# What is the natural interest rate?

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*What real interest rate should a central bank aim for if it wishes to attain a normal level of resource utilisation? In modern monetary policy theory, the real interest rate that is consistent with a normal level of resource utilisation is usually called the 'natural interest rate'. One way of determining whether monetary policy is expansionary or contractionary is to compare the actual real interest rate with the natural interest rate. One important characteristic of the natural interest rate is that its level varies over time. This article analyses how different types of macroeconomic disturbances of the type that were seen in the financial crisis can impact the natural interest rate in a theoretical model of the economy.*

The **nominal interest rate** is the compensation that a borrower pays to a lender in addition to the borrowed amount. It is measured as a proportion of the borrowed amount and is expressed as a percentage. For example, banks often offer loans and savings at nominal interest rates.

The **real interest rate** can be calculated as the nominal interest rate over the loan's maturity minus expected inflation over the same period. The real interest rate shows the purchasing power a borrower must relinquish to gain access to the loan, and is the most relevant factor for households and firms when they decide to borrow money.

The **policy rate** or **repo rate** is the nominal interest rate at which banks can borrow from or invest in the Riksbank over the short term. The policy rate can also be calculated in real terms by adjusting for expected inflation, which is more relevant when analysing the development of the real economy.

The **natural interest rate** is the real interest rate that would prevail if resource utilisation in the economy was normal today and was expected to remain normal in the future.

What do we mean when we say that a certain monetary policy is expansionary or contractionary? Most of us would probably agree that an expansionary monetary policy means that the central bank holds the policy rate at a low level so as to increase resource utilisation. Conversely, a contractionary policy means that the policy rate is set at a relatively high level, which, in normal cases, leads to the dampening of resource utilisation.

But what would be a more precise definition of the concepts of 'expansionary' and 'contractionary' monetary policies? Is it possible to determine an exact cut-off point for the

1 We have received assistance from many of our colleagues, and would particularly like to thank Lars E.O. Svensson and Ulf Söderström.

interest rate, below which a certain monetary policy can be characterised as expansionary and above which it can be said to be contractionary? In modern monetary policy theory, such a cut-off point exists for the *real* interest rate, that is, the nominal interest rate minus expected inflation. This cut-off point is usually called the 'natural real interest rate' or, more succinctly, the 'natural interest rate'. One important characteristic of the natural interest rate is that its level varies over time as a result of macroeconomic disturbances affecting the economy. In theory, the level of the natural interest rate must first be established, before it can be determined whether a certain monetary policy is expansionary or contractionary.

The aim of this article is to discuss what is meant by the term 'the natural interest rate'. Its starting point is a description of the economy that forms the mainstream of current research on monetary policy, sometimes known as New Keynesian theory. In the article, we describe some central relationships in a simple version of a New Keynesian model, and, on the basis of these relationships, discuss the concept of the 'natural interest rate'.[2] The appendix includes a brief mathematical description of the model. The article also includes a section with examples showing how the natural interest rate is affected by a number of different macroeconomic disturbances.

## The natural interest rate and monetary policy

According to modern macroeconomic theory, a central bank normally wants to control both the rate of inflation and the level of resource utilisation in the economy. A central bank that conducts inflation targeting and tries to hold inflation stable around an inflation target usually has two reasons for influencing resource utilisation, the first of which is directly linked to the task of maintaining price stability. Resource utilisation affects firms' costs, and the costs are decisive when firms price their products. For a central bank aiming to stabilise inflation around an inflation target, it is thus very important to also stabilise resource utilisation so that the general cost level rises at a rate that is compatible with the inflation target.

In addition to the target of stabilising inflation, the central bank may also consider the stabilisation of the real economy to be part of its objective. This need not conflict with the task of maintaining price stability: given that households and firms trust that the central bank returns inflation to target in the long term, there is normally scope for trying to find a balance in the short and medium term between the target of stabilising inflation and the ambition of stabilising the real economy. Such trade-offs are relevant when the economy is affected by macroeconomic disturbances driving inflation and resource utilisation in

2 The concept of a natural interest rate was introduced by Knut Wicksell in a series of theoretical works published around 1900. By the 'natural interest rate', Wicksell meant a real equilibrium interest rate that was independent of the actual bank interest rates and which was determined by the real disturbances affecting the economy. A central bank wishing to hold prices stable should take action aimed at holding the actual bank interest rates level with the natural interest rate. In recent decades, this concept has become an important component of what is known as New Keynesian theory, although the meaning of the concept has partly changed. Wicksell's influence on modern monetary policy theory is considered to be highly significant by a number of researchers, and, consequently, the term 'Neo-Wicksellian model' is occasionally used instead of 'New Keynesian model'. See Wicksell (1898) and Woodford (2003), particularly chapters 1 and 4.

opposite directions, for example supply shocks. Another reason for the central bank to influence resource utilisation may thus be that the stability of the real economy is seen as a monetary policy target in itself.

Under an inflation-targeting regime, monetary policy is normally a matter of finding a path for the policy rate that gives good forecasts for inflation and resource utilisation. 'Good forecasts' mean a forecast for inflation that deviates as little as possible from the inflation target, and a forecast for production and employment that deviates as little as possible from a normal level of resource utilisation.

### NORMAL RESOURCE UTILISATION AND THE NATURAL INTEREST RATE

Resource utilisation is thus one of the most important macroeconomic variables for a central bank. But how can the level of resource utilisation be measured, and what is meant by the expression 'a normal level of resource utilisation'?

One frequently used measure of resource utilisation is the output gap, which measures the difference between the actual output level (actual GDP) and the potential output level (potential GDP). When actual GDP is equal to potential GDP, the output gap is zero and resource utilisation is said to be normal. If the output gap is positive, so that actual GDP is higher than potential GDP, resource utilisation is said to be higher than normal, while, conversely, a negative output gap means that resource utilisation is lower than normal.[3]

So what is meant by the 'potential output level', and how can it be that the actual output level can differ from the potential level? In New Keynesian theory, potential GDP is usually defined as the level of output that would arise if all prices and wages were fully flexible. Full flexibility means that all prices and wages are adjusted immediately to changes in economic conditions.

However, there is a lot of evidence that suggests that prices and wages change relatively infrequently – they are sluggish. So, why is it reasonable to define potential GDP as the level that would prevail if all prices and wages were flexible? According to the theory, the sluggishness is the reason that actual GDP generally differs from its potential level. In a market economy, prices and wages play a central role, in that they convey information from one firm to another, and between firms and households. Prices convey information to households regarding firms' marginal cost levels: different firms' relative prices signal differences between their relative production costs. If prices are sluggish, there is a risk that households will get the wrong signals concerning relative costs and will thus demand too much of those goods that are comparatively expensive to produce. This could lead to the misallocation of resources within individual firms and industries, and in the economy as a whole. This latter situation will be the case if the economy's average price or wage level is not adjusted fast enough when the economy is affected by aggregate disturbances.

3 However, there are several other measures of resource utilisation in addition to the output gap. Examples of other measures are the hours gap, which measures the deviation between the actual number of hours worked and the potential number of hours worked, and the unemployment gap, which specifies the difference between the actual level of unemployment and unemployment when prices and wages are flexible.

If, on the other hand, prices and wages are fully flexible, no such mismanagement of the economy's total resources will arise. For this reason, we let potential GDP be equal to the level of output that would arise if price and wage levels were flexible. This level of output is also occasionally called the 'natural output level'.[4] However, if an economy reaches its potential output level and has a normal level of resource utilisation, this does not mean that this economy will always grow in accordance with the economy's long-term growth rate. For example, productivity and demand shocks will affect an economy with flexible wages and prices, thus diverting the economy from its long-term growth rate.

One price that is of particular interest for monetary policy is the return on savings – the interest rate. When firms and households decide to borrow or save money, the real cost or return is determined by the real interest rate. The real interest rate corresponds approximately to the nominal interest rate minus the inflation that is expected to occur during the period which the money was lent. As prices of goods and services in general change fairly infrequently, inflation is relatively sluggish. Of course, the sluggishness of price and wage formation means that the rate at which prices increase – inflation – changes more slowly than would have been the case had all prices and wages been flexible. Just as sluggishness in price and wage formation creates a gap between actual GDP and potential GDP, the same sluggishness creates a gap between the actual real interest rate and the interest rate that would apply if all prices and wages were flexible. Consequently, to the natural or potential output level there is a corresponding concept of a natural interest rate, that is, the real interest rate that would arise if prices and wages were fully flexible and resource utilisation was normal. The natural interest rate can be regarded as the interest rate that would prevail if there was no need for monetary policy to stabilise the real economy.

Before we discuss the question of which factors determine the natural interest rate, there may be reason to comment on the definition of the term we are using here. In the theoretical literature on monetary policy, the potential output level and the natural interest rate are determined by the equilibrium of flexible prices and wages. In the empirical literature, other definitions of the term 'potential output level' are often used. Naturally, by analogy with such alternative definitions of the output gap, alternative definitions of the level of the real interest rate that is compatible with a normal level of resource utilisation can be made.

### WHAT DETERMINES THE NATURAL INTEREST RATE?

The interest rate is determined by demand and supply in the credit market. To understand which factors influence this market, it is helpful to start by examining a stylized model, in which a representative household decides how much money to save (or borrow), and how much to use for consumption. In modern macroeconomic theory, it is assumed that the

4 Misallocation of resources can arise for many other reasons than just nominal constraints. However, when discussing monetary policy, it is natural to focus on these nominal constraints, since these are the causes of misallocation that the central bank can affect.

household's choice will be forward-looking – the household will choose consumption and savings to maximize the payoff from consumption today and in the future. To understand households' behaviour, two basic assumptions are made regarding how consumption is valued over time.

The first basic assumption concerns how the household values variations in consumption. Let us assume that the household has a given amount of consumer goods at its disposal, and that the household must determine how this consumption is to be allocated over time. Will the household allocate its consumption evenly over time, or will it consume large amounts in certain periods and less in others? It is reasonable to assume that an increase of consumption is valued relatively highly if the initial level of consumption is low, while an equally large increase is worth less if the level of consumption is high. An optimising household will thus plan its consumption so that the value of consumption increases today and tomorrow are equal. This means that households prefer consumption that is fairly equal across time to consumption that varies across time. In other words, the household has a basic desire to consume approximately the same amount in all time periods.

An example of this is pension savings. After retirement, income drops significantly for most households, and, to avoid an old age spent in relative poverty, it is very common for households to save a portion of their income during their working years. Another example is that households often build up a certain savings buffer that can be used in times when expenses are unexpectedly high. The assumption of consumption smoothing has been an important part of macroeconomic theory since the 1950s, when Modigliani and Brumber (1954) and Friedman (1957) launched their hypotheses on life cycle savings and permanent income.

The second basic assumption is that households gets a higher payoff from consumption early on, rather than consumption taking place at some point far in the future. Quite simply, households value consumption taking place today or tomorrow slightly higher than equivalent consumption taking place in one year's time.[5] It could be said that the value of consumption declines the further ahead in time it takes place.[6]

The two assumptions of the household's preferences that we have described determine the choice between consumption and saving. The household's preference for smooth consumption means that the household has reason to save during periods in which its income is unusually high and to cut back on saving (or borrow money) during periods

5 In theoretical models, this is captured by the size of the household's subjective discount factor. A higher value for the discount factor means that households value consumption today and in the future more equally.

6 It is possible to describe these two assumptions in a more technical manner. If households choose current and future consumption to maximise

$$\sum_{t=0}^{\infty} \beta^t u(c_t),$$

in which $\beta$ is a subjective discount factor and $u(c_t)$ is the households' benefit from consuming $c_t$, then $\beta$ captures the households' time preference, and the degree of concavity in $u$ captures the households' aversion for variation of consumption over time. If $\beta$ is less than one, households are impatient, which is to say that they value consumption today higher than consumption in the future.

in which income is unusually low. By using the credit market, the household can thus sever the consumption level from the income level at any point in time. However, the household's impatience is a force pushing in the opposite direction, as this impatience means that the household does not necessarily have reason to fully equalize consumption across time. Instead, consumption is allowed to decline somewhat over time. As we have seen, consumption taking place today is valued slightly higher than that taking place in the future.

If the household's preferences suggest that consumption will decline over time, the return on saving (positive interest) creates a counteracting incentive. If the household chooses to postpone a little of today's consumption to a later point in time, the household will be compensated via interest and will later be able to consume a little more than it has refrained from consuming today. All other factors being equal, the higher the interest rate is, the greater the reason for the household to postpone some of its consumption. Thus, there is a relationship between consumption and interest rates. In an economy where GDP and consumption grow over time, the rate of growth will have a significant impact on the real interest rate. As consumption grows, households have incentives to borrow to smooth consumption over time. If growth increases, households have incentives to borrow more, in turn driving up the real interest rate. In normal New Keynesian models, the conclusion of this analysis is that the real interest rate is primarily determined by the growth in consumption expected by the representative household and by the strength of the household's interest in consuming today rather than at a later date. The household's expected growth in consumption is, in turn, closely linked to the expected growth rate of GDP.

Because a single household is small relative to the size of the credit market, changes in that household's saving decisions have no impact on the equilibrium interest rate. However, the interest rate is affeced if changes occur that cause many households to simultaneously change their balance between consumption and saving. Assume, for example, that news of macroeconomic developments leads the average household to expect higher future rises in income than have previously been the case. As households prefer to spread consumption evenly over time, the average household thus has reason to decrease its current saving level. Households cut back on their saving and immediately start to adjust their consumption to the higher expected income. The result is that net demand for loans increases, which, in turn, leads to a rise in the interest rate. If the average household becomes more optimistic regarding future growth rates, this will lead to an increase in the natural interest rate.

If uncertainty over its future income increases, it is reasonable for a household to increase its buffer of saved funds, so that these savings can be used in case future income should be particularly low. Intuitively, we can regard this scenario as an example of the average household's impatience. In this case, many households simultaneously become less impatient. The result is that savings increases and the natural interest rate falls. This example is a reasonable interpretation of the changes in households' saving patterns that

arose during the deep recession of 2008-2009, when households' saving, as a proportion of disposable income, rose sharply.

The natural interest rate thus primarily depends upon the growth in consumption expected by the average household, and on households' impatience. Households' expected growth in consumption is, in turn, closely linked to the expected growth rate of GDP. According to theory, there is thus a close connection between macroeconomic developments (growth in GDP) and fluctuations in the level of the natural interest rate.

## SLUGGISH PRICES GIVE THE CENTRAL BANK POWER: THE MONETARY POLICY TRANSMISSION

The natural interest rate is thus the price of saved funds that would have arisen had all prices and wages been flexible. However, as actual economies are characterised by sluggishness in price and wage formation, there is no reason to expect that the actual real interest rate should coincide with the natural real interest rate. Instead, in actual economies, the short-term real interest rate is determined by the central bank. In this section, we first summarise how the central bank determines the real interest rate. Following this, we discuss what happens if and when the central bank chooses to set the real interest rate at a level differing from the natural interest rate.

The framework for the implementation of monetary policy takes different forms in different countries. In Sweden, the Riksbank controls the interest rate by determining the terms and conditions for the banks' overnight deposits in and loans from the Riksbank. These terms and conditions, in turn, set the limits for the interest rate charged by the banks to each other when they lend money to each other overnight. By way of repo transactions and what are known as fine-tuning operations, the Riksbank ensures that this interest rate lies close to the repo rate determined by the Riksbank's Executive Board. By controlling the interest rate charged by the banks to each other when they need to borrow money or invest a surplus, the Riksbank indirectly influences the interest rates offered by the banks to their customers, namely households and firms.

In the previous section, we mentioned that inflation is a sluggish variable. One consequence of this is that the central bank's control of the nominal interest rate also means that it controls the real interest rate, as the sluggishness of price and wage formation means that inflation changes relatively slowly. When the central bank adjusts the real interest rate, by adjusting the policy rate, the total demand in the economy is affected. In an actual economy, this takes place through several channels, for example through firms' investment decisions and by influencing the exchange rate. In this article, we focus on the channel that depends on households' choices between consumption and saving.

To briefly describe how changes in the real interest rate influence resource utilisation and inflation, we can consider an example in which inflation risks being above target and the central bank thus decides to raise the interest rate. Assume that resource utilisation is normal to start with, but that the private sector has inflation expectations that are clearly above the inflation target. This could, for example, be due to expectations of high future

wage increases, which, in turn, are influencing the cost situation in the business sector. When inflation expectations are high, actual inflation also risks being above target. Normal resource utilisation means that the actual real interest rate initially coincides with the natural interest rate. To prevent inflation from rising above target, the central bank raises its interest rate. This higher real interest rate changes the conditions for households' choice between consumption and saving: saving becomes more profitable, at the same time as it becomes more expensive to borrow money. When households cut down on consumption, demand in the economy decreases. This makes firms decrease production, which means that their demand for labor and equipment also declines. In turn, this leads to a gradual decrease in the rate of wage increases. The rate of price increase for existing capital also declines. When firms realize that cost pressure is easing off, they adjust their prices accordingly: inflation becomes lower than it would have been if the central bank had left its interest rate unchanged.

By raising the real interest rate above the natural interest rate, the central bank has caused a drop in economic activity. The lower level of demand has led to a lower level of resource utilisation: firms have reduced both their labour force and their demand for equipment. A low level of resource utilisation has, in turn, led firms' costs to increase at a lower rate than would otherwise have been the case, and the rate of price increase has thereby been dampened.

However, the central bank's ability to influence the real interest rate is only short-term. The average real interest rate over longer periods is determined by other factors than monetary policy, for example by the economy's long-term growth rate, household impatience and any taxes on capital. The conclusion is thus that the central bank can allow the actual real interest rate to deviate from the natural interest rate for shorter periods, but, in the long run, the central bank finds itself forced to act so that the actual real interest rate, on average, is fairly close to the natural interest rate.

### THE NATURAL INTEREST RATE AND THE OBJECTIVE OF MONETARY POLICY

The attitude monetary policy should take towards changes in the natural interest rate obviously depends on the aims of the central bank. In general, it can be said that the greater the emphasis placed by the central bank on stabilising resource utilisation, the greater reason it has to adjust the actual real interest rate to changes in the natural interest rate. This is a consequence of the definition of the term: we have defined the natural interest rate as the real interest rate that corresponds to a normal level of resource utilisation. In many cases, an inflation target also justifies adjusting the actual real interest rate to fluctuations in the natural interest rates. An actual real interest rate above the natural interest rate implies a downward pressure on firms' cost levels, as resource utilisation would then tend to fall below a normal level. This kind of contractionary policy thus leads to a lower inflation rate. Similarly, an expansionary monetary policy, in which the actual real interest rate is held below the natural interest rate, leads to rising cost levels. Inflation will then tend to rise.

However, in earlier sections, we have mentioned that various types of macroeconomic disturbances tend to drive resource utilisation and inflation in different directions. In general, under such circumstances, there is reason for the central bank not to adjust the actual real interest rate fully to changes in the natural interest rate. For example, if inflation increases at the same time as resource utilisation decreases, a short-term conflict will arise between the target of stabilising inflation and stabilising resource utilisation. If the central bank only took consideration of the target of stabilising the real economy, fully adjusting the actual real interest rate to changes in the natural economy would be justifiable. But when consideration is also taken of the target of stabilising inflation, there is reason to allow the actual real interest rate to be higher than the natural interest rate for a time. On one hand, such a policy would contribute to holding resource utilisation below a normal level for a longer period than would otherwise be the case. On the other hand, this contractionary monetary policy would also contribute towards preventing inflation from rising too far above target.

In practice, it is difficult to estimate the level of the natural interest rate, just as it is difficult to estimate the potential level of output.[7] When the level of economic activity changes, it can take time before the central bank (and other analysts) can determine which underlying circumstances have changed and what the consequences will be for future economic development. Resource utilisation can then fall below or rise above normal levels before monetary policy can react. In addition, it can take time to return resource utilisation to normal levels using monetary policy. It is thus difficult to prevent resource utilisation from occasionally lying above or below normal levels.[8]

## Changes in the natural interest rate – some examples

An economy is continually affected by different types of disturbances. This, in turn, affects important macroeconomic aggregates such as consumption and GDP. The aim of this section is to explain, with the help of a relatively simple macroeconomic model, how some of these disturbances affect the natural interest rate. The purpose is to describe, in an intuitive manner, the relationship between the real economy and the natural interest rate. To this aim, we use a variant of a model presented by Gali (2008). We have attempted to select disturbances that could have caused the deep recession of 2008 and 2009. The model is simple and cannot explain every aspect of the crisis. Consequently, we do not attempt to relate the analysis included in the following section to any empirical evidence.

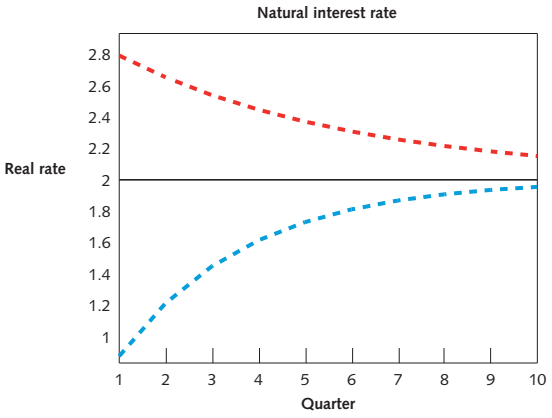
7 See, for example, Justiniano & Primicieri (2010) and Laubach & Williams (2003).

8 For these reasons, there may be reason to differentiate between the natural interest rate that applies if resource utilisation is initially at a normal level, and the natural interest rate that applies if resource utilisation is initially below or above a normal level. In the latter case, we are thus interested in the level of the real interest rate that, if implemented, would be expected to return the economy to its potential GDP and growth rate within one or two quarters. This distinction is related to the difference made in the theoretical literature between an unconditional and a conditional output gap. See also Adolfson, Laséen, Lindé & Svensson (2010).

## UNEXPECTED CHANGES IN PRODUCTIVITY

Productivity varies over time and can have major effects on economic developments. When making assessments of the level of resource utilisation and the natural real interest rate, it is important to attempt to determine the extent to which positive or negative productivity disturbances have been temporary or permanent. In practice, productivity can be affected by many factors – for example, variations in the size of the capital stock or in how well the capital stock and the labour force's capacity is being utilised (labour hoarding). In the model used here, productivity disturbances are changes in total factor productivity.[9] Disturbances in production technology can be divided up into temporary and permanent disturbances.[10] We will now examine examples of how a negative productivity disturbance affects the economy, and analyse the difference between temporary and permanent negative disturbances.

**Figure 1. The effect on the natural interest rate of unexpected changes in productivity**




The red dashed line shows the effect on the natural interest rate of a temporary and unexpected negative change, while the blue dashed line shows the effect of a permanent and unexpected negative change. The scale on the vertical axis is the yearly interest rate in percent.

The black line in Figure 1 shows the natural interest rate when the economy in the model grows along a balanced growth path with an annual real growth rate of 2 per cent. Growth is driven by gradual and permanent improvements in the productivity of the labour force. The level of the interest rate can be related to the households' choice between consumption and saving. As the economy is growing by 2 per cent per year, household consumption is also growing by 2 per cent per year, which, in turn, leads to an interest rate level that is constant over time. The interest rate level will then depend on the long-term

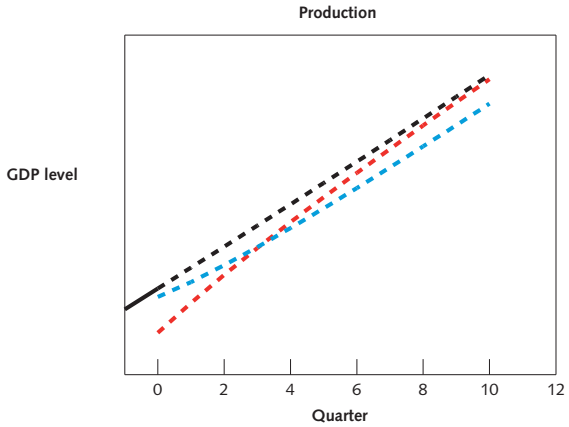
9 A change of the total factor productivity means that the output level changes, even though the use of labour, capital and other inputs remain constant.

10 In this section, we use a simple New Keynesian DSGE model, similar to the model described in chapters 2 and 5 in Gali (2008) (see appendix). The economic environment is very simple: we analyse a small, open economy in which the labour force is the only factor of production.

growth rate and on household impatience. A long-term growth rate higher than 2 per cent will mean that the interest rate will rise. As households prefer a smooth consumption level over time, a higher expected growth rate means that household demand for loans will increase: by borrowing money today, households can immediately start to translate their expected future increase in income into higher consumption. This increased demand for loans will, in turn, drive up the real interest rate.

The blue and red lines in Figure 1 show the effect on the natural interest rate of a negative disturbance to productivity impacting the economy. The red line shows the effect of a temporary disturbance that lowers the economy's potential growth rate for a limited period.[11] The effect on the economy's potential output level is shown in Figure 2. Initially, GDP develops according to the solid black line. Before the temporary disturbance affects productivity, firms and households expect the potential GDP level to continue to grow according to the dashed black line. Instead, in period 1, labour productivity falls quite steeply, and, consequently, the potential level of GDP also falls, as shown by the red line in Figure 2. However, this fall in GDP is temporary, and, after the disturbance in period 1, the potential growth rate becomes slightly higher than 2 per cent. In the long term, the economy is expected to recover from the entire fall in output level.

**Figure 2. Impact on potential output level of an unexpected change of productivity**




The black dashed line shows private-sector expectations, in period zero, of the potential output level ten quarters ahead. The blue and red dashed lines show expectations in period one, following a temporary (red line) and permanent (blue line) disturbance to productivity.

The real interest rate is a forward-looking variable, and consequently, to understand the results of the model, it is important to understand how the households in the model form expectations of future developments. When households make their consumption and savings decision, they base their choice on the real return they expect to receive today and in the future. We also assume that households understand how the model economy works.

11 Potential output level here refers to the production level in an economy with flexible prices.

Households have what are known as rational expectations. After a productivity disturbance has taken place in the first period, the households realise that GDP and consumption will grow faster than 2 per cent for a number of years, as the economy gradually returns to the long-term growth path. This higher expected growth rate means that households have a strong incentive to borrow against future income, which, in turn, initially pushes up the interest rate. When the economy later approaches the long-term growth rate, consumption growth is more in line with the long-term growth rate, which, in turn, means that the natural interest rate approaches its long-term level of 2 per cent.

If, instead, the economy is impacted by a negative, permanent productivity disturbance, the effect on consumption and interest rates will be quite different. The blue dashed line in Figure 2 illustrates that the initial fall in output is smaller[12] than when the disturbance is temporary. However, the growth rate continues to be comparatively low for a couple of years, with no expectation of reaching the old growth path. After a couple of years, the potential growth rate again reaches about 2 per cent, but the potential output level is permanently lower than households and firms had expected before the disturbance occurred.

The effect on the natural interest rate (the blue dashed line in Figure 1) is a direct consequence of households' expectation that the growth rates of GDP and consumption will be lower than 2 per cent for the next few years. The lower expected growth rate means that households' incentive to borrow against future income becomes weaker, which, in turn, pushes the interest rate down. Eventually, the interest rate gradually rises back towards its original equilibrium level, as the potential growth rate returns to 2 per cent.

The conclusion of this analysis is thus that the effect on the natural interest rate of a disturbance to productivity depends on whether the disturbance is expected to have temporary or permanent effects. We have used a highly stylised model. In a more realistic model, for example one including capital, the effects on the natural interest rate will be slightly different.[13]

### FISCAL POLICY: INCREASED GOVERNMENT SPENDING

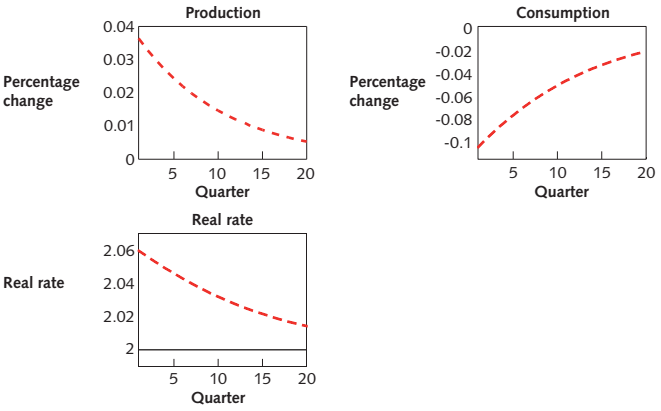
When a government formulates its fiscal policy, one of its objectives may be to stabilize resource utilisation. So how is the natural interest rate affected by an increase in public expenditure? In the simple model we are studying here, it has been assumed that the public sector uses a portion of output for government spending. Household consumption is equivalent to GDP minus government spending and net exports. An increase in government spending is modelled as an unexpected increase in the proportion of total output utilised for government consumption. The disturbance occurs in period 1, and entails an increase in the public sector's share of GDP, and also that this share is expected

12 This less severe initial fall is due to the fact that the permanent disturbance initially is fairly small. The disturbance does not reach full effect until several quarters later.

13 See also Jonsson (2002).

to be higher than normal for a number of years. However, over time, government spending as a share of GDP falls back to the level prevailing before the disturbance occurs.

**Figure 3. Effects on potential GDP, consumption and the natural interest rate of an unexpected change in government spending**



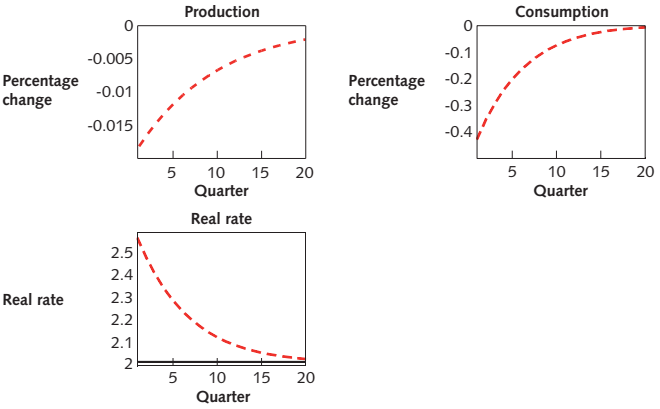

The vertical axis in the figure for GDP and consumption shows the percentage deviation from the long-run output and consumption levels. The scale on the vertical axis in the figure for the real interest rate is in percent per year.

The effects on Swedish GDP, consumption and the real interest rate of an increase in government spending are shown as the red dashed line in Figure 3. The upper left figure shows how the output level changes in relation to the long-run output level of the economy (steady state in the stationary model). The increase in government spending leads to an increase in aggregate demand, contributing to an increase in GDP. The utilisation by the public sector of a larger portion of total output means that private consumption becomes lower in relation to the initial position, as the increase in public expenditure via increased taxes reduces the private sector's scope for consumption. However, as the disturbance dissipates, both public and private consumption return to the levels expected before the disturbance occurred. One consequence of this is that private consumption is initially low in relation to its long-term level. Households' willingness to smooth consumption thus pushes up the demand for loans, in turn also pushing interest rates up. After a while, the increase in government spending goes down, and consumption and the natural interest rate thus return to their long-term levels.

### LOWER FOREIGN GDP

In this section, we analyse the effects on the domestic economy of an unexpected fall in foreign GDP. The international financial crisis and its effects on Sweden's foreign trade have dramatically illustrated the Swedish economy's dependence on foreign countries. The effects of a fall in foreign GDP on Swedish GDP, consumption and the real interest rate are shown as a red dashed line in Figure 4.

**Figure 4. Effects on potential GDP, consumption and the natural interest rate of an unexpected change in foreign GDP**




The vertical axis in the figure for GDP and consumption shows the percentage deviation from the long-run output and consumption levels. The scale on the vertical axis in the figure for the real interest rate is in percent per year.

When output falls abroad, foreign demand for domestically-produced goods also falls. This leads, in turn, to a fall in domestic output and consumption.[14] As in the case of a disturbance of government spending, this lower current consumption means that households expect more rapid growth in their consumption in the future. Households' willingness to maintain a smooth level of consumption thus pushes demand for loans upwards for a period, and thus also pushes the natural interest rate upwards. There is an indirect positive relationship between the natural interest rate abroad and the natural interest rate in Sweden – falling output abroad pushes down consumption abroad, which, in turn, increases the natural interest rate abroad. Conversely, a fall in the natural interest rate abroad entails a fall in the natural interest rate in Sweden.

### INCREASED PRECAUTIONARY SAVING

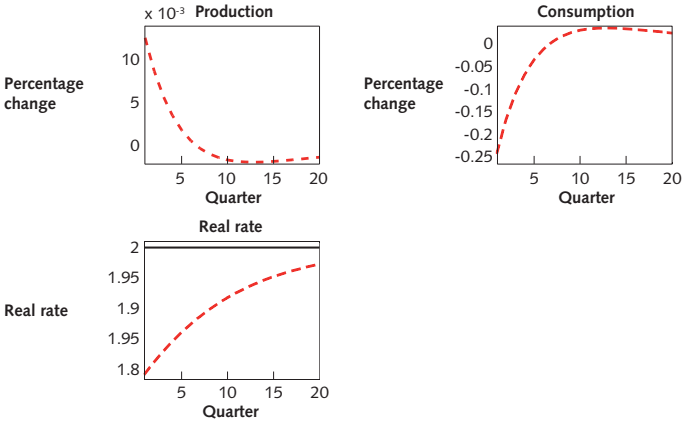
In times of economic uncertainty, there may be reason for households to increase their savings. For example, consumption fell sharply during the international crisis of 2008, when the economic situation was more uncertain than normal. Recessions normally also entail lower demand for labour, which can impact individual households via unemployment, temporary dismissals and other risks affecting income from work.[15] Here, we carry out

14 Among other factors, the mechanism described here depends on households' preferences: if the model's parameters assume other values, the effect on domestic production, consumption and thus the real interest rate can be the reverse.

15 The models we have used for our analysis in this section do not allow any formal analysis of how uncertainty affects decisions by households and firms. The method most frequently used to analyse monetary policy models entails linearising the model's equations around the model's steady state. One characteristic of this linear model is that agents only take account of the expected future values of the stochastic variables affecting their decisions; uncertainty concerning these variables that are captured by second-order terms or higher are not taken into account. On the other hand, the effect of households temporarily becoming more patient can be analysed.

a simplified analysis of such risks by studying the effects of a reduction in household impatience.

**Figure 5. Effects on potential GDP, consumption and the natural interest rate of an unexpected fall in households' willingness to consume today**




The vertical axis in the figure for GDP and consumption shows the percentage deviation from the long-run output and consumption levels. The scale on the vertical axis in the figure for the real interest rate is in percent per year.

A temporary fall in households' willingness to consume today temporarily pushes consumption down. As consumption propensity is low in times of crisis, households will wish to increase their saving. In turn, the reduced net demand for loans will push the real interest rate down.

## Concluding remarks

How monetary policy affects the economy depend on the relationship between the level of the actual real interest rate and that of the natural interest rate. The usual starting point is that monetary policy is characterised by its effect on resource utilisation. We call a monetary policy 'contractionary' if, in the medium term, it is expected to result in resource utilisation below the normal level, while a monetary policy that leads to resource utilisation above the normal level is called 'expansionary'. In this perspective, the definition of what constitutes a normal level of resource utilisation is central to the question of how monetary policy should be assessed. Here, we have used the New Keynesian definition of normal resource utilisation. The potential or 'natural' output level and growth rate are those that would prevail if all prices and wages were fully flexible. The sluggishness of price and wage formation normally give rise to a difference between actual GDP and the actual growth rate, on one side, and natural GDP and the natural growth rate on the other. These differences imply deviations in resource utilisation from its normal level.

Just as nominal sluggishness gives rise to differences between actual and natural GDP, a difference also arises between the actual real interest rate and the real interest rate that

would arise if prices and wages were flexible – the natural interest rate. In other words, the natural interest rate is the interest rate that is compatible with a normal level of resource utilisation. If the central bank equates the actual real interest rate with the natural interest rate, resource utilisation can be expected to be normal. An actual real interest rate that is lower than the natural interest rate means that actual GDP will be higher than natural GDP, so that resource utilisation will be higher than normal. When the central bank sets the actual real interest rate below the natural interest rate, monetary policy can thus be said to be expansionary. Conversely, an actual real interest rate above the natural interest rate leads to resource utilisation being lower than normal. Monetary policy is then contractionary.

It could be asked in which way the definition of the natural interest rate contributes towards a constructive discussion on monetary policy. After all, whether a particular announced monetary policy is expansionary or contractionary can be determined through an examination of the forecast for resource utilisation and inflation included in the announced policy.

The definition of the natural interest rate is reminiscent of an important insight supplied by New Keynesian theory. The level of the real interest rate that is compatible with a normal level of resource utilisation varies over time. The efforts of a central bank to normalise resource utilisation in a given situation is thus not the same thing as that central bank's efforts to bring the interest rate to a certain average, constant level. The level of the real interest rate that is compatible with a normal level of resource utilisation is, instead, highly dependent on the currently prevailing macroeconomic circumstances.

A problem is the significant difficulties associated with each estimation of the natural interest rate. It is often difficult to rapidly and correctly identify the disturbances affecting the economy. As we have seen above, a change in productivity (for example) can have completely different effects on the natural interest rate, depending on whether this change is temporary or permanent. A closely-related difficulty is formed by what is known as model uncertainty. Results from the scientific literature indicate that different economic models give different predictions of how the natural interest rate is affected by different disturbances. Empirical studies of the natural interest rate in other countries also seem to produce quite varied views of the natural interest rate.[16]

Another important aspect deals with the difference between the real interest rate at present and the private sector's expectations of future real interest rates. New Keynesian theory usually assumes that all households and firms take conscious and fully-informed decisions. One result of this is that expectations of future developments play an important part in most economic decisions. Instead of only talking about the natural interest rate, it is thus often appropriate to consider the expected path for the natural interest rate.

16 See, for example, Andres, Lópes-Salido & Nelson (2008), who estimate the natural interest rate for the United States and compare with other studies.

## Appendix. Permanent output disturbances in Gali's model

In this appendix, we describe how permanent productivity disturbances or shocks can be added to a model that closely follows Gali (2008).[17] In a model with permanent productivity disturbances and a growing technology trend, such as the one we analysed in section 2, certain variables such as output and real wages, for example, will increase over time. The growing variables are 'detrended' by dividing the variables that grow over time in the model by the (growing) level of technology $Z_t$. This lets us calculate, for example, output $Y_t$ in terms of what is known as output in efficiency units $Y_t / Z_t$, which is constant over time.[18] The difference between the model in Gali and a model with permanent disturbances in technology is that the consumers choice between consumption and saving – what is known as the Euler equation – is modified. Without permanent technology shocks, this is:

$$c_t = E_t(c_{t+1}) - \frac{1}{\sigma}(r_t - \rho_t), \qquad \text{(A1)}$$

where $c_t$ is aggregate consumption in period $t$, $E_t(c_{t+1})$ consumers' expectations in period $t$ of consumption in the next period, $r_t$ the real interest rate, $\sigma$ (the inverse of) the intertemporal substitution elasticity and $\rho_t$ a parameter that captures individuals' subjective time preference. In a model with permanent technology shocks[19], the Euler equation instead becomes:

$$c_t = E_t(c_{t+1} + z_{t+1}) - \frac{1}{\sigma}(r_t - \rho_t), \qquad \text{(A2)}$$

where $z_{t+1} = \log\frac{Z_{t+1}}{Z_t}$. Individuals also decide how to allocate time between leisure and work. Specifically, individuals choose leisure and work so that the price of leisure – real wages – is equal to the marginal rate of substitution between work (which provides more consumption) and leisure:

$$w_t - p_t = \sigma c_t + \varphi n_t, \qquad \text{(A3)}$$

where $w_t$ is wages, $p_t$ the price level, $n_t$ hours worked and $\varphi$ (the inverse of) the elasticity of the number of hours worked with regard to changes in real wages – the Frisch elasticity.

17 See Gali (2008), chapters 2 and 5.

18 In a model without capital, the (non-logarithmic) production function is $Y_t = A_t Z_t N_t$, in which $A_t$ is a technological process with a constant trend, $Z_t$ is a technological process with a growing trend and $N_t$ is hours worked. As GDP has a growing trend but hours worked are constant in the long run, we rewrite the production function in terms of efficiency units as $Y_t / Z_t = A_t N_t$.

19 In a standard model, the (non-logarithmic) Euler equation (compare with (7) in Gali) is given by $(C_t)^{-\sigma} = \beta E_t\left[(C_{t+1})^{-\sigma} R_t\right]$ where $C_t$ is aggregate consumption, $\beta$ households' subjective discount factor and $R_t$ the real interest rate. As consumption grows over time, we rewrite this as $(C_t / Z_t)^{-\sigma} = \beta E_t\left[(C_{t+1} / Z_{t+1} * Z_{t+1} / Z_t)^{-\sigma} R_t\right]$ We allow the discount factor to be time-varying and let $\rho_t = -\log\beta_t$.

Capital is ignored in the model, and output $y_t$ is then given by:

$$y_t = a_t + n_t, \tag{A4}$$

where $a_t$ is a temporary output shock.
Firms maximise their profits, and set prices and determine employment so that labour costs – the real wage – are the same as workers' marginal product:

$$w_t - p_t = a_t - n_t, \tag{A5}$$

In addition, the economy is open and the model thus includes foreign trade. Aggregate consumption then consists of goods produced both in the country and abroad. In the model, households also have the possibility of investing in domestic and foreign bonds. In normal New Keynesian models, individuals' choice of foreign and domestic assets gives an interest rate parity condition in terms of nominal exchange rates and interest rates. As we are analysing a model with flexible prices and wages, we instead obtain an interest rate parity condition in terms of the relationship between changes in the real exchange rate $q_t$, the real interest rate differential between Sweden and the rest of the world, and a risk premium that depends on the net asset position $b_t$ towards the rest of the world:

$$E_t q_{t+1} - q_t = (r_t - \rho_t) - (r_t^* - \rho^*) + \varepsilon^b b_t, \tag{A6}$$

where $r_t^*$ is the real interest rate abroad and $\varepsilon^b$ describes the sensitivity of the real exchange rate to changes in the net asset position.[20] The net assets depend on yesterday's net asset position and net exports $x_t$:

$$\kappa b_t = b_{t-1} + x_t,$$

where $\kappa$ is a constant. In turn, net exports depend on gross exports which closely follow foreign GDP, $y_t^*$, and gross imports which are determined by domestic consumption and the real exchange rate:

$$x_t = y_t^* + (\eta - \frac{1}{1-\alpha})q_t - c_t, \tag{A7}$$

where $\alpha$ is the share of imports and $\eta$ is the degree of substitutability between domestically produced goods and imported goods. The resource constraint of the economy is given by

$$y_t = (1-\alpha)(1-\bar{g})c_t + \alpha(1-\bar{g})y_t^* + \alpha(1-\bar{g})\left[\frac{\gamma}{1-\alpha} + \eta\right]q_t + \bar{g}\, g_t, \tag{A8}$$

20 In the model, we use the Euler equations at home and abroad so that (A6) becomes
$E_t q_{t+1} - q_t = \sigma(E_t c_{t+1} - c_t) - \sigma(E_t y_{t+1}^* - y_t^*) + \varepsilon^b b_t$.

where $g_t$ is government spending, $\gamma$ is elasticity between imported goods and $\bar{g}$ is the average share of government spending out of GDP. The model then consists of the equations (A2)-(A8).

The two productivity shocks follow the processes:

$$z_t = \rho_z z_{t-1} + \eta_t^z,$$

$$a_t = \rho_a a_{t-1} + \eta_t^a,$$

where $\rho_z$ and $\rho_a$ are the degree of persistence in the shocks and $\eta_t^z$ and $\eta_t^a$ are innovations. Foreign GDP, government spending and individual's subjective time preference follow the processes:

$$y_t^* = \rho_y y_{t-1}^* + \eta_t^y,$$

$$g_t = \rho_g g_{t-1} + \eta_t^g,$$

$$\rho_t = \rho_\rho \rho_{t-1} + \eta_t^\rho,$$

where $\rho_y$, $\rho_g$ and $\rho_\rho$ are the degree of persistence in the shocks and, $\eta_t^y$, $\eta_t^g$ and $\eta_t^\rho$ are innovations.

When calculating the effects of the different shocks, we set the intertemporal substitution elasticity $1/\sigma$ to $1$ (in the case of productivity shocks) or 0.3 (in other cases), labour supply elasticity $1/\sigma$ to $1$ and the import share $\alpha$ to 0.4, elasticity between imported goods $\gamma$ to 1 and the proportion of government spending $\bar{g}$ to 0.2. In addition, we set the risk premium parameter $\varepsilon^b$ to 0.01, the degree of substitutability between domestically-produced goods and imported goods $\eta$ to 4 and $\kappa$ to 0.9999 (in the case of productivity shocks) or 0.995 (in the other cases). We set the persistence parameters in both productivity shock processes to $\rho_a = 0{,}8$ and $\rho_z = 0{,}7$. We also determine the long-term growth rate and households' time preference so that the real equilibrium interest rate is two per cent over the long term. The persistence parameter in the shock processes to foreign GDP is 0.86, in government spending 0.9 and in individuals' subjective time preference 0.8.

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