] There is broad consensus that this is largely due to the *neutral* real interest rate, r*, having fallen across countries.[3] The neutral real interest rate is the level of real interest rates that would sustain stable wage and price growth in an economy if output is initially at its structural level.[4] This means that the actual real interest rate fluctuates around r*.

Very low real interest rates after the financial crisis

Chart 2



Note: Real interest rates have been calculated by deducting expected inflation in 12 months from the monetary policy rates in chart 1. The expected inflation has been calculated using an AR(3) time series model.
Source: Deutsche Bundesbank, Danmarks Nationalbank, Macrobond and own calculations.

2 On the face of it, chart 2 indicates that real interest rates were extraordinarily low in 2021-2022. However, this reflects that in order to show developments back to 1980, real interest rates are based on actual realised inflation rather than expected inflation. Because inflation is expected to decline again, the chart underestimates the current level of real interest rates. Inflation expectations derived from inflation swaps as of December 2022 thus indicate that inflation in, for example, the euro area is expected to be around 4.5 per cent over the coming year, while the chart is based on an expected inflation rate of 8.5 per cent. Against this background, the real interest rate in the euro area in December 2022 is underestimated by 4 percentage points in the chart. A similar caveat applies to the United States and Denmark.

3 See, for example, Holston et al. (2017).

4 See, for example, Woodford (2003).

Cyclical factors also contributed to lower real interest rates

After the financial crisis, a number of countries have undergone periods where inflation was below target. This applies, not least, to the euro area, where inflation averaged 1.25 per cent over the period 2009-2019, see chart 3. Against this background, there has been a need to pursue an expansionary monetary policy, which lowered the monetary policy interest rate below the neutral interest rate. This means that subdued inflation in a number of countries has contributed to reducing interest rates further.

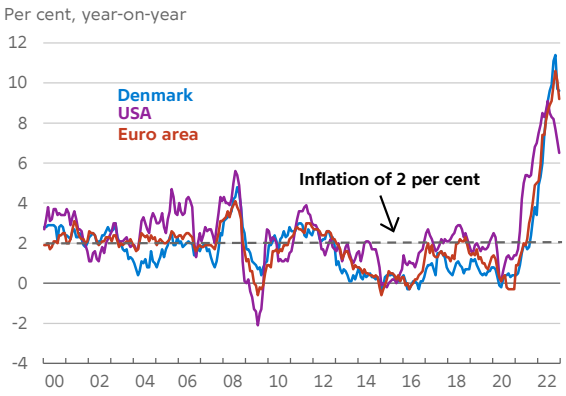
Both short and long interest rates have increased significantly across countries since 2020, see chart 1. Short market rates reflect expectations of monetary policy rates in the immediate future. Here, the increase is very much a reflection of the fact that inflation has increased sharply in the same period, see chart 3. The sharp rise in inflation has necessitated a significant tightening of monetary policy, including in the euro area. As a result of the fixed exchange rate policy, Danish interest rates have risen in line with interest rates in the euro area.

Longer-term interest rates depend less on current inflation. The reason for this is that market participants are confident that, barring further unexpected shocks to the economy, central banks will bring inflation back to target within two to three years. An increase in long-term interest rates will therefore primarily reflect expectations of higher real interest rates in the future. Over time, the expected level of real interest rates is driven by risk premia and structural factors, such as economic growth.

Estimates suggest that the prolonged decline in r* may have stagnated

The neutral real interest rate, r*, can be decomposed into a *natural* real interest rate, r^n, which reflects long-term structural economic conditions, and a cyclical component, c*, which reflects temporary factors, see box 2.[5] Changes in r* may thus be caused by long-term drivers as well as temporary factors.

Period of low inflation has been followed by significantly higher inflation Chart 3



Note: The consumer price index (CPI) has been used for the United States for the whole period. Inflation in the euro area and Denmark is represented by the EU Harmonised Index of Consumer Prices.
Source: Macrobond.

It is difficult to determine r* empirically, as neither r^n nor c* can be directly observed. However, there are methods for estimating r^n and on that basis make an informed assessment of its level. The estimates are subject to considerable uncertainty and can therefore only provide an indication of the level of r^n. To take this uncertainty into account in this analysis, Danish r^n is estimated by using three different methods, see appendix.

The estimates confirm that r^n was declining for a number of years up to 2020, see chart 4. There are indications that the declining trend has subsequently plateaued and that r^n may potentially have increased slightly recently. Nevertheless, it remains low when viewed from a longer-term perspective.

The estimates of r^n are uncertain and must therefore be interpreted with caution. The level of uncertainty is particularly pronounced during turning points

5 The explicit distinction between short-term and long-term drivers of r* and the definition of the *natural* real interest rate as the part that is determined by the long-term drivers is an extension of Danmarks Nationalbank's previous terminology on equilibrium interest rates, see, for example, Adolfsen and Pedersen (2019). Bank of England (2018), Brainard (2018) and Blanchard (2023) make a similar distinction between long-term and temporary drivers of r*.

Short-term and long-term r*

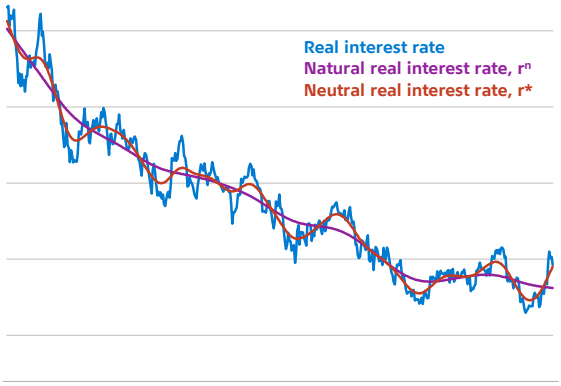
Box 2

The neutral real interest rate, r*, can be decomposed into a long-term trend component, r^n, and a short-term cyclical component, c*:

$$r^* = r^n + c^*.$$

Long-term changes in r* are due to changes in the natural real interest rate, r^n, which is affected by low frequency factors that determine savings and investment behaviour. Examples of low frequency factors are demographics and productivity growth. This means that r^n does not change significantly from year to year, but follows a trend, see the illustration in the chart below (purple curve).

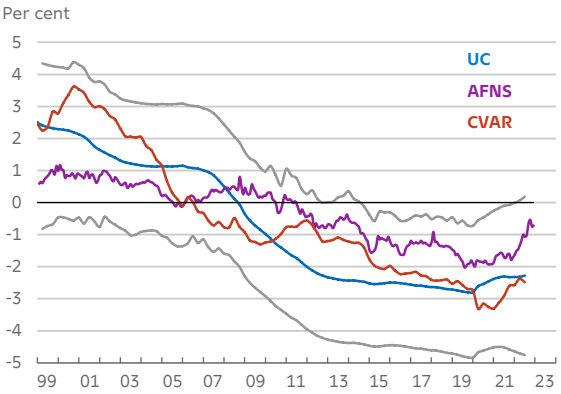
Temporary conditions may also affect r* through the cyclical component, c*, which fluctuates around 0. The temporary conditions may be due to, for example, financial turbulence, which affects investment appetite, or fiscal stimulus packages that stimulate demand, so that the actual activity deviates from its structural level. For example, a positive demand shock will push up c* and r* and imply that the real interest rate has to increase in order to keep activity in line with potential. As c* fluctuates around 0, r* will fluctuate around r^n, see the illustration below (red curve).



Note: The chart is an illustrative example.

Statistical models indicate that the decline in r^n has plateaued in Denmark

Chart 4



Note: 'UC' indicates the model in Pedersen (2015), 'AFNS' indicates the model in Christensen, Diebold and Rudebusch (2011), and 'CVAR' indicates the model in Benati (2020, 2021), see appendix. The grey lines indicate the most conservative 10 per cent and 90 per cent confidence bands among the three models.
Source: Macrobond, Refinitiv Eikon and own calculations.

such as the one economies may have experienced in 2022. As a consequence, the estimates cannot be used as a basis for concluding whether r^n has in fact changed. As data for a longer period of time become available, there will be more clarity as to whether the development in r^n has been reversed.

The following sections outline the main drivers of the long-term decline in r^n. This is followed by a discussion of whether current conditions such as higher government debt, climate change, the green transition and changing trade patterns may affect r^n in the future.

Key drivers of natural real interest rate

There is general consensus among economists that the long-term decline in r^n reflects structural con-

ditions. Fundamentally, four drivers seem to have played a particular role globally:[6]

- Demographic change
- Declining productivity growth
- Rising inequality
- Higher government debt.

The four drivers are summarised in table 1 and discussed in the following section.

Denmark is characterised by some of the same drivers. In addition, Denmark is a small open economy, which means that r^n and r* are highly dependent on global conditions. As a consequence, r^n and r* are likely to also have decreased in Denmark, as they have abroad.[7] However, there is uncertainty about how much each of the four factors has contributed to the decline in r^n. It may also be difficult to determine causality, as the individual drivers can influence the development of the other drivers.

Demographic change and declining productivity growth have reduced r^n

Several studies find that demographic change has played a significant role for r^n.[8] Lower fertility and mortality rates have gradually pushed a larger proportion of the population into age groups that typically save a lot. Together with higher life expectancies and hence higher savings over several years, this has increased total *desired* savings in the economy and put downward pressure on r^n. In addition, the concurrent decline in the labour force has reduced the return on capital, which has contributed to lowering r^n through a diminished appetite for investment.

Productivity growth in the advanced economies has declined since the 1970s.[9] One reason for this may be that the productivity gains from the early phase of globalisation have been reaped.[10] Lower productivity growth affects savings behaviour by dampening expectations of future income growth. This increases the incentive to save and pushes r^n down. The downward pressure on r^n is reinforced by companies reducing their demand for investments when they expect lower productivity growth. Some studies find that declining productivity growth has contributed almost as much to the decrease in r^n as demographic change.[11]

Rising inequality has reduced r^n

Affluent households tend to save a larger share of their income than the average household. Greater income and wealth inequality can therefore increase overall savings and push down r^n.[12] The advanced economies have generally experienced increasing inequality since the 1980s. Among other reasons, this may be a consequence of globalisation, which has exposed a number of low-paid occupations to greater competition through offshoring.[13]

Several studies find that rising inequality has contributed to a decline in r^n.[14] According to Mian et al. (2021), the increase in inequality has even been a primary driver of the decline in r^n relative to the effects of demographic change.[15]

6 Other drivers have also been suggested as possible explanations of the decline in r^n, but seem to have played a secondary role: falling relative price of investment goods (Sajedi and Thwaites, 2016, Eggertson et al., 2019, and Marx et al., 2021), a reduction in the labour share of income (Eggertson et al., 2019, Marx et al., 2021 and Peruffo and Platzer, 2022) as well as greater demand for safe assets and increased trade between countries (ECB, 2021a).

7 Adolfsen and Pedersen (2019).

8 Carvalho et al. (2016), Rachel and Smith (2017), Bielecki et al. (2018), Brand et al. (2018), Adolfsen and Pedersen (2019), Eggertson et al. (2019), Rachel and Summers (2019), Auclert et al. (2021), Gagnon et al. (2021), Papetti (2021), Cesa-Bianchi et al. (2022) and Platzer and Peruffo (2022).

9 Gordon (2015) and Antolin-Diaz et al. (2017).

10 Natal and Stoffels (2019), Guetiérrez and Philippon (2019) and ECB (2021a).

11 Adolfsen and Petersen (2019), Eggertson et al. (2019), Rachel and Summers (2019), Cesa-Bianchi et al. (2022) and Peruffo and Platzer (2022).

12 Dynan et al. (2004), Fagerend et al. (2021), Straub (2019) and Mian et al. (2021).

13 See, for example, Autor et al. (2013), who find that competition from China can explain a quarter of the reduction in manufacturing jobs in the United States from 1990 to 2007.

14 Rachel and Smith (2017), Auclert and Rognlie (2018), Brand et al. (2018), Rachel and Summers (2019), Straub (2019), Mian et al. (2021) and Platzer and Peruffo (2022).

15 Andersen et al. (2022) point out that inequality has increased significantly less in Denmark. This indicates that the results for the United States cannot necessarily be generalised to other advanced economies.

Rising government debt and expansion of social safety nets have counteracted the decline in r^n

While the three factors discussed above have contributed to reducing r^n, there are indications that the concurrent increase in government debt has exerted a counteracting effect. Higher government deficits relative to GDP reduce aggregate desired savings in the economy, thereby pushing up r^n.[16] Continuous deficits increase the level of central government debt, resulting in a greater supply of safe, liquid assets. This raises interest rates on these assets relative to less safe assets.[17]

The expansion of social safety nets in a number of countries may also have put upward pressure on r^n. Public pension systems redistribute funds through the tax system to pensioners, who generally have a relatively high propensity to consume. At the same time, the expansion of various unemployment benefit and public health insurance schemes has reduced the need for households to save to insure themselves against unemployment and illness ('precautionary saving').[18]

Several studies find that, overall, these fiscal changes have had a counteractive effect on the decline in r^n.[19] In particular, Rachel and Summers (2019) argue that these factors have significantly counteracted the decline in r^n for the United States. According to their estimates, there would have been a significantly greater decrease in r^n since the 1970s in the absence of rising government debt and expansion of social safety nets.

Higher interest rates since 2020 primarily reflect temporary conditions

The significant increase in nominal interest rates since 2020 raises the question of whether r* has risen. Moreover, if r* has increased, it is crucial for future interest rate developments whether this is due to an increase in the long-term component, r^n, or the short-term cyclical component, c*.

The global economy is currently characterised by drivers pulling the supply and demand for goods and services in opposite directions. This is, for example, reflected in a significant increase in inflation.[20] At the global level, there has been an increase in demand as the lockdowns were lifted following the covid-19 pandemic. The increase in demand has in many countries been supported by accommodative economic policies. At the same time, supply shortages have reduced potential output. The lockdowns introduced to contain the pandemic thus created bottlenecks in supply chains that have not yet been normalised. In addition, Russia's war in Ukraine has caused significant disruptions to the international energy and food markets, resulting in large price increases, especially in Europe.

Overall, the imbalance between demand and supply has increased capacity pressures in the advanced economies. This induces a higher r*, as a higher real

16 This assumes that the private sector does not reduce its savings accordingly at the prospect of having to pay higher taxes in the future to finance the repayment of government debt (Ricardian equivalence).

17 Krishnamurthy and Vissing-Jørgensen (2012).

18 The importance of pension systems and social safety nets for r^n depends on how these schemes are funded. In general, tax-funded pay-as-you-go systems will have a negative effect on r*, while savings-based systems will have a positive effect (Bloom et al., 2007).

19 Eggertson et al. (2019), Rachel and Summers (2019), Papetti (2021) and Platzer and Peruffo (2022).

20 See, for example, Harr and Spange (2023).

Drivers behind the natural real interest rate

Table 1

	Development up to 2020	Going forward
Ageing population and declining birth rates		
Increased pension savings	↓	↓
Less demand for capital due to reduced workforce	↓	↓
Lower productivity growth		
Increased savings because incomes grow more slowly	↓	→
Lower demand for capital	↓	→
Inequality		
Higher savings among affluent households	↓	?
Changes to fiscal policy		
Expansion of social safety nets	↑	?
Higher government debt	↑	↑
Energy supply, climate change and green transition		
Increased savings due to greater uncertainty and expectations of loss		↓
Lower demand for capital due to productivity loss and natural disasters		↓
Increased demand for capital for climate adaptation, reconstruction and green transition		↑
Changed trade patterns		
Increased savings resulting from decreasing incomes due to productivity loss		↓
Lower demand for capital due to productivity loss		↓
Reduced market concentration, lower inequality and financial disintegration		↑

interest rate is necessary to align demand with the temporarily lower supply. The recent hikes in monetary policy rates in many countries must therefore be seen in the context both of a sharp rise in inflation and a cyclical situation pulling towards an increased c* and thus a temporarily higher r*.

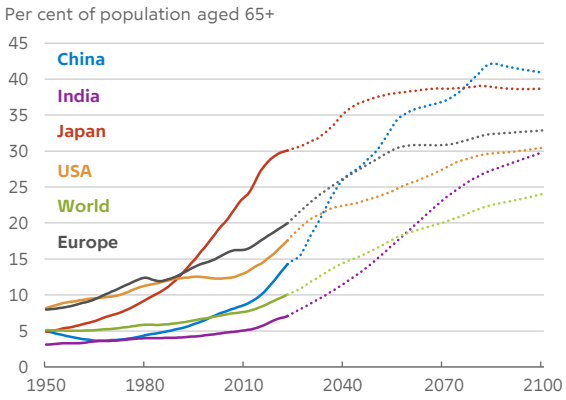
Uncertainty about real interest rates in the long run

The higher level of r* as well as the estimates of r^n in chart 4 give reason to consider developments in r^n since 2020 and going forward.

On the one hand, there are indications that the current drivers behind the decline in r^n will continue to contribute to keeping r^n at a low level. For example, demographic projections indicate that the proportion of elderly people will increase globally during this century, see chart 5. Based on this, model simulations indicate that demographics will continue to pull r^n down in the coming decades.[21] There is greater uncertainty about future developments in productivity growth and inequality, but there are no clear indications that the development in these factors has reversed.[22]

On the other hand, a number of new trends may potentially affect r^n, although both the direction and the size of their effects are uncertain. These new trends are discussed in the remainder of the section and summarised in table 1.

Ageing population going forward Chart 5



Note: Dotted lines mark the projection period.
Source: UN, World Population Prospects: The 2022 Revision.

Higher government debt and military build-up could potentially increase r^n

The covid-19 pandemic triggered a significant fiscal response, resulting in a substantial increase in government debt in many countries. The gross debt-to-GDP ratio increased by an average of approx. 11 percentage points from 2019 to 2021 across the advanced economies, see chart 6.

An average of estimates from the literature indicates that a 1 percentage point increase in the government debt-to-GDP ratio results in a 3.5 basis point increase in r^n.[23] A somewhat uncertain estimate of the effect of the covid-19 pandemic-related debt

21 Auclert et al. (2021), Bielecki et al. (2018), Gagnon and Johannsen (2021) and Papetti (2019). For example, Auclert et al. (2021) use population projections and data on savings behaviour to show that demographics will increase global savings throughout the 21st century, resulting in continued downward pressure on r^n. However, an alternative view is presented by Goodhart and Pradhan (2020). They argue that global demographic trends are reversing and will pull up r^n as an increasingly larger group of elderly people starts using their pension savings.

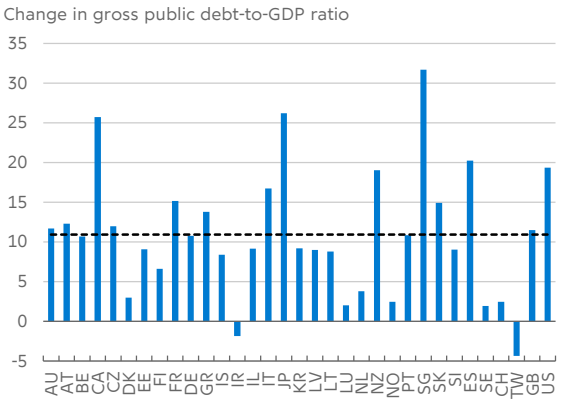
22 See ECB (2021b) for a discussion of productivity trends. Data on income distribution are published with some delay relative to aggregated data, but preliminary data for the United States indicate that income inequality growth has slowed down in recent years and that the inequality increase observed during the covid-19 pandemic was not as high as during the 2008-2009 financial crisis (Heathcote et al., 2022, and Blanchet et al., 2022).

23 Rachel and Summers (2019).

thus suggests an increase in r^n of just under 0.4 percentage points. However, this is an upper bound of the lasting effect, as the debt-to-GDP ratio is expected to decline slightly over the medium term, according to the IMF.[24] Conversely, trends pointing towards an increased use of expansionary fiscal policy may potentially lead to higher debt levels in the longer term.

The effect on r^n from government debt could be amplified if geopolitical tensions (including Russia's war in Ukraine) lead to a military build-up. However, this presupposes a significant build-up leading to expenses that are not matched by tax increases or reductions in demand elsewhere. For example, a sustained increase in military spending by all NATO countries to 2 per cent of GDP would not have a significant effect on r^n.

Large increase in government debt due to covid-19 pandemic Chart 6



Note: Change in gross government debt-to-GDP ratio from 2019 to 2021. Dashed line indicates average across countries.
Source: World Economic Outlook Database (October 2022).

Effect of climate change and green transition on r^n is not clear-cut

The green transition will to a large extent be driven by climate regulation that is going to make existing technologies unprofitable to use, even though these technologies would have been profitable in the absence of such regulation.[25] Seen in isolation, this will put negative pressure on productivity growth until the climate goals are met, thereby reducing the return on capital and demand for investments. This pulls towards a lower r^n, although the magnitude of the effect may be limited.

Natural disasters that destroy capital may likewise reduce the current rate of return on capital and thus demand. At the same time, increased uncertainty and expectations of economic losses resulting from natural disasters or more stringent climate regulation may increase household and corporate saving ('precautionary saving'). These factors may also put downward pressure on r^n.[26]

Conversely, the need for climate adaptation (for example installation of air conditioning and establishment of dikes) and reconstruction after natural disasters increase the demand for investments.[27] Likewise, the expansion of renewable energy supplies, energy renovation as well as research and development in connection with the green transition will boost demand.[28] In addition, Russia's war in Ukraine may have increased the demand for investment in energy transition over an extended number of years. These factors put an upward pressure on r^n.[29]

Empirical studies of the impact of the climate on r^n are relatively scarce, as many of the effects have not yet materialised. A number of theoretical studies have focused on the effects of lower productivity growth, increased uncertainty and expectations of

24 IMF (2022).

25 Ingholt et al. (2021).

26 Bylund and Jonsson (2020), Hambel et al. (2020), NGFS (2020), Dietrich et al. (2021), Cantelmo (2022) and Mongelli et al. (2022).

27 Keen and Pakko (2011).

28 IEA (2021) and IMF (2021) estimate that achieving global climate neutrality by 2050 will require additional global investments in the range of 0.6-1 per cent of annual global GDP over the next two decades.

29 NGFS (2020), Jørgensen (2022) and Mongelli et al. (2022).

economic losses due to climate change. The studies indicate that r^n could fall by up to 1 percentage point depending on model assumptions.[30] A single study has analysed the importance of increased demand for green investments as a result of carbon taxes. According to the study, a global carbon tax of USD 75 per tonne of CO_2, as proposed by the IMF for 2030, will increase r^n by up to 1.2 percentage points.[31]

There is considerable uncertainty about the time horizon of the theoretical effects. Negative effects on productivity growth and investment in the green transition are unlikely to be permanent. This suggests that the possible effect on r^n may decrease over time.

The effects on r^n of changing trade patterns are also not clear-cut

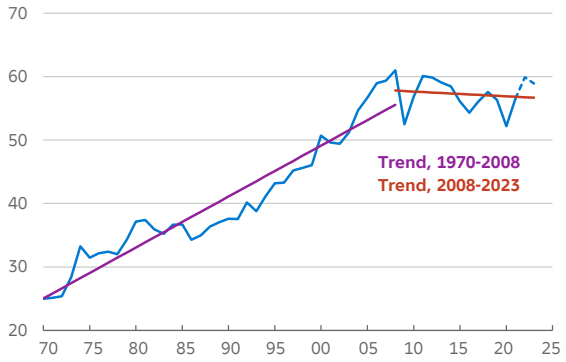
The growth in international trade since the 1970s stagnated in the wake of the 2008-2009 financial crisis, see chart 7. According to several observers, a number of major events – Brexit, the US-China trade conflict, the covid-19 pandemic and Russia's war in Ukraine – have subsequently increased the likelihood of regionalisation or actual deglobalisation of the global economy where companies relocate production to their home country or places nearby. However, there are not yet clear signs of an actual deglobalisation, but rather that globalisation has stagnated.[32]

The early phase of globalisation contributed to increased growth in productivity and wealth in the advanced economies, which supported a higher r^n. This could indicate that deglobalisation will result in a lower r^n, because the return on capital decreases and saving goes up as a result of lower expected productivity and income growth.

However, it is not clear-cut how possible deglobalisation could contribute to changes in r^n, as factors associated with deglobalisation may also contribute to increasing r^n. First, the productivity effects depend on how production is allocated among companies.

Stagnant growth in international trade Chart 7

Total exports and imports in relation to GDP, per cent



Note: The chart shows total exports and imports relative to GDP for the whole world. Broken line indicates estimates for 2022-2023 based on IMF data.
Source: World Bank (World Development Indicators) and IMF (World Economic Outlook Database, October 2022).

For example, the later stage of globalisation may have led to an increase in market concentration, which would reduce productivity growth overall. If deglobalisation results in reduced market concentration, this may cause higher productivity growth and thus a higher r^n.[33]

Secondly, the inequality effects of reshoring low-wage occupations to the home country – and thus the effect on r^n – will depend on redistributive policies.

Thirdly, globalisation has implied that emerging market economies with high saving rates, such as China, now constitute a larger share of the world economy, as well as enabling them to invest savings in the advanced economies.[34] This has contributed to pushing down r^n. If deglobalisation reduces growth in emerging market economies and weakens their ability to place savings in the advanced economies, this could increase r^n in the advanced economies.

30 Bylund and Jonsson (2020), Dietrich et al. (2021) and Mongelli et al. (2022).

31 A global tax on greenhouse gas emissions of USD 75 per tonne of CO_2 in 2030 is consistent with a goal to limit global warming to 2°C according to the IMF (2019). The estimated effect of carbon taxes on r^n comes from Jørgensen (2022).

32 Antràs (2021).

33 Gutiérrez and Philippon (2019) and Natal and Stoffels (2019).

34 The direction of savings toward advanced economies may be due to both a lack of investment opportunities in developing countries and an increased preference for safe, liquid assets (Bernanke, 2005, and Barsky and Easton, 2021).

Appendix: Estimation of natural real interest rate

The analysis uses three statistical models to estimate the natural real interest rate, r^n, in chart 4. The models are: a macroeconomic model of a small open economy, a model of long-term money demand and an arbitrage-free term structure model.

- The first model is related to the classic Laubach and Williams model (2003) and has been extended to take into account that Denmark is a small open economy, see Pedersen (2015). The model is a trend-cycle model that attempts to separate equilibrium levels (trends) and cyclical movements (cycle). The model consists of GDP in real terms, a short ex ante real interest rate, the real effective exchange rate and inflation. The natural real interest rate is derived as the trend component of the short real interest rate. The model is estimated based on quarterly data for the period Q1-1972 to Q3-2022.

- The second model estimates the natural real interest rate as a function of long-term money demand. Benati (2020) and Benati et al. (2021) demonstrate a clear empirical link between the turnover of the M1 money stock and the monetary policy rate. The intuition behind this link is that households and companies are willing to hold more money (which has a low return) when interest rates are low relative to when interest rates are high. The link between money stock and interest rates is estimated in a structural co-integrated VAR model in which the natural real interest rate is defined as the stationary linear combination of the M1 money stock and the monetary policy rate less the long-term inflation expectation of 2 per cent. The model is estimated based on quarterly data for the period Q1-1991 to Q3-2022.

- The third model includes only government yields of different maturities. The model is a dynamic arbitrage-free term structure model, see Christensen, Diebold and Rudebusch (2011). In this model, the natural real interest rate is defined as a nominal 5Y5Y forward rate[35] adjusted for the interest rate risk premium less the long-term inflation expectation of 2 per cent, see also Christensen and Rudebusch (2019). The model includes Danish zero-coupon rates with a maturity of ½, 1, 2, 5, 7 and 10 years and is estimated based on monthly data from January 1999 to December 2022.

35 I.e. the interest rate that can be locked in today on a loan that is originated in five years and matures in ten years.

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