

DANMARKS NATIONALBANK

21 OCTOBER 2020 — NO. 19

Real interest rates are affected by inflation expectations



The real interest rate is important for the economy

The real interest rate is important to economic development. The real interest rate is affected by the nominal interest rate and inflation expectations.

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Decreasing inflation expectations

Inflation expectations have been declining since the sovereign debt crisis of the early 2010s in the euro area. This has led to a higher real interest rate for a given monetary policy interest rate, entailing, viewed in isolation, a tightening of financial conditions.

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Measures of inflation expectations are uncertain

Measures of inflation expectations, and thus the real interest rate, are subject to uncertainty. The relevant inflation expectations vary across different economic agents. Consequently, short-term fluctuations in real interest rates should not be overinterpreted.

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Declining inflation expectations imply a higher real interest rate

This analysis describes the nature of the real interest rate, why it is important to real economic development, and the potential challenges related to measuring its size and impact on the economy.

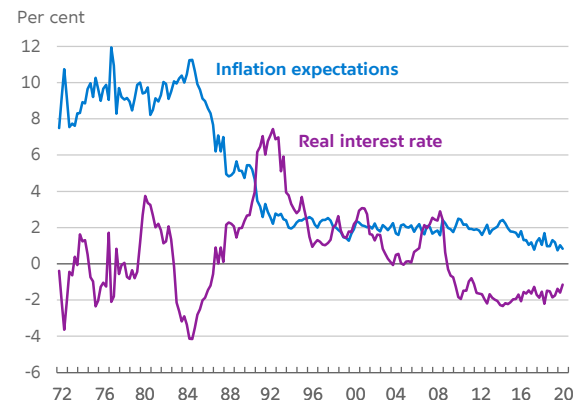
The financial situation of households and corporations depends, inter alia, on the real interest rate, defined as the nominal interest rate less expected inflation. The real interest rates play an important role in private savings and investment decisions, and thus in economic growth and inflation. This is because a fair view of the real return on savings and investments takes into account both the nominal interest rate and future price development.

In Denmark, inflation expectations have remained stable at around 2 per cent after the introduction of the fixed exchange rate policy in 1982, see Chart 1. The fixed exchange rate against the euro means that inflation in Denmark follows inflation in the euro area in the medium term.¹ Low and stable inflation provides a solid basis for long-term economic decisions.

In recent years, inflation expectations, in both Denmark and the euro area, have begun to move below the ECB's target of inflation below, but close to, 2 per cent. At the same time, the nominal interest rate has remained stable at a very low level. A sustained fall in inflation expectations may tighten financial conditions and counteract the easing effect of low monetary policy interest rates on the real economy.² This is because declining inflation expectations, all else equal, lead to a higher real interest rate, given an unchanged nominal interest rate.

Declining inflation expectations in Denmark

Chart 1



Note: Inflation expectations are estimated using a univariate AR(3) model on the basis of inflation data in Denmark. This means that inflation expectations are based on realised inflation in previous quarters in the model. The inflation expectations shown in the chart represent a projection based on this model. This statistical model is estimated over a rolling window of 40 quarters. The real interest rate has been generated using quarterly averages of the T/N rate less the series of inflation expectations.

Source: Updated estimate from Pedersen (2015).

1 Until 1999, Denmark imported inflation from Germany as a result of the fixed exchange rate policy against the German D-mark.

2 Despite an increase in recent years as a result of declining inflation expectations, the real interest rate remains at a very low level. However, the real interest rate level should be seen in the context of the low level of the natural real interest rate, r^* , see Adolfsen and Pedersen (2019). The real interest rate must be lower than r^* to help the economy grow faster than its potential, closing the output gap. This means that the effect of the current level of the real interest rate on the real economy is not as lenient as it would have been in the past, for example in the 1990s.

There is no clear-cut measure for assessing the real interest rate development. Some of the reasons are that inflation expectations cannot be observed but must be measured, and that inflation expectation measures are inaccurate. Moreover, the real interest rate is not a clear concept, as different economic operators have different inflation expectations. In addition, some economic operators may tend to focus on changes in nominal interest rates, not adjusting for changed inflation assumptions – also known as money illusion. Therefore, the real economic impact of short-term fluctuations in the real interest rate as a result of the development in certain inflation expectation measures should not be overinterpreted. On the other hand, persistent changes in a broader set of measures of inflation expectations could be an indication of changes in financial conditions resulting from changes in the real interest rate.

Real interest rates and financial decisions

The real interest rate is adjusted for expected inflation³

It is important to distinguish between *nominal* and *real* interest rates. The nominal interest rate can be considered as the gain over a period of time, measured in Danish kroner, which a consumer can achieve by saving up instead of spending the money today. The real interest rate should be interpreted as the gain in terms of consumption by deferring spending through savings.⁴ The real interest rate is therefore calculated as the nominal interest rate less the *expected* inflation. That is why it is also called the *ex ante* real interest rate.⁵

For example, if a consumer saves kr. 1,000 at a nominal return of 1 per cent p.a., the consumer will have gained kr. 10 after one year. If the price of the

consumer's basket of preferred consumer goods has increased in the meantime by, for example, 2 per cent, the consumer has effectively lost kr. 10 of the value of the preferred consumer goods relative to a situation where the consumer had spent the kr. 1,000 immediately. The consumer can thus buy fewer, and not more, goods for his or her savings, given the negative real return, here -1 per cent.

The real interest rate plays a role in household consumption decisions

When a consumer is to decide on the shares of income to spend and save, respectively, the nominal interest rate adjusted for inflation *expectations*, and not the current inflation, is relevant.⁶

The real interest rate may have contradictory effects on private consumption. If the real interest rate rises, the return on savings increases, providing an incentive to save more and spend less today (the substitution effect). Conversely, since a consumer must save less to achieve the same consumption in the future, the consumer can increase his or her current consumption (the income effect). In addition, there is a wealth effect, which is typically negative for consumption, as future income flows will be discounted harder. This reduces the present value of total life income.

The overall interest rate effect on current consumption is typically estimated to be negative, so that a decrease in interest rates stimulates consumption, viewed in isolation. In other words, the substitution effect dominates, particularly for consumers with credit restrictions.⁷

Real investment depends on the real interest rate

The real interest rate also plays an important role in corporate decisions to invest in production equipment, i.e. real capital. When a corporation invests in real capital, it tries to maximise its profits. This means investing in the capital stock until the marginal return is in line with the current cost of using capital,

3 See Appendix 1 for a model-based review of the impact of real interest rates on an economy.

4 See also Boschen (1994).

5 The following focuses on the *ex ante* real interest rate as the real interest rate on which households and corporations base their decisions. The literature also considers the *ex post* real interest rate, defined as the nominal interest rate less realised inflation over the period considered.

6 However, since other factors influence household savings decisions too, their net savings may well be positive in a situation where real interest rates are negative.

7 See, among other things, Elmendorf (1996), Di Maggio et al. (2017) and Hviid and Kuchler (2017).

including the real interest rate. Here, price developments of the corporation's product are important for measuring the real return.

Besides corporations, households can also invest in real capital. Housing investments account for the major part of real investment by households. Here, the real interest rate also plays a key role in the decision-making basis of households as the ongoing cost of financing the investment.⁸ In this context, the rules on interest deductions have been particularly important as the rules affect, among other things, the real interest rate that households have to pay for a housing loan after tax, see below for further discussion.

At the same time, the value of Danes' homes makes up a large part of household wealth. The real interest rate is an important driver of the overall development in house prices and thus the value of housing wealth. That is why the real interest rate affects consumption through a wealth channel, while it affects housing investments through the ability of households to provide collateral for credit.

The real interest rate plays a crucial role for central banks

Monetary policy affects the real interest rate through both the nominal interest rate and inflation expectations, making the real interest rate a key factor for central banks.

Several central banks have adopted explicit inflation targets. When a central bank aims to reach an explicit inflation target by easing or tightening financial conditions in the economy, it focuses not only on setting (nominal) monetary policy interest rates and the pass-through to market-based interest rates. The central bank equally focuses on inflation expectations being well anchored. If this is not the case, central banks may find it difficult to control the real interest rate development and thus ensure price stability.

Central banks with explicit inflation targets anchor inflation expectations by signalling that they will and can do what it takes to reach the target. Once a cen-

tral bank has secured well-anchored inflation expectations, it is able to control the development of real interest rates and thus consumption and investment, i.e. the macroeconomic development, and ultimately prices.⁹ In other words, the credibility of the central bank's mandate is essential for the central bank to fulfil its mandate.

In a fixed exchange rate regime, such as the Danish one, it is also important that inflation expectations are well anchored. The monetary policy interest rate in Denmark is set in order to secure the exchange rate of the krone against the euro, but inflation expectations are an important element in the development of the real interest rate and thus the impact of monetary policy on the real economy. The fixed exchange rate policy is fundamentally a monetary policy strategy for price stability, achieved by anchoring to a central bank with a credible inflation target.

The fixed exchange rate policy is pursued through intervention in the foreign exchange market and the setting of monetary policy interest rates. In practice, this means that monetary policy interest rates largely follow those of the euro area on a one-to-one basis. At the same time, there is a high degree of covariation between the business cycle and prices in Denmark and the euro area, see, among other things, Chart 2. This is partly due to the high credibility of the fixed exchange rate policy. Through the implementation of the fixed exchange rate policy, Danmarks Nationalbank thus ensures that the real interest rate in Denmark has a stabilising effect on Danish economy most of the time.

Moreover, stable inflation expectations due to the fixed exchange rate policy provide a solid basis for long-term economic decisions, ensuring a robust Danish economy.

If central banks are unable to anchor inflation expectations, real interest rates may take the opposite path from what the central bank wants. This happened in the 1970s, when inflation expectations rose, partly against a backdrop of oil crises and distrust of

⁸ In addition to the possibility of achieving a real return by investing in a home, households also enjoy an ongoing benefit from being able to use the home.

⁹ The central bank will assess the impact on activity of its monetary policy by comparing the real interest rate with the natural real interest rate, which indicates the activity-neutral level of the real interest rate, see Pedersen (2015) and Adolfsen and Pedersen (2019).

central banks' ability to control inflation. This made it difficult for central banks to obtain higher real interest rates in order to counteract the high inflation that was imported, among other things, due to the oil crises, despite the very high nominal interest rates. In many countries, attempts were made to remedy the unsustainable inflation development by introducing explicit monetary policy objectives. In several European countries, this initially meant the transition to a consistent fixed exchange rate policy against the German D-mark and, later, the transition to a single European currency union with an explicit inflation target. In Denmark, this was done by introducing the fixed exchange rate policy in 1982 and by its consistent and credible execution since then.

Falling inflation expectations are particularly problematic at the lower bound

Falling inflation expectations can be a problem for central banks pursuing monetary policies according to an inflation target if monetary policy interest rates are around the supposed lower bound. The lower bound is the level of nominal interest rates where a central bank's further lowering of the monetary policy interest rate will no longer have any effect.

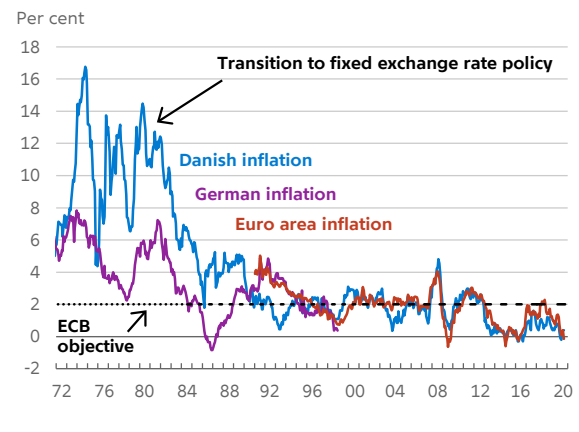
Here, the ability to control inflation expectations is key, as the (nominal) monetary policy interest rate cannot be lowered any further. A fall in inflation expectations thus leads to an increase in real interest rates and an unintentional negative impact on growth and inflation, see Chart 3. If this happens in the euro area, the Danish economy will also be affected, as the real interest rate in Denmark mirrors that of the euro area closely. Since the financial crisis in the late 2000s, several central banks with explicit inflation targets, including the ECB, have introduced unconventional measures. The use of the new monetary policy tools should be seen in light of low monetary policy interest rates and low inflation.

Different interest rates and time horizons relate to different financial decisions

So far, the real interest rate has been referred to as a whole. In practice, consumers and investors face different real interest rates. The reason is that there are different interest rates and time horizons linked to different financial decisions. The relevant interest rate also depends on whether the financial decision relates to savings or investment, including whether it is a financial investment (i.e. placing savings in financial claims) or an investment in real capital. For example, households focus on developments in

Close link between price developments in Denmark and the euro area

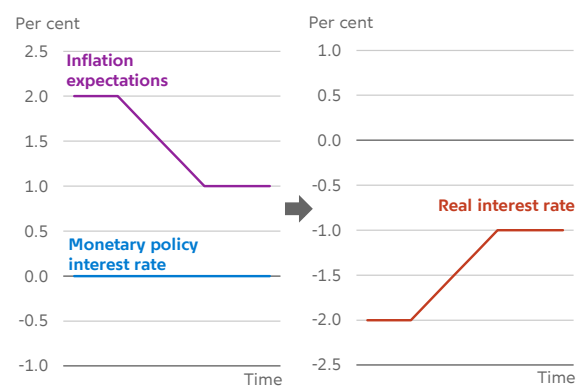
Chart 2



Note: Inflation in Germany, as measured by the consumer price index, is shown until the introduction of the euro in 1999. Until 1991, the consumer price index in Denmark is used, and after that time the Harmonised Index of Consumer Prices. For the euro area, the Harmonised Index of Consumer Prices is used.
 Source: Thomson Reuters Datastream.

Lower inflation expectations lead to a higher real interest rate at the lower bound of monetary policy interest rates

Chart 3



Note: Stylised example of the effect of a fall in inflation expectations on the real interest rate with the monetary policy interest rate at the lower bound. Here, the lower bound is assumed to be zero, although it has proved to be significantly below zero in practice.

mortgage yields and house prices in the financing of housing investments. Conversely, other interest rates are more relevant to the return on household savings. For example, the development of government yields is of great importance to Danish households' pension savings.

Nominal interest rates may vary considerably across different maturities, see Chart 4. In addition, premia linked to maturity and different types of financial contracts should be taken into account. Variation between interest rates may arise from different market conditions and risk perceptions, which may change over time. Although there may be significant differences between various types of interest rates, there is also a relatively close covariation between nominal interest rates, in terms of both different types of contracts and maturities, see Chart 5. This supports the view that a risk-free interest rate is indicative of general interest rate developments.

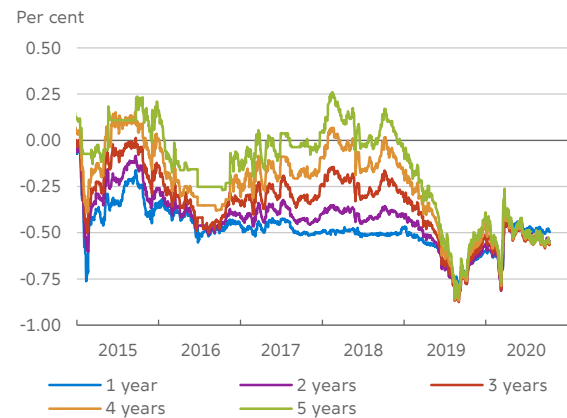
Tax rules may distort the real interest rate

The nominal taxation of capital income in Denmark, which includes deductions for interest expenses, implies a difference in the real interest rate before and after tax. The stabilisation of inflation and interest rates at a low level has reduced the impact of nominal taxation. Nominal interest rates were much higher in the 1970-80s, see Chart 6, while real interest rates were relatively low. After tax, the real interest rate was consistently negative. The reason was that taxation is based on the nominal interest rate, which was very high in the 1970-80s. Volatile inflation led to an unpredictable real interest rate after tax. The negative real interest rate after tax during the period contributed to creating economic imbalances in Denmark, and its unpredictable development provided an uncertain basis for financial decisions.¹⁰

This problem has shrunk as inflation and interest rates have stabilised at low levels. In addition, the rates in the rules on capital income taxation have been gradually reduced, including interest deductions. The difference in real interest rates before and after tax is currently less than 1 percentage point, compared with about 11 percentage points in the 1970-80s.

Interest rates may develop differently across maturities

Chart 4

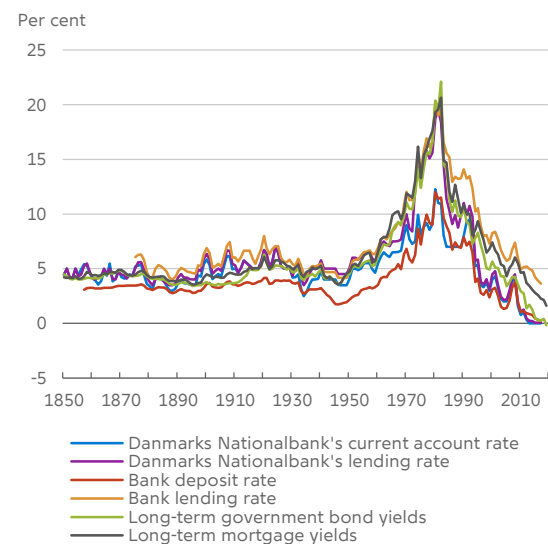


Note: Expectations of the nominal overnight interest rate in Denmark illustrated by an OIS (overnight index swap) for different maturities.

Source: Refinitiv Eikon.

Interest rate developments are relatively even across contract types and maturities

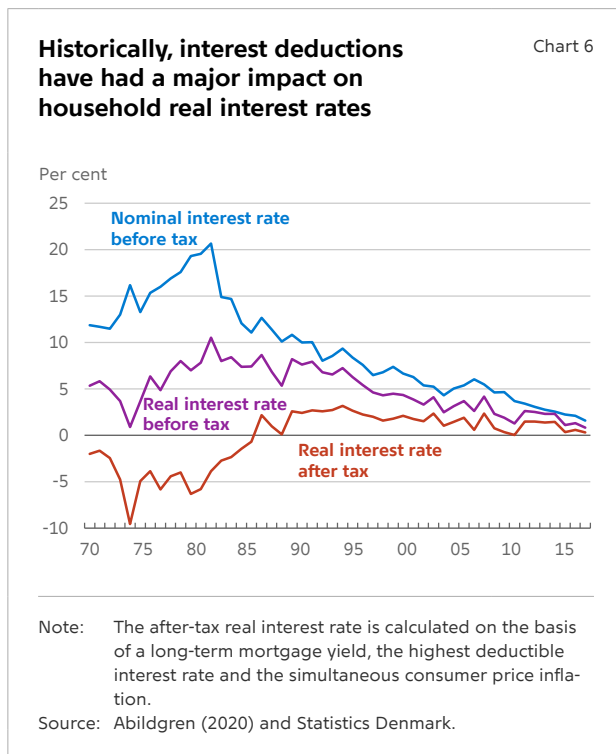
Chart 5



Note: Historical annual averages for different types of interest rates in Denmark since 1850. See Abildgren (2020) for documentation.

Source: Abildgren (2020).

¹⁰ See Pedersen (2001) for a clarification.



Money illusion may have led to a focus on nominal interest rates

Although it is crucial to consider an interest rate in real terms in a theoretical context, in practice households and corporations may tend to focus on money and interest rates in nominal terms without adjusting for inflation. This phenomenon is known as money illusion.¹¹ The consequence may be that decisions are based on nominal interest rates rather than real interest rates.

The long period of low and stable inflation since the introduction of the fixed exchange rate policy has meant that movements in nominal interest rates have become more fairly indicative of developments in real interest rates. The lower risk of future inflation may imply a lower potential gain relative to resources in predicting and insuring against fluctuations in inflation. As such, it may be regarded as one of the successes of the fixed exchange rate policy that economic operators need to devote less resources to predicting future fluctuations in inflation when weighing costs against a potential return.

Inflation expectations are difficult to measure

Whereas nominal interest rates are easy to observe, inflation expectations must be measured. Inflation expectations are difficult to measure, and there are several measuring methods. The following discusses the two most widespread measures: market-based and survey-based inflation expectations.¹² Market-based measures do not have the same disadvantages as the survey-based measures – and vice versa. That is why the two measures often complement each other in economic assessments of the development in inflation expectations.

Financial products may indicate inflation expectations

Financial products can be used as an indication of financial operators' expectations of future inflation. The most commonly used market-based measure is derived from so-called inflation swaps see box 1.

The market-based measure has the advantage of being available at a high frequency, making it possible to quickly assess the effects of, for example, economic downturns or policy actions. Another advantage of market-based inflation expectations is that the price of an inflation swap is set on the basis of real transactions. This means that the price reflects the expectations of financial investors who are willing to place funds in the market.

On the other hand, market-based measures may contain elements other than the underlying inflation expectation, such as inflation risk premia that compensate the investor for taking a risk. Therefore, the swap rate often reflects more than the actual inflation expectation, which obscures the 'true' expectation in the market.

Surveys provide a cleaner measure of inflation expectations

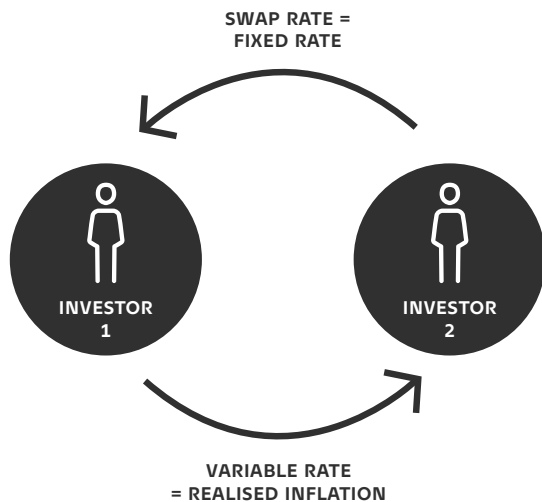
As an alternative to the market-based measures, several institutions conduct questionnaire surveys at a fixed frequency to assess households'

11 See, among other things, Shafir et al. (1997) for a study on money illusion.

12 Among other things, there are also statistically estimated inflation expectations based on historical contexts.

Inflation swaps indicate market inflation expectations

Box 1



An inflation swap is a contract between two parties under which one party pays a pre-agreed fixed rate, the swap rate, while the other party pays a variable rate equal to the realised inflation rate during the contract term. The swap rate is based on market participants' demand for participating in a swap: If the swap rate is higher than market participants' inflation expectations, the number of investors who will pay the variable inflation rate and receive the swap rate will be high. The swap rate will then fall to a point where it again reflects market expectations. In addition to market participants' inflation expectations, the swap rate will also include a possible premium required by market participants for participating in the swap. Inflation risk premia are traditionally defined to be negative if the fixed rate market price in the swap is lower than the true inflation expectation.

or professional economists' expectations of future inflation.

In the euro area, the ECB produces the quarterly Survey of Professional Forecasters (SPF), asking professional economists about their expectations of future inflation. Compared with the market-based inflation expectation measures, they provide a cleaner measure because they only express the expectations of professional forecasters of inflation at a given time in the future. This means that the measure does not include risk premia. However, a disadvantage of survey-based inflation expectations is that they are only available at lower frequencies and with a certain lag. Contrary to market-based inflation expectations, the questionnaires also have the disadvantage of not being based on real financial transactions, implying that respondents may have spent less resources on stating a qualified inflation indication.

Measures of professional forecasters' inflation expectations have fallen in recent years

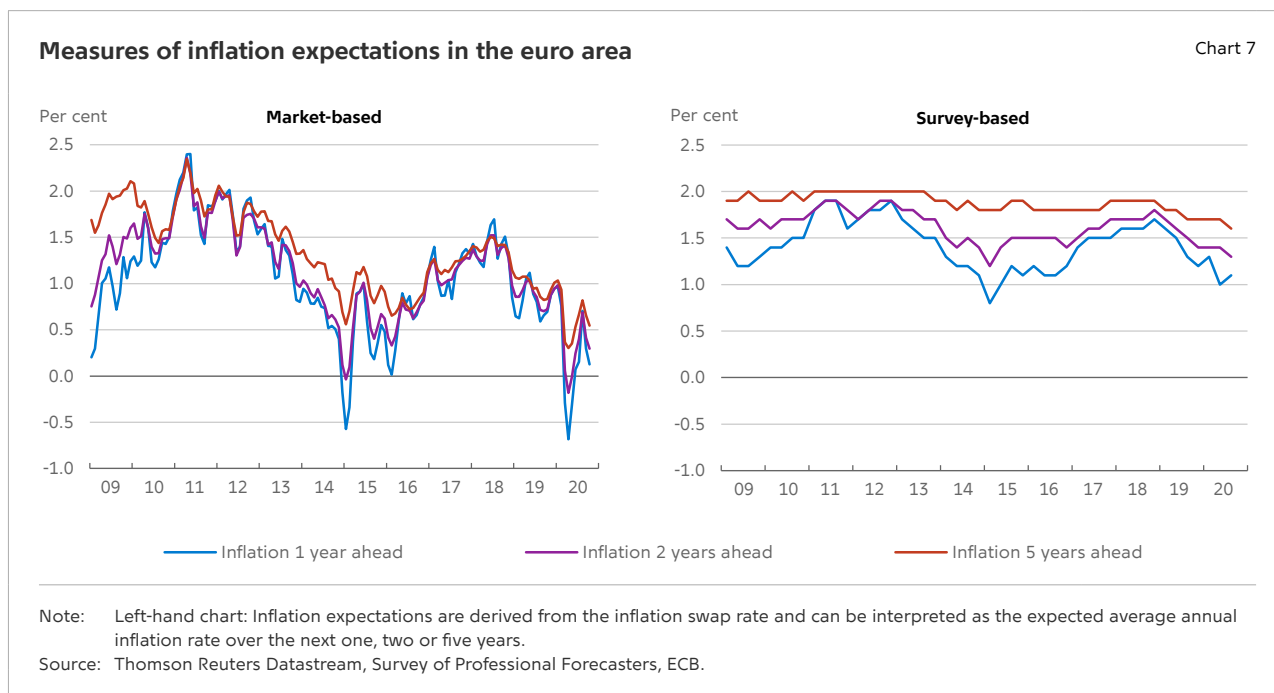
Since the early 2010s, market-based inflation expectations in the euro area have fallen by approximately 1.5 percentage points and were around 0.5 per cent in October 2020, see Chart 7, left. The

decrease is seen in inflation expectations one year, two years and five years ahead. There is no similar liquid market for inflation swaps based on inflation developments in Denmark. Due to Denmark's fixed exchange rate policy, inflation expectations in the euro area are typically used as an approximation of Danish inflation expectations. In the literature, the fall in market-based inflation expectations has raised the question of whether it reflects the fact that inflation expectations in the euro area are well-anchored around the ECB's inflation target of below, but close to, 2 per cent to a lesser degree than before the sovereign debt crisis in the euro area.¹³

However, looking at measures based on surveys among professional economists, expectations of future inflation are closer to the ECB's inflation target, see Chart 7, right. They are thus considerably higher than the market-based measures and, in particular, inflation expectations five years ahead have remained stable at just under 2 per cent in recent years.

The ECB points out that the development in the market-based measures is much more in line with the survey-based measures, taking into account the inflation risk premium, which reflects financial

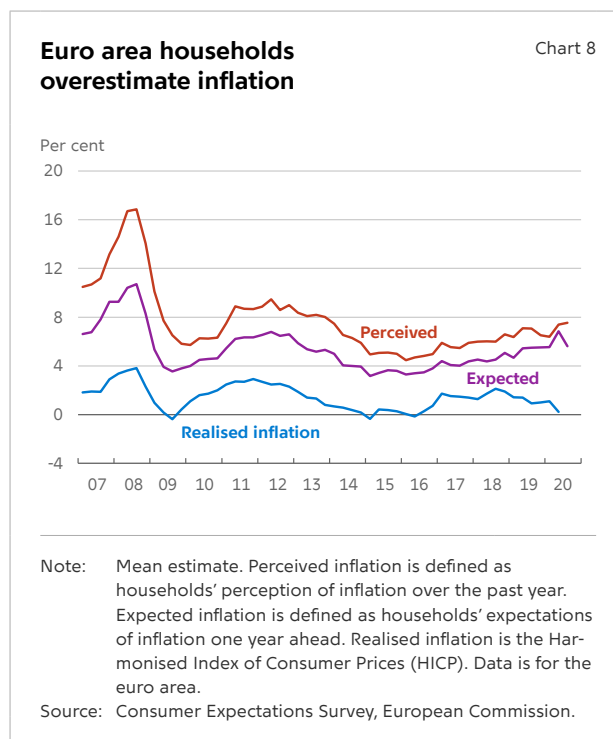
¹³ See, for example, Corsello et al. (2019).



investors' required compensation for the risk of inflation deviating from the average inflation estimate in the market. Among other things, the ECB finds that around 80 per cent of the fall in 2019 in the five-year inflation swap is due to a fall in the risk premium.¹⁴

Households overestimate inflation – but perceive the changes

Both measures of inflation expectations discussed above are based on the assessments of professional forecasters. However, household and corporate inflation expectations ultimately play a key role in the transmission of monetary policy to the real economy, as households and corporations are the ones who make the decisions to save or to spend and invest. On a quarterly basis, the European Commission publishes a household assessment of current and future expected inflation in the euro area. It shows that households consistently overestimate price developments. The 4th quarter of 2019 is a case in point. In that quarter, the actual inflation rate in the euro area was 1 per cent, while the average perceived inflation rate was 6.5 per cent, see Chart 8.



14 See Cœuré (2019).

Household inflation expectations are also significantly higher than the actual inflation development. Nevertheless, it is evidenced that households have a fairly good understanding of the changes in inflation, providing for a considerable covariation between realised, perceived and expected inflation.¹⁵

The correlation is mainly driven by price developments in certain groups of goods and services that consumers buy more often. If the item is purchased, the chance of the consumer noticing price changes is greater.¹⁶ A study on Danish data finds that changes in food prices, among other things, have a greater weight in perceived inflation than in the official price index. It is therefore argued that changes in expectations, rather than levels, should be used to analyse the development in household inflation expectations and real interest rates.¹⁷

In general, it is evidenced that both households and corporations only to a limited extent include all the information that provides indications of future inflation, or that they do so with a certain lag.¹⁸ Market-based measures account for a very large proportion of the available information, but conversely also include risk and liquidity premia that disrupt the picture.

The implications of short-lived changes in market-based measures of inflation expectations for real economic activity should not be overinterpreted, especially not in the short term. This is due to the high-frequency fluctuations in market-based measures of inflation expectations, as well as the money illusion trend among households and corporations. On the other hand, persistent changes in a broader set of measures of inflation expectations could be a strong indication of changes in financial conditions resulting from changes in the real interest rate.

The measured effect of the real interest rate

Although the real interest rate plays an important theoretical role in the development of the overall economy, the empirical significance is difficult to measure. One factor that makes it particularly difficult to measure the effect of a change in the real interest rate on the real economy is causality: central banks usually raise (lower) their monetary policy interest rates when consumption, investment and the growth and inflation outlook are high (low). The challenge for the empirical literature is therefore to separate the effect of a monetary policy interest rate adjustment on the real economy from the monetary policy response to the development in the real economy.

It is a well-established empirical finding in the international literature that central banks pursuing monetary policy according to an inflation target achieve the desired effect on growth and inflation when they adjust monetary policy interest rates.¹⁹ In other words, economic activity and inflation decrease when a central bank raises interest rates and vice versa when it lowers interest rates.²⁰ The changes in interest rates have an impact both through consumption and investment.²¹ Studies on Danish data also find that households increase their consumption when they refinance mortgage loans at a lower interest rate.²²

An empirical question that is even harder to answer is whether changes in inflation expectations, viewed in isolation, have an effect on the real economy through their impact on the perceived real interest rate. Firstly, many central banks are keeping an eye on inflation expectation measures, using them to inform their monetary policy decisions. This makes it difficult to separate the effects of the changes in nominal interest rates and inflation expectations. Secondly, there is no clear and unambiguous measure of the relevant

15 See Arioli et al. (2017).

16 D'Acunto et al. (2019).

17 See Abildgren and Kuchler (2019).

18 See, among other things, Coibion et al. (2019) and Coibion et al. (2018).

19 See, among other things, Romer and Romer (2004).

20 The literature often finds that changes in monetary policy interest rates only affect the real economy after about six months to two years, see Romer and Romer (2004). Therefore, central banks with inflation targets tend to base their monetary policy decisions more on their inflation expectations than on current inflation.

21 See, among other things, Gilchrist and Zalkrajsek (2007).

22 See Andersen et al. (2019).

inflation expectations in the economy, and households and corporations do not always incorporate all available information into the formation of their expectations. At the same time, their response may be lagged, e.g. as it takes time to invest. Consequently, households and corporations do not necessarily change their consumption and investment behaviour immediately when their inflation expectations change.

No empirical analyses on Danish data are available, isolating the effect of changes in real interest rates as a result of changed inflation expectations. In recent years, however, the international economic literature has had an increasing focus on identifying the impact of inflation expectations on real economic variables based on data for other countries. The studies have evidenced that changes in inflation expectations given the analysed conditions can, viewed in isolation, have a significant impact on the real economy. For example, on the basis of US data, it has been shown that an increase in monetary policy interest rates in the USA could lead to higher inflation in periods of strong disagreement on inflation expectations.²³ This goes against the intention of tightening monetary policy.

Based on surveys for households and corporations, it has also been evidenced that changing inflation expectations can influence consumption and investment decisions. For example, a study on Italian data shows that the probability of a corporation expanding its investments increases when it expects higher inflation, and that this effect mainly works through the real interest rate channel.²⁴ A study on New Zealand corporate data has also shown that business investment can be relatively sensitive to changing inflation expectations. The study finds that when inflation expectations fall by around 1 per cent, corporations' planned investments fall by 2 per cent. However, the study does not show whether the effect relates directly to the real interest rate channel.²⁵

The measured effect of inflation expectations on consumption is both less clear and weaker than the

effect on investment. For the euro area, an analysis has shown that higher inflation expectations among households increase the willingness to spend. This effect is higher at the lower bound of the monetary policy interest rate. When the central bank is unable to change monetary policy interest rates, an increase in inflation expectations leads to a corresponding fall in the real interest rate. Here, the effect of an increase in inflation expectations of 2 percentage points is estimated to increase total private consumption by 0.36 per cent over a three-year period. The effect is estimated to be 0.26 per cent when changes in inflation expectations are not completely passed through to the real interest rate. That is, when the central bank changes interest rates as a result of changed inflation expectations. The analysis therefore concludes that the isolated effect of inflation expectations on the real interest rate can have a significant impact on private consumption.²⁶ Some studies for other countries also identify positive effects of inflation expectations on household consumption, while other studies find no significant impact.²⁷

As mentioned, the empirical literature on the impact of inflation expectations on real economic decisions through the real interest rate channel has difficult empirical challenges and is still evolving.

23 This is because an increase in monetary policy interest rates can be seen as a sign of strong demand in the economy, inducing corporations to raise prices in the event of great uncertainty about future inflation, see Falck et al. (2019).

24 See Grasso and Ropele (2018).

25 See Coibion et al. (2018).

26 See Duca et al. (2018).

27 See Ichiue and Nishiguchi (2015), D'Acunto et al. (2016), Bachmann et al. (2015) and Burke and Ozdagli (2013).

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Appendix 1: Real interest rates, monetary policy and macroeconomic theory

In macroeconomic theory, the real interest rate and expectations of future real interest rates play not only a key role, but a dominant role as determinants of activity and inflation. Due to nominal rigidities, central banks may influence real interest rates by setting the short-term nominal interest rate. This is shown here in a simple model.²⁸

The real interest rate, r_t , is defined as

$$r_t \equiv i_t - E_t[\pi_{t+1}],$$

where $E_t[\pi_{t+1}]$ denotes inflation expectations and i_t is the short-term nominal interest rate. This relation is also referred to as the Fischer equation.

The supply side of the economy in this simple model is given by a correlation between inflation, π_t , given as developments in consumer prices, expected future inflation x_t and a measure of economic activity, here the output gap, x_t , defined as the difference between actual and potential GDP. This correlation is most often referred to as the Phillips curve:

$$\pi_t = \beta E_t[\pi_{t+1}] + \kappa x_t.$$

In simplistic terms, demand in the economy consists only of consumption and investment. An important decision for households is how much to spend now or later. The problem usually leads to a correlation between consumption today, c_t expectations of future consumption, $E_t[c_{t+1}]$, and real interest rates:

$$c_t = E_t[c_{t+1}] - \sigma r_t.$$

The impact on the consumption development of changes in the real interest rate depends on households' desire for consumption levelling over time, here represented by the parameter σ . The correlation, here in a simplistic form, is called the

Euler equation, the IS relation or the intertemporal consumption decision (Keynes-Ramsey rule) and is included in some form in virtually all macroeconomic models, including both in short-term business cycle models, such as RBC and DSGE models, and in medium-term to long-term models, such as OLG models, see, for example, Woodford (2003), Wickens (2011), Obstfeld and Rogoff (1996) or Acemoglu (2008). The relation expresses that the reduction in utility in period t by deferring consumption today must be compensated by the discounted increase in utility tomorrow from the extra savings and their return.²⁹

The investment decision for corporations can be written as $I_t - k_t = \eta q_t$, where investments relative to the capital stock, $I_t - k_t$, depend on the parameter, η , and Tobin's q , q_t .³⁰ This variable denotes the value of additional capital for the corporation relative to the cost of replacing the capital stock. This depends positively on the expected marginal product of capital – i.e. how much additional production the corporation gets from installing a little more capital, $E_t[y_{t+1} - k_{t+1}]$, and negatively on the real interest rate:

$$q_t = \theta E_t[y_{t+1} - k_{t+1}] - r_t + \beta E_t[q_{t+1}].$$

The real interest rate is included in the expression, as it is the opportunity cost for the corporation: Instead of investing in additional capital, the corporation could invest the amount in a risk-free asset at the return r_t .

Finally, a relation determines how the central bank conducts conventional monetary policy. This is done through a so-called Taylor rule, which responds positively to inflation deviations from the target,

28 The details of derivations etc. can be found in Galí (2015) or in Woodford (2003) and are quite standard.

29 The decisions of different economic operators depend on the time horizon of their savings and investment, so the real interest rate for different maturities has an impact on the economy today. The long-term real interest rate can be taken as equal to the expression and possibly a risk premium. Investors base their decisions on the full yield curve from today until the end of the investment horizon.

30 The parameter can be interpreted as the elasticity of the investment-to-capital ratio with respect to Tobin's q .

π , $\phi_{\pi}(\pi_t - \pi)$, and positively to the output gap, $\phi_x x_t$:

$$i_t = \phi_{\pi}(\pi_t - \pi) + \phi_x x_t.$$

The importance of the real interest rate today and expectations of future real interest rates for the development of the economy

The consumption and investment relations can be rewritten to depend on expectations of all future real interest rates:

$$c_t = -\frac{1}{\sigma} E_t[\sum_{j=0}^{\infty} r_{t+j}] \text{ and } q_t = E_t[\sum_{j=0}^{\infty} \beta^j (\text{mpk}_{t+j} - r_{t+j})],$$

where $\text{mpk}_t \equiv \theta(y_t - k_t)$ denotes the marginal product of capital.³¹ Similarly, inflation can be written as expectations of future output gaps: $\pi_t = E_t[\sum_{j=0}^{\infty} \beta^j \kappa x_{t+j}]$. Based on these two rewrites and the link between investments and Tobin's $I_t - k_t = \eta q_t$, the following five points can be inferred:

1. The real interest rate is an important variable for activity development: All expected future real interest rates affect today's consumption and investment decisions. In less simple models, both consumption and investment can also be backward-looking, but in most cases both variables will depend on expectations of future real interest rates.
2. When the economy is in balance, i.e. the output gap is closed, $x_t = 0$, then inflation is also on target. In other words, inflation is also a function of expectations of future real interest rates.
3. The decisions of different economic operators depend on the time horizon of their savings and investment, so the real interest rate for different maturities has an impact on the economy today. The long-term real interest rate can be taken as equal to the expression $E_t[\sum_{j=0}^{\infty} r_{t+j}]$ and possibly a premium. Investors base their decisions on the full yield curve from today until the end of the investment horizon.
4. When a central bank conducts monetary policy by setting short-term nominal interest rates, monetary policy influences activity through the real interest rate and its expectations. That is why central banks' communication on future monetary policy and anchored inflation expectations is important.
5. A fall in inflation expectations leads to an increase in the real interest rate and thus a tightening of monetary policy. This puts downward pressure on activity and inflation. If the economy is at the lower effective limit where further lowering of the nominal interest rate is not possible, and if the fall in inflation pushes down inflation expectations even more, then the economy is entering a downward spiral that could lead to sharp declines in activity. And the longer this is expected to last, the stronger the effects already today.

31 The sum of investments and consumption represents total demand in the model, which is why the insight holds true for total demand in the economy.

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This edition closed for
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