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Explaining movements in the Norwegian exchange rate

Øyvind Eitrheim and Kristin Gulbrandsen (eds.)

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NORGES BANK OCCASIONAL PAPERS No. 32

Explaining movements in the Norwegian exchange rate

Øyvind Eitrheim and
Kristin Gulbrandsen (eds.)

Oslo 2003

Foreword

The operational target set by the Government for monetary policy is an inflation rate of close to 2.5 per cent over time. In an open economy, the exchange rate channel is one of several channels through which monetary policy affects the economy. The extent to which the exchange rate appreciates as a result of an increase in key interest rates depends on several factors outside the control of the central bank. The potency of the exchange rate channel will therefore vary over time. The exchange rate will often function as an automatic stabiliser. In periods with high activity in the economy – or when there are expectations of high activity – the exchange rate may appreciate, even if the key interest rates remain unchanged. Similarly, the exchange rate may depreciate when activity is too low.

Competitiveness is important to activity in business and industry. When Norges Bank prepares the inflation outlook, it takes into account the exchange rate channel and the effects of the exchange rate on domestic activity and inflation. Thus the exchange rate is of significance to the setting of interest rates. Monetary policy is, however, not based on a fixed view of what constitutes the correct level for the exchange rate over time and there is of course no accepted view of what is the correct business structure in the long term. This is in accordance with the operational target of low and stable inflation and in line with inflation targeting practice in other countries.

The Norwegian krone strengthened considerably through 2001 and 2002. The movements in the exchange rate were analysed carefully by Norges Bank with the aim of shedding light on which factors could explain this development. In autumn 2002, Jan F. Qvigstad, Chief Economist and Director of Norges Bank Monetary Policy, took the initiative to collect this work for publication. This issue of Norges Bank's Occasional Papers contains a number of signed articles written by employees of Norges Bank, which use different approaches and methods to look at factors that may help us to *understand movements in the exchange rate. The analyses were carried out in Norges Bank in 2002 and preliminary results were presented at a seminar for the Ministry of Finance and Statistics Norway on 7 February 2003. The views and conclusions expressed are those of the authors alone and are not necessarily shared by Norges Bank or colleagues in the Bank. We would like to emphasize that this publication is not seen as a final presentation of the work; we intend to continue working with many of the problems and issues raised in these articles. We do hope, however, that this presentation of expert analyses of exchange rate movements will provide a good illustration of the scope and complexity of the literature in this area.*

May 2003, (Norwegian edition)
December 2003, (English edition)
Øyvind Eitrheim
Kristin Gulbrandsen

Contents

Chapter 1 – Introduction

Øyvind Eitrheim and Kristin Gulbrandsen[1]

The Norwegian krone appreciated substantially from summer 2000 to January 2003. In the same period, the interest rate differential against other countries was high and increasing. Interest rates abroad declined, whereas in Norway, they remained relatively high. International stock markets fell sharply. The risk of a further decline in international share prices fuelled a growing interest in interest-bearing papers and many investors started to look at currencies with high interest rates. This led to increased demand for the Norwegian krone.

The krone exchange rate was reasonably stable until the mid-1990s. This was ascribable, among other things, to low wage inflation and the fact that aggregate demand did not contribute to pressure in the economy. The krone then gradually started to fluctuate more. Movements in the exchange rate have been substantial over the past two years compared with the first half of the 1990s. However, the fluctuations are not so great when compared with those in other commodity-exporting countries. This is related to the Norwegian Petroleum Fund mechanism and the mandate for fiscal policy, which dampen the effect of changes in oil prices on the exchange rate.

The new guidelines for economic policy introduced in March 2001 changed the interaction between the different components of economic policy. Previously, growth in public expenditure was reduced or other fiscal measures implemented if the labour market was tight and wage growth was high. The government is now striving to base its budget policy on the new fiscal rule, which entails a moderate and steady phasing in of the use of oil revenues. The National Budget levels out fluctuations in the economy by means of automatic stabilisers.

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[1] Øyvind Eitrheim is Director of the Research Department and Kristin Gulbrandsen is Executive Director of Norges Bank Financial Stability. In connection with the publication of this issue of Norges Bank's Occasional Papers, we have received useful comments from a number of colleagues who have read the individual articles at the request of the editors. We would like to thank Sigbjørn Atle Berg, Gunnar Bårdsen, Jan Tore Klovland, Kai Leitemo, Ragnar Nymoen, Birger Vikøren and Bernt Arne Ødegaard for their help. We would also like to thank Berit Moen for her work with the charts.

Monetary policy will also help to stabilise economic conditions. The new guidelines were introduced in a period when the labour market was tight and wage growth in Norway was particularly high. As economic conditions were difficult abroad, a strong Norwegian krone was inevitable in periods.

Conditions in the foreign exchange market are unstable. In the short term, it can be difficult to explain – let alone predict - what is driving exchange rate movements. Economic theory can, however, help us to understand some of the fundamental forces that influence long-term trends in the exchange rate. In this booklet, we present examples of different approaches to analysing exchange rate movements. The seven articles are based on empirical and theoretical analyses and will help to cast light on movements in the exchange rate during this period, both individually and as a whole.

We start by looking at mechanisms that are of importance to the determination of long-term trends in the real exchange rate. The consequences for the Norwegian economy of phasing in oil revenues has been the subject of economic analyses for more than 30 years, see for example Report to the Storting no. 25 (1973-74), which discusses problems related to changes in industry structure resulting from changes in the use of oil revenues. The introduction of the fiscal rule in spring 2001 generated a renewed interest in the subject. In Chapter 2, Ragnar Torvik[2] analyses dynamic adjustments in the real exchange rate with increased use of oil revenues. He argues that in the short term the exchange rate will appreciate in real terms in order to realise a transfer of resources from the exposed to the sheltered sector. He shows that this real appreciation may be greater in the short term than the long term, that it may be temporary, and that the long-term equilibrium level for the real exchange rate will be determined by conditions on the supply side of the economy. If, for example, sectors that expand over time also become more productive (e.g., from "learning by doing"), the long-term result may be a real depreciation of the krone exchange rate.

Whereas Torvik focuses on long-term conditions on the supply side to explain movements in the real exchange rate, there is also a large body of literature in this field which offers a num-

[2] Ragnar Torvik is a professor at the Department of Economics at the Norwegian University of Science and Technology. He has a 20% position in the Research Department of Norges Bank.

ber of alternatives approaches to understanding long-term developments in the real exchange rate. Q. Farooq Akram, Kari-Mette Brunvatne and Raymond Lokshall[3] present an overview of some alternative explanations for movements in real equilibrium exchange rates in Chapter 3. Real equilibrium exchange rates are often used as benchmarks for assessing whether the real exchange rate is over- or undervalued. Three different methods for calculating real equilibrium exchange rates are presented: the theory of purchasing power parity (PPP), behavioural real equilibrium exchange rates (BEER) and fundamental real equilibrium exchange rates (FEER). The authors also give an overview of recent empirical research on real exchange rates based on these approaches.

The PPP approach assumes that the real equilibrium exchange rate is constant. In practice, however, we observe both trends and cycles in the real exchange rate over different time horizons. The BEER and FEER approaches are based on the assumption that the real equilibrium exchange rate may vary over time. The BEER approach defines the real equilibrium exchange rate as a function of underlying economic conditions. The real equilibrium exchange rate is derived from an empirical model that is based on actual movements in the real exchange rate. Several different economic conditions and mechanisms have proved to be important in explaining actual movements in the real exchange rate. Such conditions may include differences in productivity growth between countries, changes in variables that represent the terms of trade, differences in public expenditure between countries, net financial assets and the interest rate differential against other countries. The FEER approach is based on an empirical model of macroeconomic variables that are influenced by the real exchange rate. The real equilibrium exchange rate FEER is defined as the level that is achieved when the macroeconomic situation is characterised by internal and external balance. Conditions that contribute to increasing net foreign assets and capital income provide the basis for a stronger real equilibrium exchange rate.

In Chapter 4, Q. Farooq Akram applies the three different approaches (PPP, BEER and FEER) to Norwegian data and calculates real equilibrium exchange rates over different time horizons. It appears that actual movements in the Norwegian real exchange rate over the past 30 years can be interpreted in the light of the PPP approach, which implies a constant real equilibrium

[3] Q. Farooq Akram is acting Head of Research in the Research Department of Norges Bank. Kari-Mette Brunvatne is an advisor in the Monetary Policy Department and Raymond Lokshall is an executive officer in the Economics Department of Norges Bank.

exchange rate. However, this approach does not explain fluctuations in the actual real exchange rate over time. Nor does it cast light on which variables determine the level of the equilibrium real exchange rate. The BEER approach, which is based on an empirical model of the Norwegian real exchange rate, shows that actual movements in the real exchange rate can be linked to different productivity trends for Norway and its trading partners, the interest rate differential against other countries, as well as saving and investment behaviour and the real oil price. These variables also appear to determine the level of the real equilibrium exchange rate that is achieved when these variables are at their equilibrium level/path. Akram also illustrates that growth in public spending over a longer period can, in isolation, contribute to a relatively long-term deviation from the real equilibrium exchange rate. Such spending growth could be associated with the fiscal rule. This would imply that the oil- and business cycle adjusted government deficit should be at a level corresponding to a four per cent real return on funds invested in the Government Petroleum Fund. It is expected that this deficit will increase steadily in the years ahead and that the fiscal rule therefore entails a further phasing in of oil revenues.

With the help of the FEER approach, Akram puts the use of oil revenues in a wider perspective. He focuses on permanent income from total petroleum wealth, both that which still remains in the ground ("in the seabed") and that which has been reinvested ("in the book") in financial assets through the Government Petroleum Fund. Calculations of real exchange rates that achieve internal and external balance, FEER, show that even though highly optimistic estimates of permanent income from petroleum wealth may result in a very strong exchange rate today, it will eventually only cover a falling share of imports, as the economy expands over time and import demand increases. The real exchange rate that gives external balance must therefore depreciate over time and stabilise at a level in the long term that corresponds to the situation without petroleum wealth.

With an inflation target, the central bank will constantly assess the economic situation and set interest rates with the aim of achieving the inflation target. The economy is, however, constantly changing, and the central bank must always assess the economic situation in light of recent economic shocks and events when setting interest rates. In Chapter 5, Øistein Røisland and Tommy Sveen[4] look at how the exchange rate reacts to cost push shocks and show that the

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[4] Øistein Røisland is an assistant director in the Monetary Policy Department and Tommy

effect depends on how the central bank responds to the shock. Normally, the central bank would raise interest rates sufficiently to push up the real interest rate and thereby achieve a real appreciation in the exchange rate in the short term. The effect on the nominal exchange rate is, however, uncertain. The more emphasis the authorities place on avoiding variation in the current inflation rate measured as a deviation from the inflation target, the more likely appreciation is. If, on the other hand, the authorities place considerable importance on avoiding variations in the activity level, the result may be an instant depreciation of the exchange rate. Within a flexible inflation targeting framework, a nominal appreciation seems to be the most likely alternative.

In 2002, the interest rate differential against other countries increased, among other things as a result of interest rate cuts by Norway's trading partners. In summer 2002, Norges Bank increased its key rates in response to a change in the inflation outlook, resulting from the expansive wage settlement. The theory of uncovered interest parity says (somewhat simplified) that when the interest differential with other countries is positive, investors who want to invest at higher interest rates in Norway will take an exchange rate risk, as normally in such situations the krone would be expected to depreciate over the course of the period. The theory can also be used to indicate how much the krone will appreciate when the interest differential widens. In Chapter 6, Arne Kloster[5], Raymond Lokshall and Øistein Røisland look at how much of movements in the krone exchange rate can be explained by the interest rate differential. The authors take as their starting point the apparently striking parallelism in movements in the krone exchange rate and the interest rate differential from summer 2000 to February 2003. They use the theory of uncovered interest parity to analyse the changes in the exchange rate during this period and show that the interest rate differential only explains less than half of the nominal appreciation of the krone to November 2002, whereas the depreciation between November 2002 and February 2003 is more than covered by the narrowing of the interest rate differential in this period. Therefore, an important conclusion is that the degree to which the interest rate differential explains changes in the exchange rate will vary over time. As a possible explanation for the appreciation of the krone, the authors point out that the risk premium on investments in NOK has apparently been falling since the start of 2000 and argue that it

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Sveen is a researcher in the Research Department in Norges Bank.
[5] Arne Kloster is an assistant director in the Economics Department of Norges Bank.

seems to have been largely negative since the start of 2002. Several market participants have argued that the krone has a potential role as a "safe-haven currency" in situations where the global economy is affected by fears of war and the threat of major consequences for oil prices. This would then counterbalance the expected lower return on investments in NOK as a result of the negative risk premium.

Market participants often refer to special themes or sentiments when explaining movements in the exchange rate. Bjørn E. Naug[6] investigates whether it is possible to trace such effects in an empirical analysis of exchange rate movements in Chapter 7. He estimates a monthly model for the trade-weighted exchange rate index and includes effects from oil prices, the interest rate differential against other countries, changes in US share prices and an indicator for expected variation between major currencies. The analysis implies that the appreciation from May 2000 to January 2003 may be linked to the fact that the interest rate differential against other countries (a) increased substantially from spring 2000 to November 2002 and (b) was positive and high during the entire appreciation period. The wider interest rate differential seems to explain about 40 per cent of the appreciation from May 2000 to January 2003. The positive interest rate differential interacts with share prices and expected currency volatility and implies that falling stock markets abroad and expected weaker fluctuations between major currencies caused the krone to strengthen. This effect seems to explain more than half of the appreciation. As share prices and expected fluctuations between the major currencies fell over the appreciation period the krone became more sensitive to interest rates during this period. The appreciation in 2002 is also related to the sharp increase in the oil price and the status of the krone as a safe-haven currency during the unrest in the Middle East. The model predicts most of the depreciation from January to July 2003. It misses much of the short-run fluctuations in this period, however, and it cannot explain why the krone was relatively stable from July to November 2003. It is strongly emphasised that conditions in the foreign exchange market are expected to be unstable; it cannot be ruled out that other factors may be important in explaining changes in the krone exchange rate in the future. This could be a source of forecast errors.

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[6] Bjørn E. Naug is a researcher in the Research Department of Norges Bank.

Finally, in Chapter 8, Dagfinn Rime[7] looks at two new directions in financial economics, behaviour-based finance theory and the microstructure approach to the foreign exchange market, to see what light they can throw on movements in the exchange rate. Rime points out that the new theories raise a number of questions relating to key assumptions in established finance theory, such as all participants having the same information or that all participants can be characterised as rational in their behaviour. The conclusions are that deviations from an equilibrium exchange rate may be persistent, that it is reasonable to think that participants in the foreign exchange market may have different information and that this can have implications for exchange rate determination. Results from the behaviour-based finance theory may shed further light on persistent deviations from fundamental conditions, or explain why market participants behave in an apparently irrational manner and often reinforce the overall effect in the market through herd behaviour. Risk premiums may be permanently higher in a market with irrational participants.

[7] Dagfinn Rime is a researcher in the Research Department of Norges Bank.

Chapter 2 - The real exchange rate and phasing in of oil revenues

Ragnar Torvik[1]

1. Introduction

Two important changes in the guidelines for economic policy were implemented in spring 2001. A fiscal rule for the phasing in of oil revenues was introduced and an inflation target was adopted for monetary policy. Following these policy changes, we have experienced considerable fluctuations in the nominal krone exchange rate, which, combined with domestic cost inflation, has resulted in a deterioration in cost competitiveness. This article looks at the connection between the phasing in of oil revenues and movements in the real exchange rate.

The real exchange rate represents the price of Norwegian goods in relation to foreign goods, calculated in a common currency. Movements in the real exchange rate may therefore be due to price changes in Norway, price changes abroad, or changes in the nominal exchange rate itself. Within the framework studied in this article, the real exchange rate is defined as the price of non-tradeable goods in relation to tradeable goods, calculated in a common currency. A real appreciation means that non-tradeable goods have become more expensive in relation to tradeable goods – either because the nominal exchange rate has appreciated or because domestic price inflation (non-traded sector) is higher than abroad (traded sector).

The article is set out as follows: Section 2 illustrates how the phasing in of oil revenues affects industry structure and the real exchange rate from a theoretical point of view. The framework is standard and shows the widespread belief that the phasing in of oil revenues will result in a real appreciation of the Norwegian krone. The framework does provide an insight into how the phasing in affects the economy, but also has an obvious weakness – it is not able to give any

[1] I would like to thank Egil Matsen, Bjørn Naug, Ragnar Nymoen, Jørn Rattsø, Erling Steigum and colleagues in Norges Bank for their comments. The opinions expressed in this article are solely those of the author.

indication of what real exchange rate *path* will be. Section 3 is a review of the extensive body of literature that focuses on possible paths for the real exchange rate as a result of the phasing in of oil revenues. Four different paths are presented and the underlying assumptions for each of these paths are discussed. In section 4, the analysis is extended to take account of a gradual increase in the use of oil revenues. Section 5 looks at the apparent conflict between the real exchange rate paths presented in economic literature and the real exchange rate paths discussed in documents such as the National Budget for 2003 and Statistic Norway's Economic Survey 1/2003.

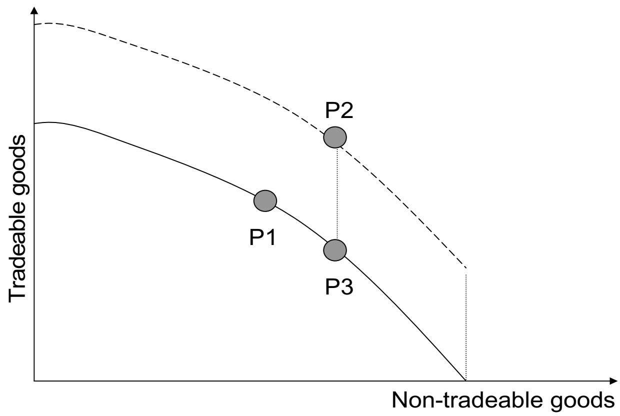
2. Oil revenues and the real exchange rate

2.1 Production and consumption

The belief that the phasing in of oil revenues will result in a real appreciation of the Norwegian krone is widespread. The reasoning for such a view is presented in Chart 1. The horizontal axis shows the production and consumption of non-tradeable goods, whereas the vertical axis shows the production and consumption of traditional tradeable goods - oil revenues are excluded for the moment. If we use a considerable share of the available labour and capital to produce non-tradeable goods, then less is available for the production of tradeable goods. This relationship is shown in Chart 1 by the production possibility frontier - the falling continuous line. The slope of the production possibility frontier shows the reduction in the production of tradeable goods when more non-tradeable goods are produced. At a given point in time, the production possibility frontier will become steeper the further to the right we are - if we already produce a lot of non-tradeable goods and only a few tradeable goods, we have to forego a considerable amount of tradeable goods in order to achieve one extra unit of non-tradeable goods. The reason for this is that labour and capital will to a certain extent be sector specific in the short run. For example, let us assume that only labour is mobile in the short run. If we already use a lot of labour in the non-traded sector, a further increase in the use of labour in this sector will only give a limited increase in production. There are already lots of workers to staff capital in the sector. On the other hand, a further reduction in the use of labour in the traded sector will result in a sharp fall in production - there are only a few workers to staff capital in the first place, and a further decrease will therefore reduce output considerably. Both effects pull in the direction of a steeper production possibility frontier.

Consumption can be adjusted at whichever point on the production possibility frontier society prefers, but without using oil revenues consumption cannot be sustained at a point that is not on the production possibility frontier – we have to limit our consumption to our income, and we get our income from production. People prefer a combination of non-tradeable and tradeable goods - let us image that consumption is adjusted at point P1 on the production possibility frontier.

Chart 1 Output and consumption possibilities



2.2 The real exchange rate

At market equilibrium, the real exchange rate corresponds to the slope of the production possibility frontier. This can be explained by a simple numerical example. Let us assume that we are at a point where the slope of the production possibility frontier equals one. We then have to forego one unit of tradeable goods in order to achieve one extra unit of non-tradeable goods. If the price of non-tradeable goods is higher than the price of tradeable goods, the manufacturers will benefit from transferring resources from the production of tradeable to non-tradeable goods – they will get a higher price for non-tradeable goods than for tradeable goods, while production costs remain the same. If the price of non-tradeable goods is lower than that of tradeable goods, the opposite will happen – manufacturers will benefit from moving resources out of non-tradeable production and into tradeable production. Only when the price ratio between non-tradeable and tradeable goods is equal to the slope of the production possibility frontier will there be nothing to gain from moving resources from one sector to the other. At market equilibrium, therefore, the price of non-tradeable goods relative to tradeable goods – or the real exchange rate – must be equal to the slope of the production possibility frontier.

At the same time, the real exchange rate must equal consumers' relative valuation of non-tradeable goods in relation to tradeable goods - if not, consumers will want a consumption that is out of step with what is being produced.

2.3 Oil revenues

Oil revenues represent a foreign exchange gift – the oil we sell gives us foreign currency income that can be used for imports. This foreign exchange gift also means that we can maintain a higher consumption of traditional tradeable goods than we ourselves produce. In Chart 1, consumption possibilities change as they move up the dotted curve and no longer coincide with production possibilities. The vertical distance between consumption possibilities and production possibilities indicates the volume of foreign currency income measured in units of tradeable goods.

Increased consumption possibilities mean that consumers want to consume more of both tradeable and non-tradeable goods. The new consumption point will therefore lie to the north-east of the old one, marked P2 in the chart. In order for consumers to be able to consume at P2, production has to be adjusted at P3. P3 lies vertically below P2 – we must continue to produce what we consume of non-tradeable goods. But in order to consume as many tradeable goods as we do at P2, we only need to produce as much as at P3 - the rest of the consumption of tradeable goods is covered by using oil revenues.

Thus we see that using oil revenues turns output in the direction of lower production of tradeable goods - P3 is lower than P1 in the chart, and higher production of non-tradeable goods - P3 lies to the right of P1. To put it simply: if we want to divide the increase in consumer spending equally between non-tradeable and tradeable goods, an increase of 1 krone in the use of oil revenues would reduce production in the traded sector by 50 øre and increase production in the non-traded sector by 50 øre. In this way, we can increase the consumption of both non-tradeable and tradeable goods by 50 øre.

At P3, the production possibility frontier is steeper than at P2 – non-tradeable goods have become more expensive relative to tradeable goods. The real exchange rate has appreciated. This real appreciation is necessary in order to adjust the economy to higher production of non-tradeable goods. For this to be profitable, the price of non-tradeable goods in relation to tradeable goods must rise - only then will manufacturers get the necessary signal to use more factor inputs in the production of non-tradeable goods and less in the production of tradeable goods.

The model outlined here is probably the basis of many economists' gut feelings about the effect of phasing in oil revenues, on the real exchange rate. In order to achieve equilibrium with the phasing in of oil revenues, the real exchange rate must appreciate. This jump in the real exchange rate is necessary in order to achieve equilibrium in the real economy when the use of oil revenues increases.[2]

However, what is not shown in Chart 1 is just as important as what is shown: the chart says nothing about the possible *time paths* in the real exchange rate. The reason for this is that the underlying model is static. The model only says that if we, at a given point in time, increase our use of oil revenues, a real appreciation will be necessary in order to maintain market balance - increased demand necessitates increased production of non-tradeable goods, which in turn requires a real appreciation. The next section gives an overview of economic literature that looks at how the real exchange rate is affected by the phasing in of oil revenues within dynamic models.

3. The real exchange rate over time

The production possibility frontier will change over time – and the change may depend on the phasing in of oil revenues. The analysis in the above section therefore only indicates what can be expected to happen to the real exchange rate in order to achieve market balance in the short

[2] Note that what the model does identify is a jump in the *real exchange rate*. It does not say whether this change occurs via domestic prices or the nominal exchange rate. This would probably depend on the prevailing monetary policy regime. If it is a credible fixed exchange rate regime, demand pressures when the oil revenues are phased in could translate into a rapid rise in the price of non-tradeable goods, whereas if it is a regime with a floating exchange rate the jump in the nominal exchange rate could contribute to the change in the real exchange rate.

run, but does not say much about movements in the real exchange rate over time. In order to analyse this, it is necessary to abandon the static framework and move on to dynamic analyses – analyses that explicitly model how the phasing in of oil revenues will affect the economy over time.

Dynamic models that illustrate the phasing in of oil revenues can be divided into two main groups: models that take the speed of the phasing in of oil revenues as given and models that discuss how fast oil revenues are phased in to the economy. In this article, discussion will be restricted to the first main group - in other words, we will look at movements in the real exchange rate given that a fiscal rule for phasing in oil revenues has been introduced. The models in the second main group will not be discussed – those who are interested can refer to Mansoorian (1991) for a descriptive model of overutilisation of resource wealth, to Robinson, Verdier & Torvik (2002) for political economic theory regarding the phasing in and allocation of oil revenues, and to Matsen & Torvik (2003) for a normative model that derives the optimal phasing in of oil revenues. In the remainder of this article, it is therefore assumed that the speed with which oil revenues will be phased in has already been politically determined and we will discuss the consequences of this for the real exchange rate.

3.1 Real exchange rate paths – an overview

Movements in the real exchange rate in the dynamic models are determined by three key features that differentiate them from the static model used above[3]:

- Factor inputs are more mobile in the long run than in the short run.
- As it is possible to change factor inputs that are given in the short term, for example, capital volume, the returns to scale of product functions will differ in the short and long term.
- Output growth in the different sectors is affected by the phasing in of oil revenues.

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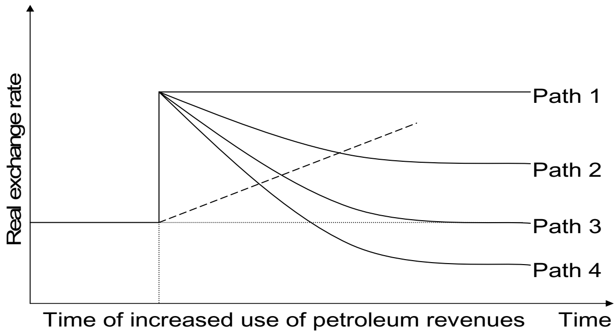
[3] The discussion on movements in the real exchange rate in the dynamic models that follows will contain mechanisms taken from several different sources in economic literature. The overview given here is based on, first and foremost, Corden & Neary (1982), Corden (1984), Neary & Purvis (1983), Neary & van Wijnbergen (1986), Steigum (1992), Torvik (2001) and van Wijnbergen (1984a). For an overview of which mechanisms are applied in which article and other mechanisms that affect real exchange rate movements discussed in economic literature, see Torvik (2001).

In literature that expands on the static model used in the previous section in order to discuss what movements in the real exchange rate will be over time, four different exchange rate paths are put forward.

The path you get depends on the features of the economy summarised in the three points above.[4] The real exchange rate paths discussed in economic literature are shown in Chart 2.

Chart 2 Real exchange rate paths in connection with the phasing in of petroleum revenues



Path 1 show a scenario where all factor inputs are equally mobile in the short term and long term, and where production has decreasing returns to scale. The initial appreciation from the static model then takes us immediately to the dynamic equilibrium – there is no difference between the short and long term.

Path 2 shows a scenario where factor inputs are more mobile in the long run than the short run

[4] Strictly speaking, it could be said that a fourth feature of the economy - the private sector's demand response to increased public use of oil revenues - is also of importance to the real exchange rate paths. This is a key factor in models that study Ricardian equivalence. It is possible that the private sector may counteract the increased use of oil revenues by reducing their demand. If the reduced private sector demand perfectly counteracts the phasing in of oil revenues, the result may be that the real exchange rate does not need to appreciate when the use of oil revenues is increased. An underlying premise in the analysis in this article is therefore that the increased use of oil revenues, either in the form of higher public spending or tax cuts, will entail a net increase in demand. Other aspects of the private sector's demand response may also be of significance – see Footnote 5.

and where production also has decreasing returns to scale in the long run. Following an initial appreciation, factor inputs are gradually moved from the traded to the non-traded sector. The supply of non-tradeable goods therefore increases relative to the supply of tradeable goods - and when this happens, the price of non-tradeable goods in relation to tradeable goods starts to fall. The price will continue to fall until the reallocation of factor inputs has ended. In the new long-run equilibrium, there has been a real appreciation compared with the situation prior to the phasing in of oil revenues. Even in the long term, it is necessary to have higher prices for non-tradeable goods relative to tradeable goods, because production has decreasing returns - and the relative price then has to be changed in order to change the relative production.

In relation to the initial change in the exchange rate, we have now have a depreciation – the short-run exchange rate appreciation represents what is often termed overshooting. But overshooting in this context is something different from what is meant by overshooting in literature about monetary policy, where an overshooting of the *nominal* exchange rate is the result of changes in expectations regarding future interest rate differentials. The overshooting of *the real exchange rate* that arises in dynamic models with the phasing in of oil revenues, has other causes – it is a short-term price signal in the real economy that is necessary in order to achieve market equilibrium. (Naturally, this does not preclude the fact that nominal overshooting could be the mechanism that gives the necessary overshooting in the real exchange rate – in an economy with a floating exchange rate, the most important changes will, in most cases, originate from changes in the nominal exchange rate).

Path 3 shows a scenario where factor inputs are more mobile in the long run than the short run, but where production has constant returns to scale in the long run. The initial real appreciation will continue to be followed by a depreciation when the supply of non-tradeable goods increases relative to the supply of tradeable goods. But factor inputs will now only be reallocated as long as the real exchange rate is higher than it was initially – with constant returns in production, manufacturers only need a higher price for the period when they are transferring factor inputs between the sectors. When this has been done, the price falls back to its original level. With constant returns in production in the long run, there is no need to change the relative price in order to change the relative production.

Path 4 shows a scenario from more recent endogenous growth theory, where the phasing in of oil revenues affects productivity growth. These theories discuss different effects that may pull in the direction of both higher and lower productivity growth as a result of phasing in oil revenues. The discussion naturally focuses on how oil revenues affect the *absolute* level of a country's productivity – see Røisland & Torvik (2000) and Torvik (2001) for a more extensive discussion of this literature. However, in terms of the effect on the real exchange rate, it is the *relative* level of productivity between the non-traded and traded sectors that is decisive - and here the different contributions from more recent endogenous growth theory concur: in the long run, the non-traded sector becomes comparatively more productive than the traded sector as a result of the phasing in of oil revenues.

When oil revenues are phased in, production in the traded sector falls and production in the non-traded sector rises. A decline in production in the traded sector pulls in the direction of lower productivity growth in this sector, not only because the knowledge that is acquired through manufacturing decreases, but also because the incentives for research and development decrease. The effect in the non-traded sector is the opposite. Higher production generates more knowledge and increases incentives for research and development. Given that the spillover effect on skills between the sectors does not dominate the direct effect within each sector, the non-traded sector will be relatively more productive than the traded sector.

In turn, the shift in relative productivity has implications for the real exchange rate. When productivity in the non-traded sector rises at a faster pace than productivity in the traded sector, the supply of non-tradeable goods expands more rapidly than the supply of tradeable goods. A larger supply of non-tradeable goods relative to tradeable goods will lead to a fall in prices for non-tradeable goods in relation to tradeable goods - i.e. there is a real depreciation. The result is a version of the wellknown Balassa-Samuelson effect: when relative productivity between the traded and non-traded sectors moves in one direction, the relative price will move in the other direction. The only difference is that in the model used here, changes in relative productivity are not given exogenously, but are determined within the model - and dependent on the phasing in of oil revenues.

In path 4, the long-run real exchange rate will lie at a lower level than prior to the phasing in of oil revenues. The short-run appreciation is not only an overshooting of the long-run equilibrium level – it is also a movement in the opposite direction.

We see that the assumption regarding returns to scale in the production function is decisive to movements in the real exchange rate as a result of an increase in oil revenues. Models with decreasing returns entail an appreciation in the real exchange rate, models with constant returns entail no change in the real exchange rate, whereas models with (dynamic) increasing returns to scale entail a long-term depreciation of the real exchange rate[5]. A shared feature of the paths for real exchange rate movements discussed here is that initially there is a relatively swift appreciation of the real exchange rate, which is then followed by a depreciation.

4. Gradual phasing in of oil revenues

In the previous section, we considered a permanent one-off increase in the use of oil revenues. We will now look at the effect if oil revenues are phased in gradually. Before we reach long-run equilibrium where we use a constant share of petroleum wealth, the phasing in entails rising use of oil revenues.

In this case, agents' expectations of the future and the way in which these manifest will be decisive. It is useful to differentiate between two extremes. In the one scenario, agents are not forward-looking and in the other, they perfectly predict all current and future effects of the phasing in and take optimal consideration of these when making decisions. Most people will be of the view that agents' actual expectations and behaviour lie somewhere between the two extremes.

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[5] Mechanisms other than those discussed above can influence the real exchange rate path even though they do not affect the long-run result. For example, we have not discussed temporary unemployment in the transition period between equilibria. For an analysis of a model with unemployment, see van Wijnbergen (1984b). Nor have we placed much importance on discussing *intra*temporal or *inter*temporal substitution on the part of the consumer. The closer substitutes for non-tradeable and tradeable goods are at any given time, the smaller the initial real appreciation will be. The rise in prices for non-tradeable in relation to tradeable goods will then switch much of demand from non-tradeable goods to tradeable goods. Intertemporal substitution will give the following effect: the more easily consumers can substitute their consumption over time, the smaller the initial real appreciation will be, but the slower the real exchange rate will be in returning to its original level. The reason for this is that consumers will switch consumption of non-tradeable goods from periods when they are temporarily "expensive" (in the first stages of the phasing in) to periods when they are "cheaper" (in the later stages of the phasing in). The increase in demand will therefore be less earlier on, and more later on, than if consumers had difficulties in moving consumption over time. Nor have we touched on expectations formation and investment, which will be mentioned in section 4 .

Let us first assume that agents are not forward-looking – the increase in the use of oil revenues comes as a surprise in each period and the shock is repeated over time. Initially, the same mechanism will apply as in the section above. The increase in demand for non-tradeable goods necessitates a higher price for these relative to the price for tradeable goods - the real exchange rate appreciates. Following this initial real appreciation, there are two mechanisms that will pull the real exchange rate in different directions over time.

On the supply side of the economy, factors of production are reallocated to the non-traded sector - the relative supply of non-tradeable goods increases and this pulls in the direction of a real depreciation in the exchange rate, as is the case with a one-off increase in the use of oil revenues. On the demand side, there is a rise in demand for non-tradeable goods while oil revenues are being phased into the economy. In other words, the supply of and demand for non-tradeable goods in the market will both rise over time – whether the initial appreciation is then followed by a period of real appreciation or real depreciation depends on which effect is the strongest. If the effect through increased supply is strongest, there will be a real depreciation. If the opposite is the case, the initial appreciation will be followed by a further appreciation. When the phasing in period is complete, we return to the analysis in the previous section and the long-run effects on the real exchange rate are determined by the factors discussed there.

At the other extreme - where agents' perfectly predict the future – the real exchange rate will return to its original level more swiftly. Also there will now be a jump in the real exchange rate at the start of the phasing in – this jump is necessary in the short run in order to achieve market equilibrium when demand rises. But manufacturers will see that the demand for non-tradeable goods continues to rise and will therefore reallocate more factor inputs at an earlier stage than if they did not expect this. The more forward-looking manufacturers are, the faster the supply of non-tradeable goods will rise and the faster the real exchange rate will depreciate, following the initial appreciation.

With a gradual phasing in of oil revenues, there would be a period of rising demand for non-tradeable goods. The more forward-looking manufacturers are, the more supply will keep pace with demand and the faster the real exchange rate will depreciate after the initial appreciation. The level at which the real exchange rate finally settles is determined by the same factors mentioned in the scenario with a one-off permanent increase in the use of oil revenues.

5. Gradual real appreciation?

In summary, key results of literature on the phasing in of oil revenues are as follows: when oil revenues are phased in, there will initially be a period with a real appreciation followed by a period with a real depreciation. It is interesting to note that this is contrary to the path for the real exchange rate apparently underlying the decision to change policy guidelines in spring 2001. It is also contrary to the paths discussed by key participants in the ongoing national debate on the economy, for example, as presented in Statistics Norway's "Perspectives" in Economic Survey 1/2003.

The guidelines for economic policy are set out in Report to the Storting no. 29 of 29 March 2001, which introduces the fiscal rule and the inflation target for monetary policy. It appears that the reasoning behind the simultaneous introduction of the fiscal rule and inflation target is that they support each other and ensure that the nominal exchange rate remains relatively stable. The phasing in of oil revenues necessitates a real appreciation. An inflation target that is somewhat higher than that of our trading partners may contribute to this over time. Note that such reasoning says somewhat more than simply what movements in real exchange rate will be - it also indicates what the *nominal* path of variables included in the real exchange rate might be.

The National Budget for 2003 refers to calculations that show a necessary real appreciation in the region of 4-8 per cent in the period to 2010. This ties in well with an inflation target that aims to hold inflation at ½ - 1 per cent above that of our trading partners. This will perhaps ensure that we achieve a real appreciation even though the nominal exchange rate is stable. In the National Budget, it is stated:

"The nominal appreciation of the krone has contributed to a clear deterioration in cost competitiveness. This deterioration is considerably greater than that which is estimated as a result of the phasing in of oil revenues in the period to 2010, in accordance with the fiscal rule for budget policy."

And in the discussion on monetary policy it is pointed out that the real exchange rate has appreciated by around 15 per cent since the start of 2001. It further states:

"Participants in the foreign exchange market will be able to anticipate a deterioration of competitiveness as a result of a gradual increase in the use of oil revenues. The nominal appreciation of the krone exchange rate in recent months has, however, contributed to a deterioration in cost competitiveness that is considerably greater than that which our calculations of an increase in the use of petroleum revenues in line with the fiscal rule for budget policy would entail."

It is easy to get the impression from the background documents on the changes in economic policy in spring 2001 and the discussions in the National Budget, that the real appreciation in the period to 2010 will occur gradually.

The idea of a gradual real appreciation is also referred to in Economic Survey 1/2003. In "Perspectives" it says:

"It is also assumed in the argument for changing the guidelines for economic policy in 2001 that an inflation rate peculiar to Norway that is around half a per cent higher than that of our trading partners, with a corresponding deterioration in competitiveness, will be necessary and sufficient to realise the structural changes required by the more expansionary fiscal stance that the fiscal rule entails. There should therefore be no need for a nominal appreciation of the krone."

It continues:

"A comparison of the reasoning for and intentions underlying the policy changes in 2001 and actual developments in 2001 and 2002 highlights a substantial discrepancy. A stronger krone resulted in a real appreciation that was considerably more than half a per cent each year."

A path with a gradual real appreciation is illustrated by the dotted line in Chart 2 - a real appreciation can occur with a stable nominal exchange rate. But is this scenario realistic? There are at least two key arguments against the view that the phasing in of oil revenues will result in gradual real appreciation and that this can happen with a stable nominal exchange rate. The first argument is that this exchange rate path conflicts with the real exchange rate paths outlined in theoretical literature on the phasing in of oil revenues. The theoretical literature may, of course, have disregarded important mechanisms that pull in the opposite direction and that are strong enough to dominate the standard effects. It is also possible that conditions peculiar to Norway may entail that the phasing in of oil revenues has different effects here than in other countries. If this is so, it is important to identify these mechanisms and conditions more clearly than is the case in the documents referred to here.

Whereas the first argument is linked to the real exchange rate path, the second is linked to how realistic the notion of a stable nominal exchange rate is. A fixed nominal exchange rate means that monetary policy has to be oriented towards a nominal interest rate level that is the same as that of our trading partners. As we have a higher inflation target, this means that real interest rates in Norway will be lower than those of our trading partners. Monetary policy shall be expansive. The phasing in of oil revenues also entails an expansionary stance. We would then have an economic policy that comprises an expansionary fiscal policy and an expansionary monetary policy, at the same time that we have to achieve the inflation target. The reality of this is questionable.

6. Concluding comments

When oil revenues are phased into the economy, there is reason to first expect a period where the exchange rate appreciates rapidly, before then entering a phase with a gradual real depreciation. The appreciation in the initial stages of the phasing in is necessary in order to achieve equilibrium – the phasing in of oil revenues will result in higher demand for non-tradeable goods that has to be met through increased national production. This necessitates a rise in the price for non-tradeable goods relative to tradeable goods. In the long run, the reallocation of production resources to the non-traded sector and possibly also changes in relative productivity between the non-traded and traded sectors, will result in an increase in the supply of non-tradeable goods in relation to traditional tradeable goods. This will pull in the direction of a real depreciation of the exchange rate.

The real exchange rate paths underlying the introduction of the fiscal rule and inflation target seem to differ considerably from the paths discussed in economic literature. It is questionable whether a gradual real appreciation of the exchange rate in the event of oil revenues being phased in, is realistic. The economic mechanisms that underlie such paths should be elucidated more and the reasons why there is this discrepancy with standard theoretical literature should be clarified.

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Chapter 3 – Real equilibrium exchange rates

Q. Farooq Akram, Kari-Mette Brunvatne and Raymond Lokshall[1]

Real exchange rates often appreciate or depreciate over longer periods of time. Such behaviour may be caused by changes in their equilibrium values. This paper presents some of the popular explanations for changes in equilibrium real exchange rates and methods for calculating them. It focuses on three common approaches: the theory of purchasing power parity, the behavioural equilibrium exchange rate and the fundamental equilibrium exchange rate approaches. The paper also reviews briefly some of the recent empirical studies based on these approaches.

1. Introduction

The real exchange rate expresses the terms of trade for domestic and foreign goods and services. It is defined as the nominal exchange rate adjusted by the relative price between domestic and foreign goods and services. An appreciation of the nominal exchange rate or higher price inflation at home relative to other countries may serve to strengthen the real exchange rate. This can weaken the home country's competitiveness and result in a foreign trade deficit, lower domestic activity and subdued domestic wage and price inflation. The opposite can occur if the real exchange rate depreciates.

The equilibrium real exchange rate is often used as a benchmark for assessing whether the actual real exchange rate is too strong or too weak. It can be defined as the real exchange rate level that is consistent with a state of internal and external balance. Internal balance means that all available factors of production, such as labour and capital, are being fully utilised and wage and price inflation is stable. External balance can be characterised as a state of stable net foreign assets.

However, the equilibrium real exchange rate is not an unambiguous concept in economic literature and a large number of equilibrium exchange rate concepts have been proposed, see Driver and Westaway (2001), Hinkle and Montiel (1999) and MacDonald and Stein (1999). We will, however, limit our focus to the three relatively popular approaches in economic literature. These are the theory of purchasing power parity (PPP), the behavioural equilibrium exchange

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rate (BEER) approach and the fundamental equilibrium exchange rate (FEER) approach. We will present some of the common explanations for movements in equilibrium real exchange rates and also give a brief account of recent empirical studies based on these approaches and discuss some of the main issues involved.

The article is set out as follows: the theory of purchasing power parity is presented in Section 2, followed by a brief summary of results based on Norwegian and a few international empirical studies. This approach leads primarily to a descriptive analysis of movements in the real exchange rate. Section 3 uses the Scandinavian model of inflation as a framework for explaining why a number of factors and mechanisms may contribute to trends and fluctuations in real exchange rates. Many of these factors are included in most empirical studies of real exchange rates based on the BEER approach. This approach is presented in more detail in Section 3.3. Section 4 looks more closely at the FEER approach and offers a brief overview of the main issues related to FEER-calculations. The final section (5) is a summary of the key points.

2. Purchasing power parity - constant equilibrium exchange rate

The theory of purchasing power parity is a usual starting point for calculations of the equilibrium exchange rate. According to this theory, domestic goods will generally cost the same as foreign goods measured in a common currency, when adjusted for international trade costs. Price differences over and above such costs will be eliminated in the long run through international trade. This means that the general terms of trade between domestic and foreign goods, measured in terms of the real exchange rate, will be in equilibrium at a certain level. Alternatively, it could be said that the equilibrium real exchange rates (R^*) is constant:

$$R^* = \alpha. \tag{1}$$

This constant level (α) can represent conditions that entail sustained, but stable deviations from absolute purchasing power parity. Absolute purchasing power parity implies one-to-one terms of trade between domestic and foreign goods, i.e. $R^* = 1$. Deviations from absolute purchasing power parity may be ascribed to transportation costs and trade barriers. They may also be due to technical reasons such as different methods of calculating the general price level at home and abroad. For example, differences in consumption and production patterns between countries may result in different weights being given to individual goods when calculating the general price level.

The real exchange rate can be defined as $R \equiv EP^f/P$, where E is the nominal exchange rate and P^f/P is the ratio between the general price level abroad and in the home country. E denotes the price of foreign currency in domestic currency units. A constant real exchange rate implies equal rates of price inflation at home and abroad when adjusted for changes in the nominal exchange rate.

There can be both internal and external balance when the real exchange rate is at its equilibrium level. Any deviation from the equilibrium level may give rise to internal and external imbalances. Such imbalances will, however, bring the real exchange rate back to its equilibrium level.

If, for example, the actual real exchange rate is stronger than the equilibrium real exchange rates ($R < R^*$), domestic goods will cost more than foreign goods (even when trading costs are deducted). Poor competitiveness may then result in a trade deficit, low domestic activity and unemployment. The trade deficit may in turn contribute to weaken the nominal exchange rate (raise E). At the same time, the low activity level may slow wage and price inflation at home relative to that in other countries (raise P^f/P). The increase in the nominal exchange rate and relative price level will weaken the real exchange rate (increase R) so that it returns to its equilibrium level.

The real exchange rate may, however, become weaker than the equilibrium level ($R > R^*$) before stabilising at the equilibrium level. This can occur if the home country builds up foreign debt when the exchange rate is stronger than the equilibrium exchange rate. A depreciation in the exchange rate relative to the equilibrium exchange rate may result in a trade surplus, thereby making it easier to service and repay the accrued foreign debt. The speed with which the real exchange rate converges towards the equilibrium exchange rate will depend on how much and how quickly the nominal exchange rate and prices react to a deviation from the equilibrium level: $(R - R^*)$. This is determined, among other factors, by how much and how rapidly the real exchange rate affects foreign trade and the activity level, by the nominal exchange rate's response to changes in foreign trade and by how strong and fast prices respond to changes in the activity level and the nominal exchange rate. The stronger these relationships are, the faster internal and external imbalances will be eliminated and the faster the real exchange rate will stabilise at the equilibrium level, see Section 3 for further discussion.

2.1. Empirical evidence of purchasing power parity

An increasing number of studies show that real exchange rates have a tendency to converge towards a stable rate in the long run, see for example Rogoff (1996), Sarno and Taylor (2002), Cheung and Lai (2000) and the references therein. This tendency seems to be particularly clear in studies that observe movements in real exchange rates over longer periods and in studies of real exchange rates between countries with similar economic structures and growth rates, e.g. countries with comparable income per capita. In addition, data from small open economies with fixed exchange rate regimes and flexible product and labour markets that have not experienced major real economic shocks also tend to provide support for stable real exchange rates, all else being equal. These features of empirical studies can be explained in light of the presentation in Sections 3 and 4.

It can, however, take a relatively long time before differences between the actual real exchange rate and the equilibrium exchange rate are eliminated. In industrial countries, it can take 3–5 years for half of a deviation to be eliminated, all else being equal. Such a long half-life is often seen as a puzzle, as it cannot be explained by lags in price changes, see Rogoff (1996). The adjustment to the equilibrium level appears to occur faster in developing countries, where the half-life is often found to be 1–2 years, see for example Cheung and Lai (2000).

Studies of Norwegian data from the past thirty years support the theory of purchasing power parity, see Akram (2000, 2002). It is particularly interesting to note that the half-life for a given deviation seems to be around 1 1/2 years, despite the fact that the Norwegian economy has experienced major real economic shocks since the 1970s. The discovery of oil and gas on the Norwegian continental shelf and revaluations of petroleum wealth as a result of substantial oil price shocks are examples of such shocks. Akram (2003) examines movements in the Norwegian real exchange rate in more detail in chapter 4 of this Occasional Paper.

Recently, a number of studies have pointed out that there may be methodological reasons for the higher estimates of half-lives and the rejection of the theory of purchasing power parity in some studies. For example, Taylor (2001) points to the use of annual data rather than quarterly or monthly data that is better able to capture price adjustments as they happen, as a possible reason; Imbs, Mumtaz, Ravn and Rey (2003) point to the use of general price indices rather than sub-indices, which can take into account possible differences in half-lives between groups of goods; and Taylor, Peel and Sarno (2001) point to the use of linear models rather than non-linear models, which can take into account whether it is unprofitable to adjust prices when there is only a small deviation from the equilibrium level.

Half-life calculations may, however, give a distorted impression of how quickly deviations from the equilibrium exchange rate are actually eliminated. The reason being that exchange rates are continuously subject to shocks, so that the real exchange rate may deviate from its equilibrium level for a longer period than expressed by partial observations, cf. Figure 1. The figure shows movements in the real trade-weighted krone exchange rate together with corresponding real exchange rates for the UK and New Zealand. The real exchange rates generally seem to fluctuate around a given level, without any persistent trends in one direction or the other. However, they do display rather long cycles. This indicates that deviations from any constant equilibrium level may last for several years. The fluctuations in the Norwegian real exchange rate are,

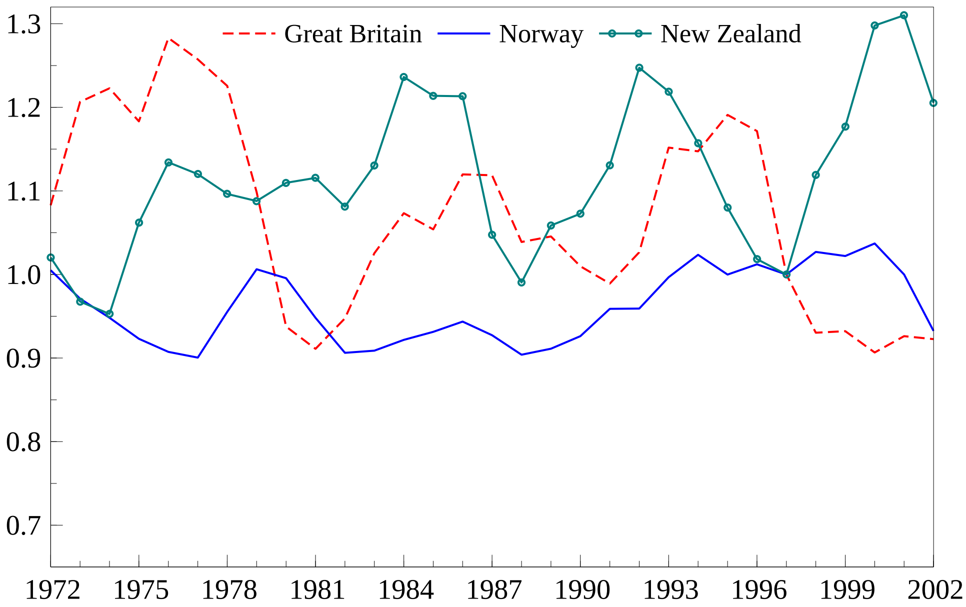

Figure 1: *Trade weighted real exchange rates for New Zealand, Norway and the UK in the period 1972–2002. Annual observations; base year 1997 = 1. Source: OECD MEI.*

however, relatively modest in comparison to the two other real exchange rates which support calculations of a relatively low half-life for the Norwegian real exchange rate compared with typical estimates for other industrial countries.

Figure 2 illustrates changes in some real exchange rates that appear to have experienced trend movements over a longer period of time. The figure shows that the real trade-weighted exchange rates for Australia, Canada and Sweden have become steadily weaker over time, but have experienced substantial fluctuations in periods. In the next section, we present some explanations as to why real exchange rates may show trend movements or long-term deviations from purchasing power parity.

3. The equilibrium real exchange rates vary

This section presents some of the usual explanations of fluctuations and trends in real exchange rates over different time horizons, using the Scandinavian model of inflation (the "main course" theory) as a framework, see Aukrust (1977) and Calmfors (1977). In this model, overall wage growth is determined in the sector exposed to international competition (hereafter c-sector),

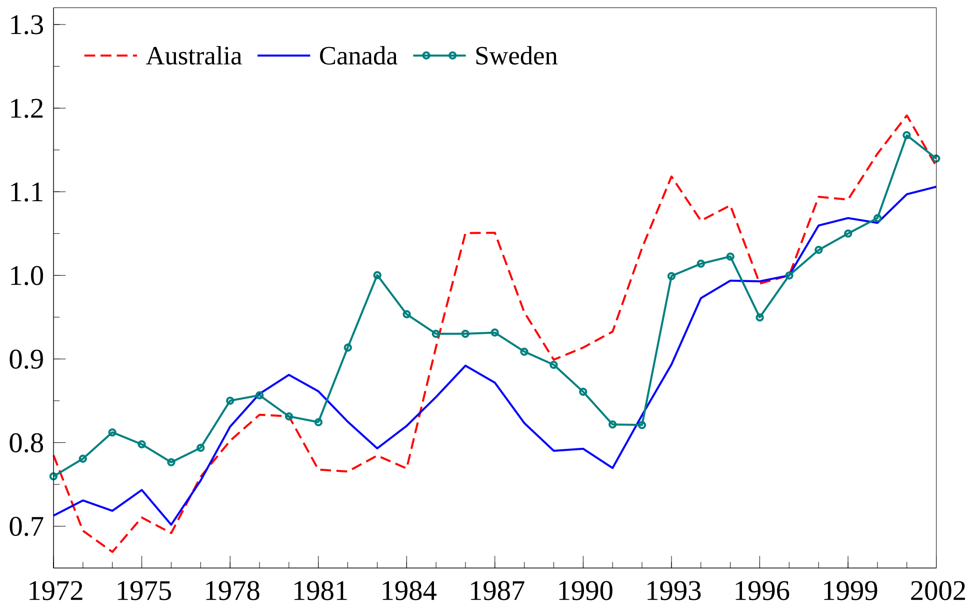

Figure 2: *Trade weighted real exchange rates for*

conditional on imported inflation and productivity growth in c-sector. Therefore, price growth in the sheltered sector (hereafter s-sector) rises with productivity growth in the c-sector, but declines with productivity growth in the s-sector itself. Thus, higher productivity growth in the c-sector relative to that in the s-sector contributes to price inflation in the home country, see Aukrust (1977) for a formal exposition.

3.1. In the long term

Sustained differences in relative productivity growth between the c-sector and s-sector in the home country and abroad can contribute to trend movements in the real exchange rate, see Balassa (1964) and Samuelson (1964). This effect can be explained within the framework of the main-course theory.

Relative changes in the real exchange rate (Δr) can by definition be decomposed into nominal exchange rate changes (Δe) and differences in inflation between the home country and abroad:

$$\Delta r = \Delta e + \Delta p^f - \Delta p. \tag{2}$$

The lower case letters r, p, p^f and e are the logarithms of the real exchange rate, the general price level at home and abroad and the nominal exchange rate, respectively. The main course theory implies that domestic inflation (Δp) is determined in the long run by imported inflation ($\Delta e + \Delta p_c^f$) and the difference in productivity growth between the c-sector and the s-sector ($\Delta q_c - \Delta q_s$):

$$\Delta p = \Delta e + \Delta p_c^f + \omega(\Delta q_c - \Delta q_s). \tag{3}$$

Here, ω is the weight given to non-tradeable goods in the domestic price index. It is common to assume that productivity growth in the c-sector is greater than in the s-sector both at home and abroad.

Productivity growth in the c-sector (Δq_c) determines wage inflation in the c-sector and the s-sector, conditional on price inflation in the world market for tradeable goods in domestic currency ($\Delta e + \Delta p_c^f$). If productivity growth is higher in the c-sector than in the s-sector, the growth in prices for non-tradeable goods will increase relative to the growth in prices for tradeable goods. This will contribute to higher inflation and an appreciation of the real exchange rate (real appreciation, $\Delta r < 0$). A corresponding difference in productivity growth between the c-sector and the s-sector abroad may result in higher foreign inflation, which may contribute to weaken the real exchange rate (real depreciation, $\Delta r > 0$), assuming that inflation abroad is determined in the same way as in the home country:

$$\Delta p^f = \Delta p_c^f + \omega^f(\Delta q_c^f - \Delta q_s^f). \tag{4}$$

The extent to which the real exchange rate appreciates or depreciates will therefore depend on the difference in relative productivity growth between the c-sector and the s-sector at home and abroad. This can be expressed with the help of equation (5), which is obtained by inserting the expressions for Δp and Δp^f from (3) and (4) in equation (2):

$$\Delta r = \omega^f(\Delta q_c^f - \Delta q_s^f) - \omega(\Delta q_c - \Delta q_s). \tag{5}$$

This equation indicates that persistent differences in productivity between the c-sector and the s-sector at home and abroad may result in a persistent real depreciation or real appreciation, and thus contribute to trend movements in the real exchange rate.

Equation (5) indicates that trend movements can also be ascribed to differences in the size of the c-sector at home and abroad. The larger the country's c-sector is (in relation to the s-sector), the greater is its importance to inflation in the economy as a whole. All else being equal, it therefore follows that if the domestic c-sector share is larger than the foreign c-sector share, the real exchange rate will become weaker.

This can be illustrated by reformulating equation (5) as follows:

$$\Delta r = \omega\left\{(\Delta q_c^f - \Delta q_s^f) - (\Delta q_c - \Delta q_s)\right\} + (\omega^f - \omega)(\Delta q_c^f - \Delta q_s^f). \tag{6}$$

The first expression on the right hand side represents the effects of differences in productivity growth between the c-sector and the s-sector at home and abroad, whereas the second expression represents the effect of differences in size of the c-sector at home and abroad, represented by the difference in the weights for non-tradeable goods in general price levels: $(\omega^f - \omega)$. Equation (6) implies that if the domestic c-sector share is greater than the foreign c-sector share, $(\omega^f - \omega) > 0$, the real exchange rate will depreciate, ceteris paribus.

3.2. In the short and medium term

Movements in real exchange rates in the short and medium term may be due to unsynchronised business cycles and differences in domestic and foreign monetary and fiscal policy. It has also been observed that movements in nominal exchange rates may explain a considerable part of changes in real exchange rates in the short and medium run, see for example Mark (1990). This may in part explain why real exchange rates are often more stable under fixed exchange rate regimes than under floating exchange rate regimes, see Mussa (1986). Flexible product and labour markets can also have a stabilising effect on the real exchange rate, cf. Section 2.

The importance of these factors to movements in real exchange rates can also be illustrated within the framework of the Scandinavian model of inflation by modifying some of the assumptions. Let us assume that the rates of inflation at home and abroad are both affected by the (own) activity level and that the impact of changes in the nominal exchange rate on price inflation in the c-sector is incomplete in the short or medium term. These modifications can be taken into account by including expressions for output gap (difference between actual and potential GDP) in equations for domestic and foreign price inflation and by allowing the impact of changes in the nominal exchange rate on domestic inflation to be delayed. This results in the following models for price inflation at home and abroad in the short and medium term:

$$\Delta p = \Delta e_{-1} + \Delta p_c^f + \omega(\Delta q_c - \Delta q_s) + \mu(Y - \overline{Y}), \tag{7}$$

$$\Delta p^f = \Delta p_c^f + \omega^f(\Delta q_c^f - \Delta q_s^f) + \mu^f(Y^f - \overline{Y}^f). \tag{8}$$

Here, for example, Y and $\overline{Y}$ symbolise the actual and potential level of domestic output, whereas μ indicates how strongly the output gap $(Y - \overline{Y})$ affects domestic inflation. Δe_{-1} represents the change in the nominal exchange rate, which is assumed to have full impact on price inflation after a period. For the sake of simplicity, we have disregarded any possible lags in the impact on domestic and foreign inflation of changes in prices for tradeable goods (Δp_c^f). We have also overlooked the possibility that productivity growth can have different effects on inflation in the short and long run.

By including the equations for inflation in the short and medium term, (7) and (8), in equation (2), we get the following model for changes in the real exchange rate:

$$\Delta r = \omega^f(\Delta q_c^f - \Delta q_s^f) - \omega(\Delta q_c - \Delta q_s) + \mu^f(Y^f - \overline{Y}^f) - \mu(Y - \overline{Y}) + \Delta e - \Delta e_{-1}. \tag{9}$$

Equation (9) indicates that a period of economic expansion at home $(Y - \overline{Y}) > 0$, which coincides with an economic downturn abroad $(Y^f - \overline{Y}^f) < 0$, contributes to an appreciation of the real exchange rate ($\Delta r < 0$). This can be explained by the fact that a positive output gap at home contributes to higher domestic inflation, whereas a negative output gap abroad lowers the rate of inflation abroad, all else being equal. Both effects entail a strong real exchange rate. Conversely, the real exchange rate may depreciate if there are available resources at home and pressure on resources abroad. However, if the domestic business cycle is in phase with that abroad, it is uncertain whether the real exchange rate will depreciate or appreciate. This depends on the size of the output gap and its importance to price inflation at home and abroad, i.e. on μ and μ^f.

The importance of flexible labour and product markets to movements in the real exchange rate can also be explained with the help of equation (9). Let us assume, for example, that the real exchange rate appreciates ($\Delta r < 0$) as a result of a shock and that this translates into a lower activity level and negative output gap at home ($(Y - \overline{Y}) < 0$). Equation (9) implies that the negative output gap would serve to reverse the appreciation of the real exchange rate. However, the speed with which the exchange rate then depreciates depends on the strength of the relationship between the activity level and price inflation, i.e. on μ. The stronger that prices respond to the output gap (the greater μ is), the faster the appreciation in the real exchange rate will be reversed by lower price inflation.

In the long run, the output gap at home and abroad will close (internal balance), so that the real exchange rate will be determined by conditions on the supply side such as differences in productivity growth. In the short to medium term, however, differences in the business cycle will contribute to weaken or strengthen the exchange rate over a long period, depending on the flexibility of price formation.

Differences in the business cycle may be due to asymmetric effects of shocks or asymmetric shocks. For example, a higher oil price normally has a contractionary effect on the activity level for most of Norway's trading partners that are oil importers, whereas it has an expansionary effect in Norway, which is an oil exporter. Higher oil prices may therefore lead to a stronger real exchange rate, while a fall in the oil price may result in a weaker real exchange rate, see equation (9). Differences in monetary and fiscal policy at home and abroad can be seen as asymmetric shocks. For example, public consumption of oil revenues will generate positive demand impulses in the Norwegian economy over several years. This can contribute to pressure on prices and a stronger real exchange rate, see Torvik (2003) and Akram (2003). In the same way, interest rate differentials between the home country and abroad can effect output gaps in different directions, forcing a change in the real exchange rate. Interest rate differentials may also have a considerable effect on the nominal exchange rate and result in substantial fluctuations in the real exchange rate, as explained below.

The effect of changes in the nominal exchange rate on the real exchange rate can be explained with the help of the last expression in equation (9): $\Delta e - \Delta e_{-1}$. Under a floating exchange rate regime, there can be substantial movements in the nominal exchange rate, for example, as a result of interest rate differentials. This may lead to corresponding movements in the real exchange rate in the short run. In the longer run, however, changes in the nominal exchange rate may translate into price inflation so that the initial effect on the real exchange rate is cancelled out. Equation (9) shows, for example, that an appreciation of the nominal exchange rate ($\Delta e < 0$) may contribute to an immediate appreciation in the real exchange rate, only to weaken it subsequently, when the nominal appreciation has impacted on price inflation. It could also be said that $\Delta e - \Delta e_{-1} = 0$ in the longer term, so that movements in the real exchange rate are not dependent on the nominal exchange rate in the longer run. Therefore, the effect of nominal exchange rate changes under a floating exchange rate regime is the same as under a fixed exchange rate regime in the long run. A fixed rate regime can be expressed as $\Delta e = \Delta e_{-1} = 0$. It could thus be said that the real exchange rate is independent of the exchange rate regime in the long term.

Lags in the impact of exchange rate changes on prices are important in terms of how long the real exchange rate is affected by the nominal exchange rate. The slower the impact on prices is, the longer it will take for the real appreciation resulting from a nominal appreciation to be reversed. The impact of changes in the exchange rate on prices may also be asymmetrical. If a nominal appreciation is slower to impact than a nominal depreciation, it will take longer for a real appreciation to be reversed than for a real depreciation.

3.3. Behavioural equilibrium exchange rate - BEER

The BEER approach takes into account the possibility that the above mentioned macroeconomic variables may generate long swings and trend movements in the real exchange rate, see Clark and MacDonald (1998). In particular, this approach allows cross country differences in productivity growth and fiscal and monetary policies to contribute to persistent deviations from purchasing power parity, cf. sections 3.1 and 3.2. We will look at this approach in more detail below and refer to some results from studies based on this approach. The BEER approach is based on the hypothesis of uncovered real interest parity, which can be formalised as follows:

$$r = r^e - (ir^e - ir^{e,f}), \tag{10}$$

where r^e symbolises the logarithm of the expected real exchange rate and $(ir^e - ir^{e,f})$ represents the expected real interest rate differential between the home country and abroad. This equation indicates that an increase in the real interest rate differential coincides with a real appreciation of a corresponding size for a given expected real exchange rate. The expected real exchange rate can be determined by a set of macroeconomic variables z that characterises (relevant) aspects of the domestic and foreign economies:

$$r^e = \alpha_0 + \beta z, \tag{11}$$

where α_0 is constant and β represents the effects of z. The expected real exchange rate is assumed to be equal to the equilibrium exchange rate in the long run.

The equilibrium exchange rate in the long run (BEER, r^*) is the real exchange rate that arises when the (effects of) macroeconomic variables are at their equilibrium levels or paths. e.g. when $\beta z = \beta\bar{z}$:

$$r^* \equiv \alpha_0 + \beta\bar{z}.$$

The equilibrium exchange rate r^* will reflect the development in $\beta\bar{z}$, i.e. in the linear combination of variables represented by $\bar{z}$. It follows that r^* will display a trend behaviour if $\beta\bar{z}$ evolves as a trend, but will be a constant if $\beta\bar{z}$ is constant. Note that $\beta\bar{z}$ can be a constant even though the variables that are represented by $\bar{z}$ individually display trend behaviour. It should also be noted that BEER may be equal to the PPP level of the equilibrium exchange rate if $\beta\bar{z}$ is equal to zero and $\alpha_0 = \ln\alpha$, cf. equation (1).

The following model of actual movements in the real exchange rate in the short run can be derived:

$$r = \alpha_0 + \beta z - (ir - ir^f) + \varepsilon, \tag{12}$$

by inserting for r^e from equation (11) in (10) and by assuming that the actual real interest rate differential deviates from the expected one by an expectation error. ε is a stochastic add factor that represents the expectation error and the short-term effects of other factors on the real exchange rate.

The real exchange rate that is consistent with the current macroeconomic development at home and abroad can be defined as $\widehat{r}$. It may be calculated on the basis of an estimated version of equation (12):

$$\widehat{r} = \widehat{\alpha}_0 + \widehat{\beta} z - (ir - ir^f), \qquad (13)$$

where $\widehat{\alpha}_0$ and $\widehat{\beta}$ denote estimates of the unknown parameters α_0 and β. Equation (12) may be estimated by taking into account the time series properties of r, z and $(ir - ir^f)$. $\widehat{r}$ may also be considered the equilibrium real exchange rate in the medium run, as it does not (explicitly) take into account short-run determinants of the real exchange rate.

The behaviour equilibrium real exchange rate in the long run (r^*) may be estimated by making assumptions about the equilibrium level or path of $\widehat{\beta} z$. Estimates of r^* ($\widehat{r}^*$) may then be obtained from the following relationship:

$$\widehat{r}^* = \widehat{\alpha}_0 + \widehat{\beta \bar{z}},$$

where $\widehat{\beta \bar{z}}$ denotes an estimate of $\beta \bar{z}$.

Estimates of $\widehat{r}$ and $\widehat{r}^*$ may be used as a benchmark for assessing whether the real exchange rate is over or undervalued relative to current macroeconomic conditions and the long-run equilibrium rate, respectively. It should be noted, however, that such calculations are model-dependent. The size of a misalignment depends on e.g. the choice of variables that are included in z, on estimates of their effects on the real exchange rate (β) and on assumptions about the equilibrium level or path $\beta \bar{z}$. This places considerable demands on real exchange rate models, as an apparent over or undervaluation may be due to incorrect specifications of the model. One requirement is that the effects of all variables that are important in the medium and long run are represented in the model. Another is that estimates of the equilibrium values of explanatory variables are reasonable. As these calculations are shrouded in uncertainty, it is common to assume that the deviation must be of a given magnitude before it can be deemed to be significant. Often, the difference between the actual real exchange rate and the estimated equilibrium exchange rate is required to exceed ± 2 times the estimated standard deviation before one concludes that a currency is significantly over- or undervalued.

3.3.1. Empirical studies based on the BEER approach

A number of variables appear to recur in empirical models of real exchange rates based on the BEER approach. In addition to the real interest rate differential, the difference between domestic and foreign productivity growth is often included, as are variables representing the terms of trade with other countries, differences between domestic and foreign public debt, and domestic net foreign assets. The relevance of several of these variables is illustrated in Subsections 3.1 and 3.2, whereas some of the variables, particularly net foreign assets, can be said to be motivated by the FEER-approach, see Section 4. Which variables are of greatest importance naturally varies from study to study, depending on the country and the period on which estimations are based, see MacDonald and Stein (1999) for an overview.

Empirical studies of the Norwegian real exchange rate indicate that the interest rate differential with other countries, the real oil price and differences in domestic and foreign productivity growth can explain some of the fluctuations in the Norwegian real exchange rate, see for example Haldane (1997), Chaudhury and Daniel (1998), Chortareas and Driver (2001) and Bjørnland and Hungnes (2002). Akram (2003) develops an empirical model of the Norwegian real exchange rate by including all these explanatory variables in addition to the share of aggregate investment in GDP. Differences in productivity growth and the interest rate differential, however, seem to be more robust explanatory factors than the real oil price and aggregate investment.

4. Fundamental equilibrium exchange rate - FEER

FEER is the real exchange rate that is explicitly consistent with internal and external balance. Internal balance means that actual production equals the potential production level, so that price inflation is stable. External balance is characterised by a sustainable level of the current account balance vis-à-vis other countries.

Calculations of FEER require an empirical model of macroeconomic variables that are influenced by the real exchange rate. Some studies use a general macroeconomic model for one or more countries, whereas others use a partial model for the balance of payments. The partial approach seems to be more popular, partly because the mechanisms that determine FEER are more transparent, but also because model development and maintainance require fewer resources.

Below, we will present a stylised version of a partial model for the balance of payments that can be used to derive FEER, see e.g. Ahlers and Hinkle (1999) for an elaboration. This model can also be used as a reference for discussing issues that may arise when calculating FEER.

Let us assume that the import volume (B) measured in domestic product units is determined by the domestic income level (Y) and the real exchange rate (R). A rise in the income level has a positive effect on imports, whereas a stronger real exchange rate has a negative effect on imports. This implies the following import function:

$$B = B(\underset{(+)}{Y}, \underset{(-)}{R}). \tag{14}$$

Similarly, the domestic export volume (A) measured in domestic product units is assumed to depend positively on foreign income levels Y^f and the real exchange rate. This leads to the following export function:

$$A = A(\underset{(+)}{Y^f}, \underset{(+)}{R}). \tag{15}$$

The trade deficit (TD) can then be expressed as a function of domestic and foreign income and the real exchange rate. By including import and export in the definitional equation for the trade deficit, we arrive at:

$$\begin{aligned} TD &= B(Y, R) - A(Y^f, R) \\ &= TD(\underset{(+)}{Y}, \underset{(-)}{Y^f}, \underset{(-)}{R}). \end{aligned} \tag{16}$$

The import and export functions imply that the trade deficit falls with the income level abroad and the real exchange rate, but increases with the income level at home.

The expression for the trade deficit (16) can also be used to derive the real exchange rate for given values of the trade deficit and for domestic and foreign income levels. This possibility can be expressed more explicitly by inverting equation (16) and solving it with respect to R:

$$R = R(\underset{(+)}{Y}, \underset{(-)}{Y^f}, \underset{(-)}{TD}). \tag{17}$$

This relationship indicates that the real exchange rate must depreciate when there is an isolated increase in domestic income, in order to offset the increase in the trade deficit as a result of higher import, see equations (16) and (14). Similarly, the real exchange rate must appreciate when there is an isolated increase in foreign income levels in order to avoid a fall in the trade deficit as a result of higher export, see equations (16) and (15). The net effect on the real exchange rate of income increases abroad and at home will depend on movements in income-determined import demand in relation to movements in income-determined export demand. The expression for the real exchange rate also implies that a partial increase in the trade deficit requires a stronger real exchange rate.

FEER can be defined as the level of the real exchange rate when the trade deficit and domestic and foreign income levels are at their equilibrium levels:

$$R^* = R(\underset{(+)}{\overline{Y}}, \underset{(-)}{\overline{Y}^f}, \underset{(-)}{\overline{TD}}). \tag{18}$$

Equilibrium levels for the domestic and foreign income levels ($\overline{Y}$ and $\overline{Y}^f$) can be set equal to the potential GDP levels at home and abroad. These can be assumed to rise in line with exogenously given growth rates in each period. The equilibrium level for the trade deficit ($\overline{TD}$)

can be determined in light of the value of net foreign assets. If the country has positive net foreign assets, $\overline{TD}$ can be set equal to the return on these assets from abroad. In the absence of such income, $\overline{TD}$ must be zero in the long run and import costs must be covered by export earnings. In such cases, the FEER level in the short and medium term can be determined by setting $\overline{TD}$ equal to the level that can be funded by borrowing abroad.

The larger the sustainable trade deficit is, the stronger the real exchange rate will be. This means that all factors that increase income from abroad will entail a stronger equilibrium exchange rate, all else being equal. One factor, for example, could be a higher saving rate, which may result in positive net financial investment abroad. An improvement in the terms of trade with other countries and other conditions that could increase the trade surplus would also be positive for net financial investment abroad and provide the basis for a stronger equilibrium real exchange rate. The discovery of natural resources that can be exported would also serve to strengthen the equilibrium real exchange rate. Valuation changes for such resources would also lead to changes in the equilibrium real exchange rate. This is consistent with empirical studies that reject the hypothesis of a constant equilibrium real exchange rate, based on data from countries that have discovered natural resources, see e.g. Patel (1990).

There is a substantial difference between the FEER and BEER approaches, even though they do share some common features. Both BEER and FEER are variable equilibrium exchange rates in general. In the case of a linear model, the expression for FEER may even have the same form as in a BEER model. For example, equation (18) can be written as follows in a linear form:

$$R^* = \alpha + \beta_1 \overline{Y} - \beta_2 \overline{Y}^f - \beta_3 \overline{TD}. \tag{19}$$

The partial effects on the equilibrium exchange rate will, however, depend on the mechanisms in the macroeconomic model used to derive FEER. Thus a variable can have a different effect in a BEER and a FEER model. For example, higher domestic economic growth may strengthen the equilibrium exchange rate in a BEER model. On the other hand, in a FEER model, higher economic growth may lead to a weaker equilibrium exchange rate, if the growth contributes to a foreign trade deficit. This can be explained by the fact that the parameters in a BEER model represent the partial effects of different variables *on* the real exchange rate, while the parameters in the expression for FEER functions represent the effect *of* the real exchange rate on different variables, e.g. import and export. It could also be said that the expression of FEER in itself does not represent a theory for determining the real exchange rate. When calculating FEER, however, it is implicitly assumed that the equilibrium real exchange rate derived from a real exchange rate model, such as the BEER, will coincide with the equilibrium real exchange rate arising from a macroeconomic model in the state of internal and external balance, i.e. with the FEER.

FEER can also be constant, as in the theory of purchasing power parity, when external balance is characterised by trade balance ($\overline{TD} = 0$) and the ratio between $\beta_1\overline{Y}$ and $\beta_2\overline{Y}^f$ remains unchanged, as could be the case if growth rates at home and abroad are equal and $\beta_1 = \beta_2$. For an illustration of this case, see for example Akram (2003).

Another special instance where FEER can be constant is if changes in the real exchange rate have an extremely strong effect on import or export, and thus on the trade deficit. In such cases, FEER will be independent of variables that define internal and external balance. The derived parameters in equation (19) will then be equal to zero. The intuition is that the trade deficit can be steered to the targeted value with slight changes in the real exchange rate if this has an extremely strong effect on import or export. This would, for example, be the case with cost-free international trade.

4.1. FEER calculations in practice

The FEER approach is a widely used method for calculating equilibrium real exchange rates. Well known contributions to the literature include Williamson (1994), Barrel and Wren-Lewis (1989), Artis and Taylor (1995), Faruqee, Isard and Masson (1999) and the article collections Hinkle and Montiel (1999) and MacDonald and Stein (1999). With the exception of Kristoffersen (2002) and Akram (2003), however, there do not seem to be published applications of the FEER approach on Norwegian data.

Below we will present some key issues that are recurring themes in economic literature on FEER, which will make it apparent that there is considerable uncertainty attached to FEER calculations. This indicates that one should be cautious when assessing whether a currency is over or undervalued in relation to a calculated path/level for FEER. This has also motivated calculations of the confidence interval in connection with estimations of FEER and sensitivity analyses. Such analyses look at the degree to which estimates are influenced by alternative assumptions regarding equilibrium values of variables that define internal and external balance.

One of the recurring themes in many FEER calculations is the magnitude of income and price elasticity for import and export. Most empirical studies estimate income elasticity at greater than 1 and price elasticity at less than 1 in numerical value, see for example Marquez (2002, p. 25–26) and Hinkle and Montiel (1999, p. 355 and p. 475). In some studies this is seen as unreasonable a priori, as the budget share of import goods can in theory increase over time and exceed 1 in calculations for long time horizons. This can result in unreasonable estimates for FEER particularly if import does not respond much to changes in the real exchange rate (low price elasticity). In such cases, changes in the FEER level may be deemed to be unreasonably large in the event of a partial change in the income level. In some models, income elasticity is therefore given a value equal to 1. The disadvantage of this can be that the effect of changes in the income level on FEER in the short and medium term may be underestimated.

Another recurring theme in FEER calculations based on large macroeconomic models is the properties of the macroeconomic model. One of the requirements is that the equilibrium properties of models can be interpreted in light of economic theory, otherwise it may be difficult to have confidence in the estimate for FEER that is obtained by solving the model. It is also advantageous if the mechanisms in the model are uncomplicated and transparent so that the partial effect of a variable on FEER can be explained intuitively. The use of a partial approach is often motivated by the desire to achieve a better overview of the mechanisms behind FEER calculations. One disadvantage in doing this can be that the specifications of internal and external balance become less satisfactory, as explained below.

A third theme that is given a great deal of thought in literature is the specification of internal balance. The equilibrium level for GDP is often assumed to be equal to the potential GDP level. There are, however, different ways in which to derive this level. In calculations based on larger macroeconomic models, GDP is modelled as a function of factors of production such as labour and capital. Potential GDP is calculated as that part of GDP than can be explained by changes in factors of production. By using a partial approach, on the other hand, potential GDP is calculated rather mechanically with the help of a filter, for example a Hodrick-Prescott filter, which extracts the trend component from the time series for GDP. It is also fairly common to characterise potential GDP with the help of time trends. Alternatively, this approach is made operational by extrapolating the GDP level from a typical year with the help of average growth rates over a longer time horizon.

One argument that can be used against most studies based on a partial approach is that by estimating the equilibrium level for GDP outside the FEER model, they neglect possible feedback effects from the real exchange rate level to the GDP. Studies carried out thus far, however, suggest that estimates of FEER do not differ greatly when such interactions are taken into account, see Driver, Power and Ramsay (2001).

Another argument is that studies that estimate the equilibrium level for GDP with the help of time trends and average growth rate observations neglect the fact that (potential) GDP does not grow at a fixed rate in each period. Empirically, GDP growth is found to be variable and to a great extent unpredictable. This unpredictability may be ascribed to technological innovations and other unpredictable events. This would also indicate that caution should be used when interpreting FEER calculations.

A fourth point on which studies differ considerably is the specification of external balance, i.e.

the sustainable level of the current account balance with other countries. The simplest approach is to assume that the country does not have sustainable income from abroad, and the trade has to be balanced. Accordingly, current account balance is set at zero. However, this requirement can be too strict in the short and medium term as a deficit or surplus on the current account balance can often last for several years. This may also result in unreasonable estimates for FEER if the time perspective of interest is the short and medium term. In some studies, external balance is therefore defined as the average current account balance over a business cycle, or that the deficit or surplus on the current account balance constitutes a constant share of GDP. For countries with substantial net foreign assets or debts, the current account balance can be set equal to an estimate of income from net assets abroad. For example, in Akram (2003) income from net assets abroad is assumed to be equal to the permanent income from Norway's petroleum wealth.

Separate calculations of a sustainable level for the current account balance can also be criticised for not taking sufficient account of the saving and investment behaviour of the private and public sectors. In some more recent studies, the current account balance is viewed as an endogenous variable and modelled as a function of variables that influence public and private saving and investment behaviour, see Faruqee et al. (1999). Such variables include demographic trends and public sector budget deficits.

5. Summary

Equilibrium real exchange rates are used as benchmarks for assessing whether a real exchange rate is over or undervalued. In this article we have presented three of many approaches to calculating equilibrium real exchange rates: the PPP, BEER and FEER approaches. This has allowed us to point to several factors that are important to movements in the real exchange rate over different time horizons. We have also given a brief overview of empirical results and issues presented in economic literature regarding these approaches.

The theory of purchasing power parity (PPP) entails a constant equilibrium real exchange rate. This means that domestic price inflation in the long run must be equal to price inflation abroad when adjusted for nominal exchange rate movements.

An increasing number of studies show that real exchange rates have a tendency to converge towards a stable level in the long term. It has also been observed that real exchange rates in small open economies with a fixed exchange rate regime and flexible wage and price formation, which generally trade with countries with roughly the same growth rates and economic structure, often converge more rapidly towards an equilibrium level than real exchange rates in other countries. Countries that are exposed to real shocks and that do not have the above-mentioned features, have a tendency to experience long swings and/or trend movements in the real exchange rate.

Long-term trend movements in the real exchange rate may be ascribed to persistent differences in the relative productivity growth between the traded and non-traded sectors at home and abroad. Factors that may be of importance to real exchange rates in the short and medium term include unsynchronised business cycles between the home country and abroad as a result of differences in monetary and fiscal policy, or the asymmetrical effects of shocks at home and abroad. One example of a shock that has a different effect depending on whether the country exports or imports oil, is a change in the oil price. Changes in the nominal exchange rate can also have a direct impact on the real exchange rate when changes in the exchange rate are slow to translate into price changes. Changes in the nominal exchange rate may, for example, be due to a change in the interest rate differential between the home country and other countries.

The BEER approach takes account of the fact that the above mentioned macroeconomic variables can give rise to long swings and trend movements in the real exchange rate. The equilibrium real exchange rate in the medium to long run is defined as the exchange rate level that is achieved as a result of actual values and equilibrium values for macroeconomic variables. The relationship between macroeconomic variables and the real exchange rate is estimated within an empirical model of the real exchange rate.

The FEER approach is also based on the assumption that equilibrium real exchange rates can vary over time. It is calculated on the basis of an empirical model of macroeconomic variables that are influenced by the real exchange rate. Estimates of FEER are often based on assumptions regarding potential domestic and foreign GDP and a sustainable level for the trade deficit with other countries. Conditions that increase foreign investment income result in a stronger equilibrium real exchange rate, as the sustainable level of the trade deficit rises. On the other hand, an increase in domestic GDP that pushes up the trade deficit will weaken the equilibrium exchange rate so that the trade deficit does not exceed foreign investment income.

Calculations of the equilibrium real exchange rate based on all three approaches require that the relevant empirical relationships provide satisfactory characteristics of underlying economic conditions. Estimates of BEER and FEER are also conditional on assumptions regarding the equilibrium values of a number of macroeconomic variables. There is therefore considerable uncertainty attached to estimates of equilibrium real exchange rates. An estimated misalignment should therefore be of a given magnitude before the real exchange rate can be said to be too strong or too weak.

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Chapter 4 – Real equilibrium exchange rates for Norway

Q. Farooq Akram[1]

This article presents and employs the theories of purchasing power parity (PPP), behaviour equilibrium real exchange rate (BEER) and the fundamental equilibrium real exchange rate (FEER) to estimate the equilibrium real exchange rate for Norway. It also discusses whether the real exchange rate was overvalued in 2002 relative to the implied estimates of the equilibrium real exchange rate and whether Norway's substantial petroleum wealth imply a permanently strong equilibrium real exchange rate. It appears that both the PPP and the BEER approaches imply a constant equilibrium exchange rate for Norway. Estimates of the equilibrium real exchange rate imply that the real exchange rate was overvalued in 2002. On the other hand, the FEER approach implies an estimate of the equilibrium real exchange rate on a par with the actual exchange rate in this period. However, the equilibrium exchange rate can not remain at a strengthened rate. Calculations of FEER suggest that it weakens over time and converge towards the rate that balances foreign trade with traditional goods and services. This is because the share of import that can be financed by petroleum revenues becomes insignificant in the long run as import of goods and services is assumed to grow with growth in income.

1. Introduction

The Norwegian real exchange rate strengthened considerably in the course of 2002. A pertinent question would be whether this represented an adjustment to a stronger equilibrium real exchange rate (hereafter equilibrium rate) or simply a temporary deviation from the existing equilibrium rate. In particular, it has been argued that the real exchange rate strengthened permanently because of a permanent increase in government spending, financed by revenues from the Norwegian Petroleum Fund, see e.g. Svensson, Houg, Solheim and Steigum (2002) Moreover, a strong equilibrium real exchange for Norway is often justified on the grounds that Norway has substantial net foreign assets in the form of petroleum wealth and the Norwegian Petroleum Fund which reduce the need for exporting traditional goods and services to pay for imports.

[1] I would like to thank Ida W. Bache, Øyvind Eitrheim, Jan T. Klovland, Fredrik Wulfsberg and other colleagues and participants in seminars at Norges Bank for their constructive comments. It is emphasized that all views and conclusions in this article are those of the author alone.

This article presents and applies three different approaches to determine the equilibrium exchange rate for Norway. These approaches are: the theory of purchasing power parity (PPP), the behavioural equilibrium real exchange rate (BEER) approach and the fundamental equilibrium real exchange rate (FEER) approach, see MacDonald and Stein (1999), Akram, Brunvatne and Lokshall (2003) and the references therein. The FEER-approach is particularly suitable for discussing whether, to what extent and for how long revenues from petroleum wealth imply a strong equilibrium real exchange rate for Norway.

The three approaches focus on different aspects of the economy and therefore identify several factors that are important to movements in the Norwegian real exchange rate over different time horizons. Use of different methods to calculate the level of the equilibrium exchange rate also gives several benchmark values when assessing whether and to what extent the real exchange rate is over or undervalued.

The article is organised as follows: Section 2 considers the theory of purchasing power parity and points out that it enables us to characterise the behaviour of the Norwegian real exchange rate over time. The section also discusses how rapidly the real exchange rate can return to its equilibrium level when a deviation occurs. The presentation of the PPP approach is relatively brief, as we have already analysed the Norwegian nominal and real exchange rates using this approach in Akram (2000a, 2002).

Section 3 employs the BEER approach and derives an empirical model of the Norwegian real exchange rate that is used to calculate the equilibrium exchange rate in the medium and long term. A dynamic model of the real exchange rate is also derived. A number of factors that have short run effects on the exchange rate are included in this model, including growth in public spending, which may help to explain transitory or quite persistent deviations from the equilibrium level.

Section 4 presents the FEER approach, where the equilibrium exchange rate is determined on the basis of a model of Norwegian import and export of traditional goods and services, i.e. non-petroleum products including services. Given the lack of studies adapting the FEER approach to the Norwegian context, this section starts out by developing a theoretical model that can be used to derive FEER. This model can be used to examine the importance of petroleum revenues to the equilibrium exchange rate over time. Thereafter, we employ an empirical version of this model to derive a path for the Norwegian equilibrium real exchange rate far into the future: until 2070. It emerges that, as Norway has substantial net foreign assets in the form of petroleum wealth, the equilibrium exchange rate may be stronger than the level that balances external trade with traditional goods and services. This section also derives alternative paths for the equilibrium exchange rate, conditional on different assumptions regarding, for example, the size of oil revenues and the rate of economic growth in Norway and abroad. This helps us to discuss whether relatively large revenues from petroleum wealth can justify a permanent appreciation of the equilibrium exchange rate. Section 5 presents a summary of the key results.

2. Equilibrium exchange rate based on PPP

According to the theory of (relative) purchasing power parity (PPP), the real exchange rate would be constant in equilibrium. This is expressed in equation (1):

$$R^* = \alpha, \tag{1}$$

where R^* is the real exchange rate in equilibrium and α is a constant parameter. The real exchange rate is defined as $R \equiv EP^f/P$, where E is the nominal exchange rate, which expresses the price of foreign currency in the home country's currency, and P^f/P is the ratio between the general price level abroad and the general price level at home. When the real exchange rate is at its equilibrium level, the rate of inflation in the home country will equal that abroad once we account for changes in the nominal exchange rate.

When the economy is in a state of internal and external balance, the real exchange rate will be at its equilibrium level. Any deviation from the equilibrium level may give rise to internal and external imbalances. Such imbalances will, however, bring the real exchange rate back to its equilibrium level. For example, if the actual exchange rate R is weaker than R^*, $(R > R^*)$, competitiveness will improve and may result in trade surplus. This will be accompanied by a rise in the activity level and contribute to a tighter labour market. The trade surplus may result in an appreciation of the nominal exchange rate (lower E), while the high activity in the economy will serve to push up wage and price inflation (raise P^f/P). As a result, the real exchange rate will appreciate (R falls) and return to the equilibrium level, though this can occur in cycles around the equilibrium level until imbalances are eliminated, see Akram et al. (2003) (Chapter 3 of this Occasional Paper) for a more detailed explanation.

Movements in the Norwegian real exchange rate over the past thirty years comply well with predictions based on the theory of purchasing power parity. Figure 1 shows quarterly movements in the Norwegian effective real exchange rate in the period 1971:1–2002:4. The straight line at 0.975 represents an estimate of the equilibrium real exchange rate (R^*). This is calculated as the average of the real exchange rate over the sample period. The figure shows that the real exchange rate fluctuated around the estimated equilibrium level throughout the sample period, where positive deviations from the equilibrium level ($R > R^*$) were followed by negative deviations ($R < R^*$) sooner or later. There appears to be no sustained trend in one direction or the other,

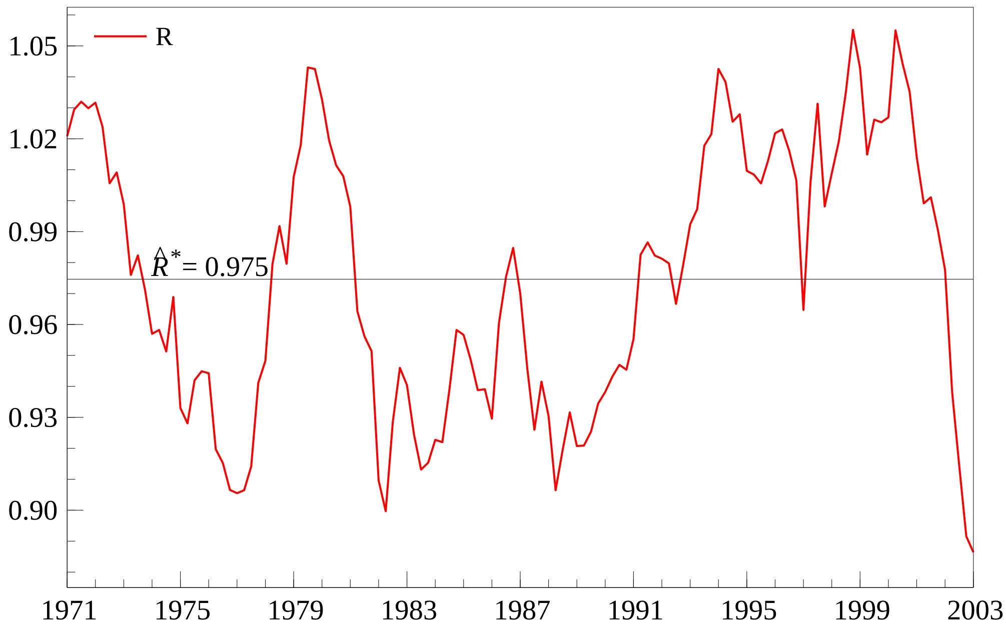

Figure 1: *Trade-weighted real exchange rate in period 1971:1–2002:4. The real exchange rate is constructed by dividing the product of the trade-weighted nominal exchange rate index and foreign consumer price index with the consumer price index in Norway. All indices have a value equal to 1 in 1997. An increase in the real exchange rate indicates a real depreciation.*

nor in the fluctuation margin. This impression is confirmed by several formal tests, see Akram (2000a, 2002). Some of these tests are presented in Table 1. Several more recent studies of other countries also find that real exchange rates generally converge towards a given level in line with the theory of purchasing power parity, see for example Sarno and Taylor (2002), Cheung and Lai (2000) and references therein.

Empirical evidences suggests that the Norwegian real exchange rate has a tendency to converge relatively rapidly towards the equilibrium level. Figure 2 shows the time path of a deviation from the equilibrium level, $(R - R^*)$. We see that one unit's deviation from the equilibrium level is halved in the course of five quarters, whereas 3/4 of the deviation is eliminated in the course of ten quarters, all else being equal. This figure is based on the time series model for the real exchange rate in Table 1. Similar studies for other industrial countries report half-lives of three to five years, see Rogoff (1996). The Norwegian real exchange rate's rapid adjustment speed (low half-life), on the other hand, is comparable with that found in studies for developing countries: one to two years, see Cheung and Lai (2000).

Table 1: Tests of PPP, speed of adjustment and contribution to adjustment

I. A time series model of the effective real exchange rate

$$\Delta\widehat{R}_t = \underset{(3.673)}{0.161} - \underset{(-3.681)}{0.167}\, R_{t-1} + \underset{(2.133)}{0.212}\, \Delta R_{t-1} + \underset{(1.491)}{0.156}\, \Delta R_{t-3} + \underset{(1.417)}{0.156}\, \Delta R_{t-5} + \underset{(1.845)}{0.202}\, \Delta R_{t-7}$$

$t-ADF = -3.681$, DF-critical values: 5 % $= -2.887$, 1 % $= -3.489$
Sample period: 1972:2–1997:4; Method: OLS

II. Adjustment towards equilibrium rate under different exch. rate regimes

Regime:	Stable and floating	Stable	Floating
Period:	1972:2–2001:4	1972:2–1992:4	1993:1–2001:4
$\Delta\widehat{R}_t$:	−0.118 (0.037)	−0.214 (0.052)	−0.398 (0.132)
$t{-}ADF$	−3.16	−4.16	−3.01
Half-life	5.5 quarters	3 quarters	1.4 quarter

III. Contrib. from nominal exch. rate and price level to stabilise the real exch. rate

$$\Delta\widehat{e}_t = \underset{(0.042)}{-0.161}[e-(cpi-cpi^f)]_{t-1} + \text{ short-run effects}$$

$$\Delta\widehat{cpi}_t = \underset{(0.018)}{0.032}\,[e-(cpi-cpi^f)]_{t-1} + \text{ short-run effects}$$

Sample period: 1972:2–1997:4; Estimation method: FIML

IV. Contrib. from nominal exch. rate and domestic prices under different regimes

Regime:	Stable and floating	Stable	Floating
Period:	1972:2–2001:4	1972:2–1992:4	1993:1–2001:4
$\Delta\widehat{e}_t$:	−0.139 (0.037)	−0.149 (0.045)	−0.287 (0.131)
$\Delta\widehat{cpi}_t$:	0.028 (0.016)	0.033 (0.020)	0.056 (0.031)

Note: The results in panel II were achieved by re-estimating the time series model in panel I with data for different periods. We only report coefficient estimates (and associated t-values) for the coefficient for R_{t-1}. The half-life is calculated by using the standard formula: $ln(1/2)/ln(1-\alpha)$, where α denotes the estimated absolute value of the coefficient of R_{t-1}. The division between stable and floating regimes is approximate. Panel III reports the results from a simultaneous model of relative changes in the nominal exchange rate, inflation in Norway and in trading partner countries. The coefficient estimates in front of the terms that show differences between the logarithm of the nominal exchange rate and price ratio, indicate the degree of adjustment towards a constant real exchange rate through changes in the nominal exchange rate and domestic inflation, respectively. Due to lack of space, the short-run effects of the different variables on each other are not shown, nor is the equation for inflation in trading partner countries, see Akram (2002).

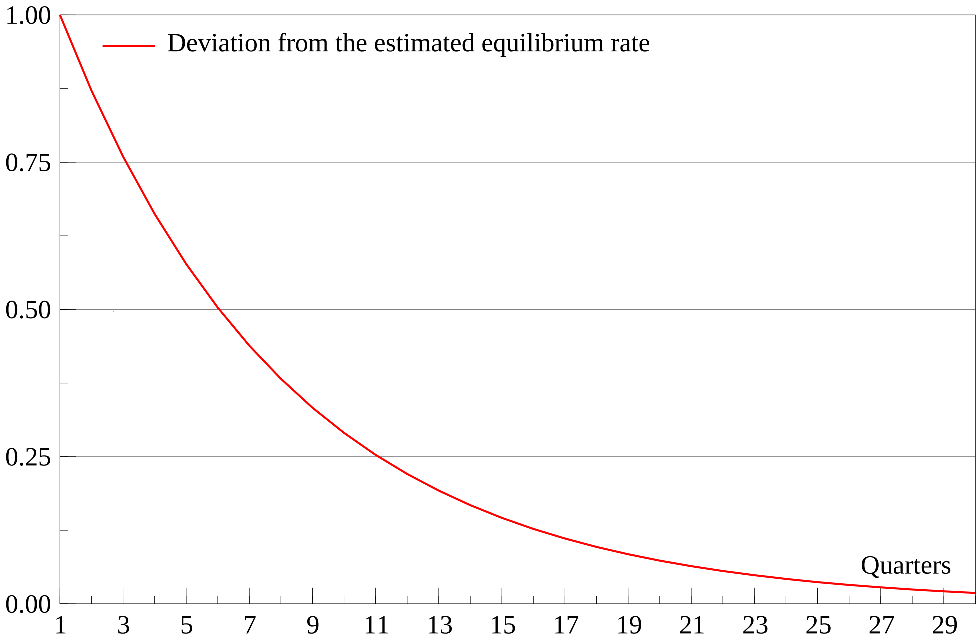

Figure 2: *Evolution of a deviation from the estimated equilibrium exchange rate, all else being equal. The shock that creates the deviation occurs in Q1.*

This type of analysis may, however, give an excessively optimistic impression of how rapidly the real exchange rate actually returns to the equilibrium level, as everything else is assumed to remain unchanged whilst the exchange rate adjusts towards the equilibrium level. Exchange rates are constantly exposed to shocks and this may contribute to deviations from the equilibrium level over longer periods of time than those implied by such partial analyses, cf. Figure 1.

The tendency of the Norwegian real exchange rate to converge more rapidly towards the equilibrium level than real exchange rates in many other industrial countries may be because the Norwegian economy is more open. Changes in the real exchange rate/competitiveness may therefore swiftly result in internal and external imbalances, which on the other hand may have a stronger and more rapid effect on the real exchange rate. While the averages for import and export comprise a share of less than 1/4 of GDP in a typical industrial country, the corresponding average value for Norway is less than 1/3, see Cheung and Lai (2000). This is also the case if one looks at Norwegian foreign trade in traditional goods and services relative to mainland-GDP, cf. Figure 8 in section 4.2. Furthermore, Norwegian export contains a relatively large share of commodities and semi-manufactures that face greater competition on the world market than finished goods, cf. the rapid adjustment speed for developing countries. The relative openness and composition of export may serve to strengthen the relationship between the real exchange rate, foreign trade and the activity level more than can be expected in many other industrial countries. It is therefore no coincidence that considerations for competitiveness have played an important role in the formulation of Norwegian monetary and fiscal policies, particularly in the past thirty years. For example, in the period to mid-1986, the Norwegian krone was devalued on several occasions to offset a deterioration in competitiveness and reduce foreign trade deficits.

Another cause for the rapid adjustment towards equilibrium could be that wages and prices react more strongly to imbalances in the labour and product markets in Norway than in most other industrial countries. For example, Layard, Nickell and Jackman (1991, ch. 9) report that the wage and price response to imbalances in the labour and product markets in Norway is the second highest of 19 industrial countries. The high wage and price response may be due to centralised and coordinated wage bargaining, which contributes to internalising the overall costs of a strong real exchange rate, for example in the form of high unemployment. This in itself contributes to restraining wage demands and thereby to lower price inflation in the face of low competitiveness. In a system with centralised and coordinated wage bargaining it is also easier for the authorities to influence wage and price formation through incomes policies.

Empirical studies show that both the nominal exchange rate and domestic prices react when the real exchange rate deviates from the equilibrium level and contribute to its convergence towards the equilibrium level, see Table 1 and Akram (2002). The contribution from the nominal exchange rate, however, appears to be 4–5 times greater than the contribution from (wage and) price inflation. There is little to indicate that the contributions from the nominal exchange rate and prices have diminished in the past decade relative to their sizes in the 1970s and 1980s, rather to the contrary. The evidence in Table 1 indicates that the nominal exchange rate and prices reacted more sharply to deviations from the equilibrium level in the 1990s than previously. This may be ascribed to greater capital mobility and the abandonment of a fixed exchange rate policy, which contributed to rigidity in the nominal exchange rate. But the possibilities of convergence towards the equilibrium level being reversed also increase when the exchange rate is floating. Deviations from equilibrium may therefore persist over longer periods, despite a possibly stronger (partial) response of the nominal exchange rate to a misalignment.

3. The behavioural equilibrium exchange rate (BEER)

The PPP approach in the above section does not identify factors that have given rise to fluctuations in the Norwegian real exchange rate over time. Nor is it given that only trade costs and other conditions compatible with PPP can imply a stable equilibrium exchange rate. In this section, we seek to explain fluctuations in the real exchange rate and identify variables that may determine the level of the equilibrium exchange rate in the medium and long term. We adopt the behavioural equilibrium exchange rate (BEER) approach that implies the following model for the real exchange rate, see MacDonald and Stein (1999) or Akram et al. (2003) for a derivation:

$$r = \alpha_0 + \beta z - (ir - ir^f) + \varepsilon \tag{2}$$

where r symbolises the logarithm of the real exchange rate (R); z represents a vector of macroeconomic variables and $ir - ir^f$ denotes the real interest rate differential between the home country and abroad. α_0 is a constant term, β represents the partial effects of z on the real exchange rate and ε is a stochastic residual that represents the effect of all variables that individually or collectively have short-run effects on the real exchange rate.

The equilibrium exchange rate in the "medium run" can be determined by the actual values of z, and the actual interest rate differential, if this has a tendency to be positive or negative over longer periods. More specifically, it can be equated to the "fitted values" of r over the sample period if one has an estimated version of the model (2). Hence, the equilibrium exchange rate in the medium term is also referred to as the "current" equilibrium exchange rate.

The long run behavioural equilibrium exchange rate (BEER, r^*) is implied by model (2), when βz is at its equilibrium level/path βz^* and $ir - ir^f = 0$, if we assume real interest rate parity in the long run:

$$r^* = \alpha_0 + \beta z^*. \tag{3}$$

It follows that BEER will be constant if βz^* is also a constant term. BEER can be equal to the PPP-level of the equilibrium exchange rate if βz^* is zero, cf. equation (1). This can occur if a linear combination of the variables in vector z^* that is defined by vector β becomes equal to zero, even though z^* and β individually are different from zero.

In the following, we first present an empirical variant of model (2) that is used to derive the equilibrium exchange rate in the medium and long term. When deriving this model, we specified the vector z in the light of previous empirical studies of real exchange rates based on the BEER approach. Commonly, vector z consists of indicators for the differences in productivity growth between the home country and abroad; terms of trade; differences in public debt and or government spending between the home country and abroad; and domestic net foreign assets, see MacDonald and Stein (1999) for an overview.[2]

[2]The BEER-approach is commonly adopted to explain the behaviour of real exchange rates when it displays long swings and persistent movements in one or the other direction, displaying weak if any signs of convergence towards a certain level, i.e. when there is not any or sufficient evidence in support of purchasing power parity. The behaviour of the explanatory variables that are included in z, therefore ususally display similar characteristics as the real exchange rate over time. However, it suffices that the behaviour of the linear combination of the variables in z, i.e. βz, is able to match that of the real exchange rate.

Second, we present a model that contains several variables that are important to the real exchange rate in the short run. We also demonstrate that continuous demand impulses in the form of e.g. growth in public spending over several years, can contribute to relatively long-term deviations from the real exchange rate, despite a strong partial equilibrium correcting response of the real exchange rate to deviations from its equilibrium rate.

The empirical results in the following sections are based on quarterly data for the period 1972:1–2001:4 and the models that are presented are estimated by the OLS method.

3.1. Equilibrium exchange rate in the medium run

Actual movements in the real exchange rate can be broadly explained with the help of the following static empirical model, cf. (2):

$$
\begin{aligned}
r &= 0.09 - \underset{(-8.52)}{0.23}\,[(p_s - p_c) - (p_s - p_c)^f] - \underset{(-2.05)}{0.012}\,roilp - \underset{(-2.78)}{0.19}\,I.Y \\
&\quad - \underset{(-8.98)}{1.05}\,(i - i^f).
\end{aligned} \tag{4}
$$

The model suggests that the real exchange rate is determined by the difference between relative prices for sheltered (s) goods and services and those exposed to international competition (c) in Norway and trading partner countries ($(p_s - p_c)-(p_s - p_c)^f$), the real oil price in USD (*roilp*) and investment-GDP ratio ($I.Y$). The nominal interest rate differential between Norway and its trading partners is also included ($i - i^f$). All the variables in the equation are in logarithmic form, with the exception of the interest rate differential and the investment share ($I.Y$). A minus sign in front of a variable indicates that an increase in the variable's value has an appreciating effect on the real exchange rate; the figures in brackets show (standard) t-values.[3] The explanatory variables in model (4), probably with the exception of the investment share, have also been used in previous studies of the Norwegian real exchange rate, see e.g. Chaudhury and Daniel (1998), Alexius (2001) and Bjørnland and Hungnes (2002).

The difference in relative prices for s and c-goods (and services) may reflect differences in productivity between the exposed and sheltered sectors ($q_c - q_s$). It is implied, for example by the Scandinavian model of inflation, that the ratio between prices for n and c-goods can be set equal to the ratio between productivity in the sheltered and exposed sectors, i.e. $p_s - p_c = q_c - q_s$, see Aukrust (1977). Accordingly, an increase in the productivity differential results in higher prices for s-goods relative to c-goods. This is because wage growth in the sheltered sector, which is determined by productivity growth in the exposed sector for a given rate of

[3] Use of standard *t*-values presuppose that variables are stationary, which we are not confident about. Formal tests, however, do not suggest that the empirical model represents a spurious relationship between the real exchange rate and the right hand side variables, cf. equation (5).

imported inflation, rises relative to productivity growth in the sheltered sector. An increase in the productivity differential between the exposed and sheltered sectors therefore contributes to higher inflation and a real appreciation. A corresponding increase in the productivity differential between the exposed and sheltered sectors in trading partner countries contributes to higher foreign inflation and a real depreciation. The extent to which the real exchange rate appreciates or depreciates will therefore depend on the relative productivity differential between the exposed and sheltered sectors in Norway and abroad, here represented by the relative price differential between n and c-goods.[4]

The relative price differential between n and c-goods can also capture the effects of different demand impulses in Norway and abroad as a result of, for example, differences in fiscal policies. Public expenditures are largely directed towards the production of sheltered goods and services. An increase in public spending may therefore result in higher price inflation in the sheltered sector than in the exposed sector, thereby pushing up inflation and contributing to a real appreciation. Similarly, growth in public spending abroad may have a depreciating effect on the real exchange rate. The effect on the real exchange rate will thus be determined by the difference in growth of public spending between Norway and abroad. We found no direct effect of public spending when deriving the empirical model (4), though. This does not, however, preclude effects of public spending through the relative price differential.

We use the real oil price to represent the terms of trade between Norway and other countries. An improvement in the terms of trade (increase in the oil price) contributes positively to the trade surplus vis-à-vis other countries and raises the value of the petroleum wealth in the seabed. This increases net foreign assets, which provides the basis for capital revenues from other countries. This in turn gives rise to a real appreciation as a larger trade deficit can be financed by revenues from abroad, see section 4 for a more detailed discussion. Moreover, the actual trade surplus may raise demand for Norwegian krone, which may engender a nominal and thereby real appreciation. However, in statistical terms, it is doubtful whether the real oil price affects the real exchange rate in the long run, as the t-value is relatively low (in absolute terms). It should also be mentioned that we found no significant effects of alternative indicators for the terms of trade between Norway and other countries, for example, the ratio between export and import prices.

The investment share correlates, among other things, with the saving share and the economy's growth potential. A part of saving takes the form of an increase in net foreign assets. This provides the basis for higher capital revenues from abroad and thereby for a larger trade deficit, which entails a stronger real exchange rate. An increase in the investment share as a result of

[4] It is not obvious whether this effect, which is known as the Balassa-Samuelson effect, should be considered as short run or long run in this context, see Balassa (1964) and Samuelson (1964). One may argue that cross-country productivity differentials between sectors may not persist between countries that have a fairly similar economic structure and are at comparable levels of income, e.g. Norway and its main trading partners.

higher saving can therefore coincide with a real appreciation. Expectations of higher income in the future as a result of a higher investment share may also justify a larger trade deficit and an immediate real appreciation. The reason for this is that economic growth increases opportunities for a trade surplus and higher net foreign assets in the future.

Our use of the nominal interest rate differential, instead of the real interest rate differential, also begs an explanation. The nominal interest rate differential, here defined as the differential between six-year bond yields in Norway and trading partners countries, just turned out to have a far greater explanatory power than the corresponding real interest rate differential. The latter was defined by adjusting the nominal interest rate differential for differences in consumer price inflation. This may be because changes in real exchange rates in the short run are largely due to movements in the nominal exchange rate that are influenced quite considerably by nominal interest rate differentials, see Mark (1990). Note also that the coefficient estimates of 1.05 can be considered as 1, both numerically and statistically, see equation 2.

Figure 3 shows that the actual exchange rate has fluctuated around the medium-term or current equilibrium exchange rate. There is no sign of a persistent over or under valuation of the actual real exchange rate relative to the equilibrium exchange rate in the period 1972:1–2001:4. This is more apparent in Figure 4, which shows misalignment (over- or undervaluation) in relation to the medium-term equilibrium exchange rate at different points in time.

We note that over and under valuation (measured as a negative or positive deviation) is not persistent, but has a tendency to be (partially) corrected in the following period. Equation (5) shows that around 1/4 of a given deviation is (normally) eliminated in the following period. In the absence of more shocks, the deviation will be more or less eliminated in the course of two years. The equilibrium level in the medium term can therefore be reached within two years, given that there are no new shocks.

$$\Delta(R-\widehat{R})_t = \underset{(-4.72)}{-0.30}\,(R-\widehat{R})_{t-1} \tag{5}$$

The fact that deviations are not persistent indicates that they are caused by factors that have temporary effects on the real exchange rate.

3.2. Equilibrium exchange rate in the long run (BEER)

The long-run equilibrium exchange rate (BEER) can be estimated by making assumptions about the values of the right-hand variables in model (4) in the state of internal and external balance. Internal balance is characterised by equilibrium in the product and labour markets at home and abroad. When this is the case, domestic and foreign inflation will also be at a stable rate, which

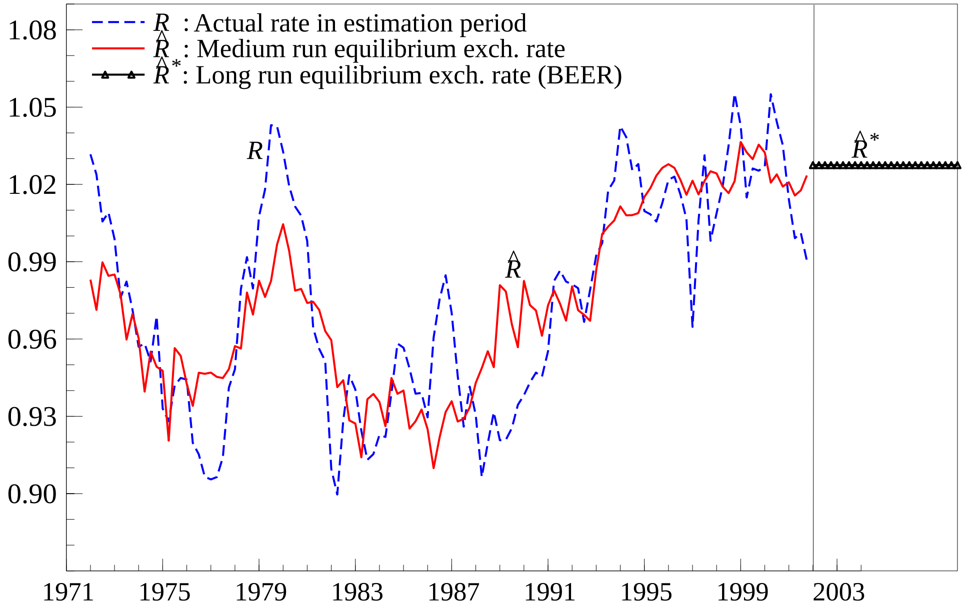

Figure 3: *Actual values of the real exchange rate (R) and estimates of the medium-term equilibrium exchange rate in the period 1972:1–2001:4. Estimates are based on model (3) for actual values of explanatory variables over the same period. The figure also shows estimates for the long-term equilibrium exchange rate, conditional on our assumptions about the equilibrium values/paths of the explanatory variables.*

can be assumed to be equal to the inflation targets at home and abroad. External balance is characterised by stable net foreign assets. That is when the current account surplus is equal to zero and (physical) investment is equal to total saving. Real interest rate parity implies that the real interest rate differential between the home country and other countries is equal to zero in the long run, so that the nominal interest rate differential reflects the difference in inflation targets between the home country and abroad.

We have specified the state of internal and external balance as follows. The nominal interest rate differential is set at 0.5 percentage point, which corresponds to an assumed difference in the inflation target between Norway and (several of) its trading partners. The investment share $I.Y$ is assumed to be equal to 0.24, which is the historical average value for the period 1966–2001. This level is also equal to the saving share in this period. The relative price differential between the n and c-sectors is assumed to be constant and equal to the value at end-2001:–0.086. The real oil price is assumed to equal 17 dollars, as assumed in the National Budget for 2003.

The equilibrium exchange rate (BEER) was estimated at 1.03 for the assumed equilibrium values

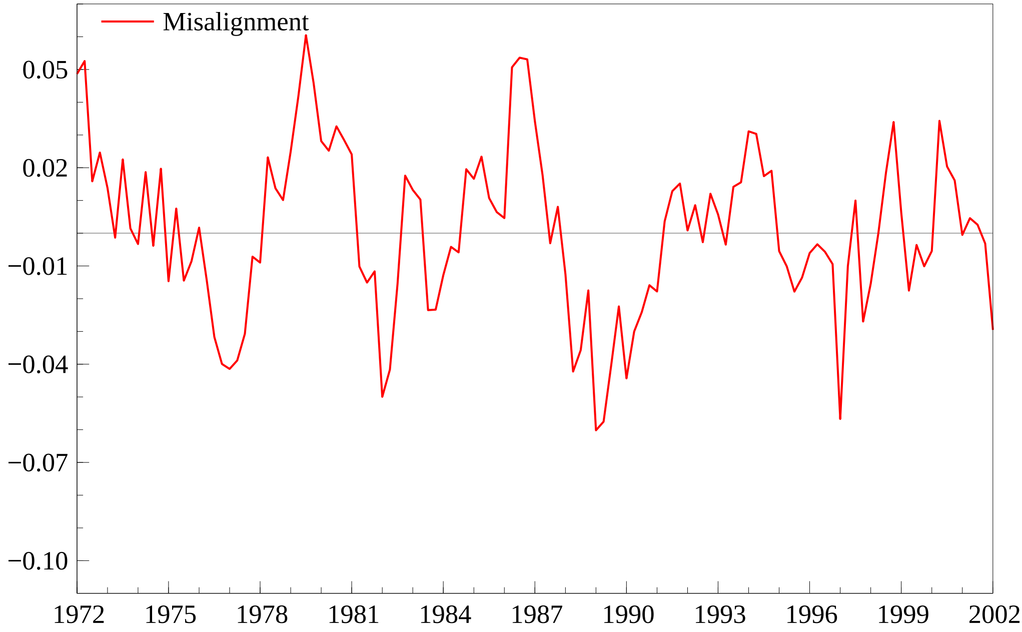

Figure 4: *Deviations (misalignment) from medium-term equilibrium exchange rate in the period 1972:1–2001:4. Deviations are the difference between actual values of the real exchange rate and estimates of the medium-term equilibrium exchange rate in Figure 3.*

of explanatory variables. Reasonable changes in the assumptions regarding the values of the right-hand side variables in the state with internal and external balance did not lead to any substantial changes in the estimate for the equilibrium exchange rate. The lower and upper limits for a 95 per cent confidence interval were estimated at 0.97 and 1.08, respectively. [5]

The lower limit of the confidence interval for the estimate for BEER is close to the PPP estimate of the equilibrium exchange rate (0.975), see Figure 1. The difference between the PPP and BEER estimates can be ascribed to the fact that the PPP estimate is equal to the average value of the real exchange rate in the period 1971:1– 2001:4, whereas the BEER estimate is based on values other than the average values of explanatory variables in the period 1971:1–2001:4. The estimated value of BEER becomes equal to the PPP estimate for the equilibrium exchange rate, if we use average values for explanatory variables as estimates for their equilibrium values. [6]

[5]Such confidence intervals may underestimate the uncertainty associated with the estimate of the equilibrium exchange rate, given that one assumes that the model is correctly specified and the true parameter values are equal to their estimates.

[6]This applies generally, as the average of the actual values of the left hand side variable is generally equal to estimated values of the left-hand side variable. For example, OLS implies that $1/T\Sigma_{t=1}^{T}(r_t - \widehat{r}_t) = 0$, where $\widehat{}$ symbolises an estimated value and T denotes number of observations. Then it follows that: $1/T\Sigma_{t=1}^{T} r_t = 1/T\,\Sigma_{t=1}^{T}\widehat{r}_t = \widehat{\alpha_0} + \widehat{\beta}(1/T\,\Sigma_{t=1}^{T} z_t) - 1/T\,\Sigma_{t=1}^{T}(ir_t - ir_t^f)$.

3.3. The short run

Even though actual movements in the real exchange rate can be broadly explained with the help of model (4), there is still a considerable part of the variation that is left unexplained. However, it seems that the unexplained part is caused by variables that only have short-run effects on the real exchange rate, see equation (5). A number of these affect the real exchange rate regularly, whereas others only have sporadic effects. Equation (6) shows the variables that regularly influence the real exchange rate. In the equation, we have decomposed a change in the real exchange rate into partial contributions of a number of explanatory variables in explaining a change in the real exchange rate.

$$\begin{aligned}\Delta r_t = &-\underset{(-2.08)}{0.004} - \underset{(-3.07)}{1.63}\,\Delta\left(\frac{ir-ir^f}{4}\right)_t - \underset{(-2.27)}{0.05}\,\Delta(q_c-q_s)_{t-1} + \underset{(1.62)}{0.34}\,\Delta y^f_{t-1} \\ &- \underset{(-2.91)}{0.12}\,\Delta_4(g-y)_t - \underset{(-3.83)}{0.10}\,\Delta roilp_t \times F(14) + \underset{(4.15)}{0.31}\,\Delta r_{t-1} \\ &- \underset{(-4.94)}{0.23}\,[r-(r^e-(i-i^f))]_{t-1} - \underset{(-3.86)}{0.04}\,cid97q1 + \widehat{\varepsilon}.\end{aligned} \tag{6}$$

A change in the real exchange rate may be ascribed to changes in the real exchange rate differential ($\Delta(\frac{ir-ir^f}{4})_t$)), the productivity differential between the sheltered and exposed sectors ($\Delta(q_c-q_s)$), economic growth in trading partner countries (Δy_t^f), annual growth in public spending relative to GDP ($\Delta_4(g-y)$) and changes in the real oil price when the nominal oil price is at a relatively low level (under 14/15 dollars), see Akram (2000b) for details. A part of the change in the real exchange rate can also be ascribed to adjustments for deviations from the equilibrium level in the preceding period, see equation (5). It also appears that a real appreciation/depreciation in one period contributes to a continued real appreciation/depreciation in the following period. This may be due to lags in the behaviour of participants in the foreign exchange market, so that the exchange rate does not change at the same pace as changes in macroeconomic variables, or due to persistence in price inflation as a result of unsynchronised and gradual price adjustments on different goods at home and abroad, or due to other factors that have a systematic effect on the exchange rate, but that are not included explicitly in the model. $\widehat{\varepsilon}_t$ represents unidentified factors that combined appear to have transitory effects on the real exchange rate. The variable $cid97q1$, which is 1 in 1997:1 and – 1 1997:2, represents factors underlying the relatively sharp nominal and real appreciation in 1996/1997 and subsequent depreciation. The other variables in the model could not fully explain these sharp movements in the real exchange rate.

In this model we have included explicitly productivity growth in Norwegian manufacturing industry and private services production as indicators for productivity growth in the exposed and sheltered sectors. The growth rate for foreign GDP Δy_t^f can be interpreted as an indicator for trading partners' productivity growth. Growth in public spending relative to growth in GDP is also explicitly included. It follows that an increase in public spending can contribute directly to a real appreciation in the short run, in addition to the possibly indirect effect via an increase in prices for s-goods. It has also been possible to establish a relationship between changes in the real exchange rate and the real interest rate differential (instead of the nominal interest rate differential) in the short term. Annual interest rates are quarterlised by dividing them by four, for simplicity.

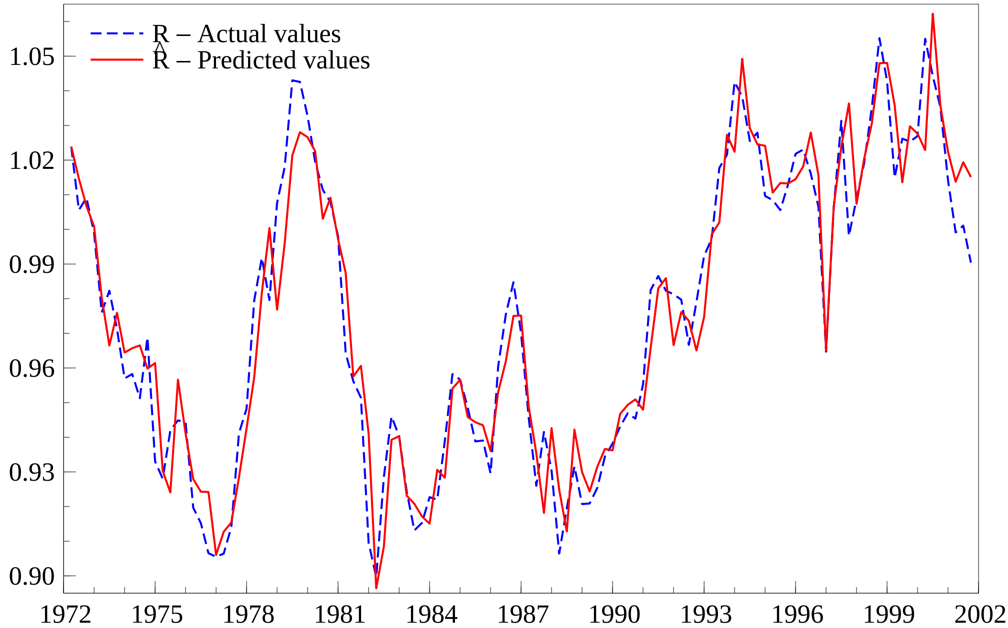

Figure 5: *The dynamic model's explanatory capacity over the estimation period 1972:3–2001:4. The predicted values are represented by the continuous curve.*

Figure 5 shows that the model's explanatory power is relatively good over the estimation period. The figure displays actual movements in the real exchange rate, the predictions from model (6) at historical values of the explanatory variables. We note that the model does not lead to systematic over or under prediction of the actual values.

Statistical tests suggest that the dynamic model gives a quite satisfactory description of actual movements in the real exchange rate, see Table 2.

The dynamic model can be used to study deviations from equilibrium as a result of continual changes in the different explanatory variables. As an illustration, we look at the (direct) effect on the real exchange rate of growth in public spending over the next thirty years. We assume

Table 2: Statistical evaluation of the dynamic model of the real exchange rate

Properties	
R^2	0.46
$\widehat{\sigma}$	1.2 %
RESET $F(1,\ 108)$	0.03 [0.87]
ARCH 4: $F_{arch,1-4}(4,\ 101)$	0.17 [0.95]
AR 1-5: $F_{ar,1-5}(5,\ 104)$	0.67 [0.65]
Normality: $\chi^2_{nd}(2)$	3.83 [0.15]
Heterosc.: $F_{\mathrm{Xi}^2}(16,\ 92)$	0.65 [0.83]
Heterosc.: $F_{\mathrm{XiXj}},(37,\ 71)$	0.79 [0.78]

Note: See Doornik and Hendry (2001) and references therein for a more detailed description of the different tests.

that public spending relative to GDP grows at the same rate as the structural budget deficit in relation to mainland GDP, see National Budget for 2003. Growth in public spending relative to GDP is specified in Figure 6. As we assume that the budget deficit in its entirety is due to the growth in public spending, public spending as a share of GDP increases by around 6 per cent over the course of the next thirty years.

Figure 7 shows the partial effect on the real exchange rate of the growth in public spending outlined above. It appears that the immediate real appreciation is 0.3 per cent and that after four years, the real appreciation is 0.4 per cent. The real appreciation then slows gradually to zero in the long run.

This may be less than the total effect of growth in public spending. In order to calculate the total effect of growth in public spending, the indirect effect of the growth through e.g. higher prices on s-goods relative to c-goods must also be taken into account.

4. The fundamental equilibrium exch. rate (FEER)

An equilibrium exchange rate that is consistent with internal and external balance can also be derived with the help of a simple model of export and import of traditional goods and services. The implied equilibrium exchange rate can be termed FEER in this case, see e.g. Akram et al. (2003) for a discussion of the FEER approach. The model presented in section 4.1 takes into account the fact that positive net foreign assets generate revenues that can finance a part of import expenditures. It appears that FEER generally is a variable equilibrium exchange rate, but that it can be constant or converge towards a constant level in the long run under some not unreasonable conditions, cf. PPP and BEER approaches. The underlying assumption and empirical results are presented in section 4.2. In this section, we particularly investigate whether

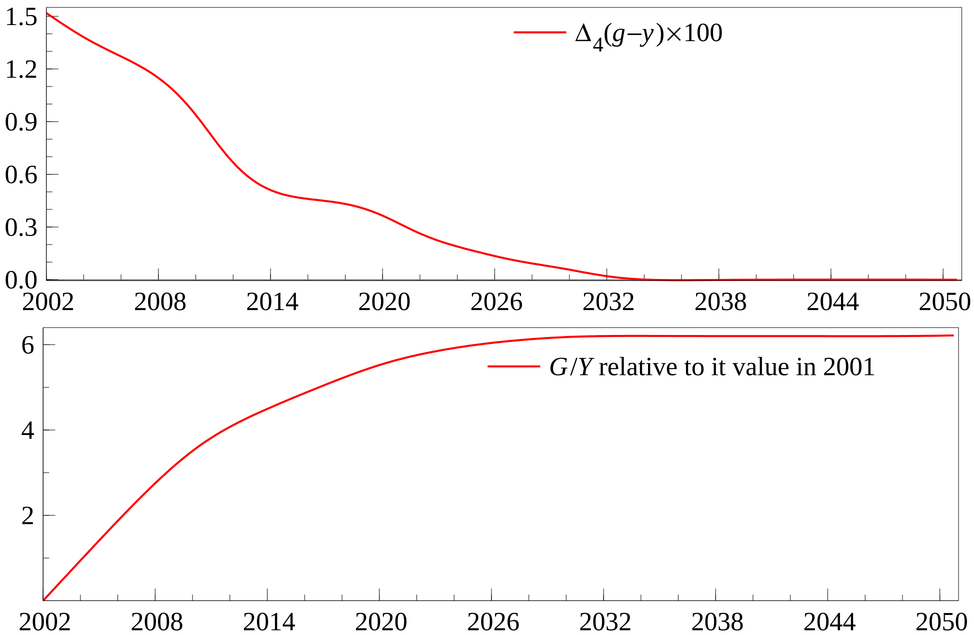

Figure 6: *Changes in public expenditure (public consumption and gross public investment) relative to GDP in the period 2002:1–2050:4. Top: annual growth in public expenditure relative to GDP. Bottom: public expenditure as a share of GDP, measured in relation to the level in 2001.*

Norway's relatively large petroleum wealth justifies a permanently strong real exchange rate.

4.1. Theoretical derivation

Let us assume that the import volume (B) measured in terms of domestic product units increases with the income level in the home country (Y) and the strength of the real exchange rate (R; low values of R indicate a strong real exchange rate). Such an import function can be expressed by equation (7):

$$B = Y^{\beta_1} R^{-\alpha_1}, \tag{7}$$

where the Greek letters are constant parameters with positive values. β_1 represents the income elasticity of import and $-\alpha_1$ denotes the price elasticity of import, i.e. sensitivity to changes in the real exchange rate.

Similarly, the home country's export volume (A) in terms of domestic product units is assumed to increase with the income level abroad Y_f but fall with the strength of the real exchange rate,

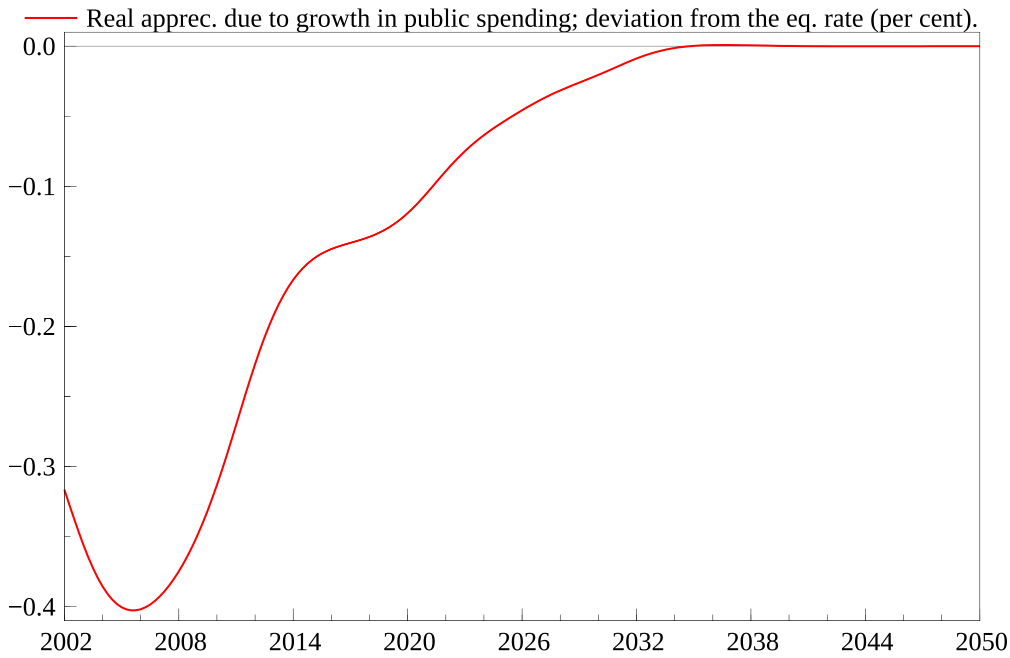

Figure 7: *Real appreciation in per cent as a result of growth in public expenditure, as specified in Chart 6. Real appreciation: percentage difference in relation to equilibrium exchange rate.*

as expressed by the export function (8):

$$A = Y_f^{\beta_2} R^{\alpha_2}. \tag{8}$$

Here, β_2 and α_2 denote the income elasticity and price elasticity of export, respectively.

The trade deficit (TD) can then be expressed as a function of domestic and foreign income and the real exchange rate. By inserting the import and export functions in the definition of the trade deficit, we get:

$$TD \equiv B - A = Y^{\beta_1} R^{-\alpha_1} - Y_f^{\beta_2} R^{\alpha_2}. \tag{9}$$

The import and export functions entails that the trade deficit increases with the domestic income level, but falls when the real exchange rate weakens and income level abroad rises.

Equation (9) implies a unique negative relationship between the trade deficit and the real exchange rate for given values of domestic and foreign income. It can therefore be used to find the real exchange rate that is compatible with a given level of the trade deficit (for given values of domestic and foreign income).

This possibility can be expressed more explicitly by inverting equation (9) and solving it with respect to R:

$$R = \left[\frac{Y^{\beta_1}}{Y_f^{\beta_2}} \left(1 - \frac{TD}{B} \right) \right]^{1/(\alpha_1 + \alpha_2)} . \tag{10}$$

This relationship indicates that the real exchange rate must depreciate when domestic income rises in order to offset the increase in the trade deficit caused by higher import, see equations (9) and (7). Similarly, the real exchange rate must appreciate when foreign income increases, so that the trade deficit does not fall as a result of higher export, see equations (9) and (8). The net effect on the real exchange rate will depend on the evolution of income-determined import demand Y^{β_1} relative to income-determined export demand $Y_f^{\beta_2}$, i.e. the evolution of $Y^{\beta_1}/Y_f^{\beta_2}$. This ratio can be interpreted as the income-determined trade deficit. The term for the real exchange rate also implies that the real exchange rate is stronger in the case of trade deficit ($TD > 0$), than in the case of trade balance ($TD = 0$), or trade surplus ($TD < 0$).

The fundamental equilibrium exchange rate (FEER) can be defined as the real exchange rate level that results when there is internal and external balance, i.e. trade deficit and domestic and foreign income levels are at their equilibrium levels, PI, $\overline{Y}$ and $\overline{Y}_f$ respectively. In other words,

$$FEER = \left[\frac{\overline{Y}^{\beta_1}}{\overline{Y}_f^{\beta_2}} \left(1 - \frac{PI}{B} \right) \right]^{1/(\alpha_1 + \alpha_2)} . \tag{11}$$

$\overline{Y}$ and $\overline{Y}_f$ can be assumed to be equal to potential GDP in the home country and abroad, while the trade deficit can be said to be at its equilibrium level (PI) when it can be financed without accumulating foreign assets or debt (external balance). This would be the case if the trade deficit is financed by the return on net foreign assets, i.e. if PI equals the permanent income from net foreign assets. External balance requires that the trade deficit is equal to zero ($TD = 0$) if there is no income from net foreign assets, i.e. PI = 0. Import expenditures then would have to be covered solely by export income.

It is worth noting that it is not the level of permanent income from net foreign assets (PI) itself that is of importance to the real exchange rate, but the share of import that can be financed by the permanent income. When there is external balance, PI/B (which is equal to $(B-A)/B$) can be interpreted as the share of import that is financed by the permanent income, whereas $(1-PI/B)$ can be seen as the share of import that is financed by export. The greater PI/B is, the stronger the equilibrium exchange rate can be, see equation (11).

4.1.1. Is FEER a variable or constant equilibrium exchange rate?

FEER is generally a variable equilibrium exchange rate. This is because the income-determined trade deficit $\overline{Y}^{\beta_1}/\overline{Y}_f^{\beta_2}$ can change over time if trend growth in the home country and abroad differ, or import's income elasticity differs from export's income elasticity. Moreover, the permanent income (PI), and thereby also the sustainable level of the trade deficit, can be revised as a result of changes in net foreign assets or the rate of return on such. In addition, import and export can become more sensitive to changes in the real exchange rate, for example, as a result of increased globalisation. In this case, α_1 and α_2 can increase and thus influence the equilibrium exchange rate.

FEER can also weaken over time even though $\overline{Y}^{\beta_1}/\overline{Y}_f^{\beta_2}$ and PI remain unchanged. This is because import demand will increase over time as a result of economic growth at home. The import share that can be financed by permanent income (PI/B) will thus diminish steadily. In order to keep the trade deficit equal to permanent income, the real exchange rate has to depreciate steadily to slow import and boost export.

FEER can, however, be constant in the long run if $\overline{Y}^{\beta_1}/\overline{Y}_f^{\beta_2}$ remains unchanged over time. This is because PI/B may become insignificant in the long run, i.e. $PI/B \longrightarrow 0$, if import demand continues to grow. The bulk of import will then have to be financed by export. This could happen even if permanent income is revised upwards over time, as long as import increases at a higher rate than the permanent income. Thus the FEER level for $PI > 0$ will converge towards the FEER for PI = 0, which balances trade with other countries. It could also be said that in the long run, FEER is not dependent on the level of permanent income and hence on a given stock of net foreign assets. In summary:

$$FEER \longrightarrow \left[\frac{\overline{Y}^{\beta_1}}{\overline{Y}_f^{\beta_2}}\right]^{1/(\alpha_1+\alpha_2)} \quad \text{as } \frac{PI}{B} \longrightarrow 0 \text{ if } \Delta\overline{y}_t > 0.$$

This also implies that changes in permanent income are of more importance to FEER in the short run (when B is small) than in the long run (when B is large). The equilibrium exchange rate that balances foreign trade will depend positively on the equilibrium income-determined trade deficit: $\overline{Y}^{\beta_1}/\overline{Y_f}^{\beta_2}$. The higher the import level is relative to the export level, the weaker the equilibrium exchange rate will have to be in order to achieve trade balance.

FEER will equal 1, as in the theory of absolute purchasing power parity, if import and/or export are extremely sensitive to changes in the real exchange rate:

$$FEER \longrightarrow 1 \text{ if } (\alpha_1+\alpha_2) \longrightarrow \infty.$$

In such cases, the equilibrium exchange rate will neither depend on permanent income nor on income at home and abroad. This can be explained by the fact that an arbitrary trade deficit can be achieved and sustained with the help of minor changes in the real exchange rate when price elasticity is extreme. If, for example, the domestic income level becomes much higher than in other countries, the real exchange rate only needs to depreciate marginally in order to offset the income effect on import so that the trade deficit does not exceed *PI*.

4.2. FEER and foreign trade in equilibrium

This section presents paths for the equilibrium exchange rate, FEER, based on simulations to the year 2070. The simulations are based on empirical models of Norwegian import and export of traditional goods and services that have been derived for this purpose. The empirical models are documented and evaluated in more detail in Akram (2003). Here we will therefore just specify variables that have been used to derive these models, briefly discuss their behaviour over the sample period and present our estimates of key parameters. Internal and external balance is then specified and we derive the equilibrium exchange rate that is consistent with this specification. In addition, the equilibrium exchange rate that balances trade of traditional goods and services with other countries is also derived. A path for FEER depends on the permanent income from Norway's net foreign assets, which are assumed to only constitute Norway's petroleum wealth in the form of oil reserves in seabed and the Norwegian Petroleum Fund. In addition, paths for FEER depend on the economic growth rate at home and abroad. We illustrate this dependency by deriving several paths for FEER by changing our assumptions regarding the size of permanent income and the growth rate.

4.2.1. Assumptions

Import (B) and export (A) here mean the import and export of traditional goods and services measured in NOK billion at fixed 1999 prices. These are explained by the trade-weighted real exchange rate (R) that was defined above, mainland GDP (Y) and trading partners' GDP Y_f. We have used quarterly data for the period 1979:1–2001:4 to estimate dynamic econometric models of import and export in line with the functions (7) and (8). The time series of import, export and the trade deficit over the estimation period are presented in Figure 8 while that of the real exchange rate is presented in Figure 1.

Figure 8 suggests that the import and export volumes (of traditional goods and services) grew more or less continuously in the period 1979–2001. Measured as a share of mainland GDP, import and export have also generally expanded over time. However, import has grown at a swifter pace than export, thus increasing the trade deficit (TD) over time.

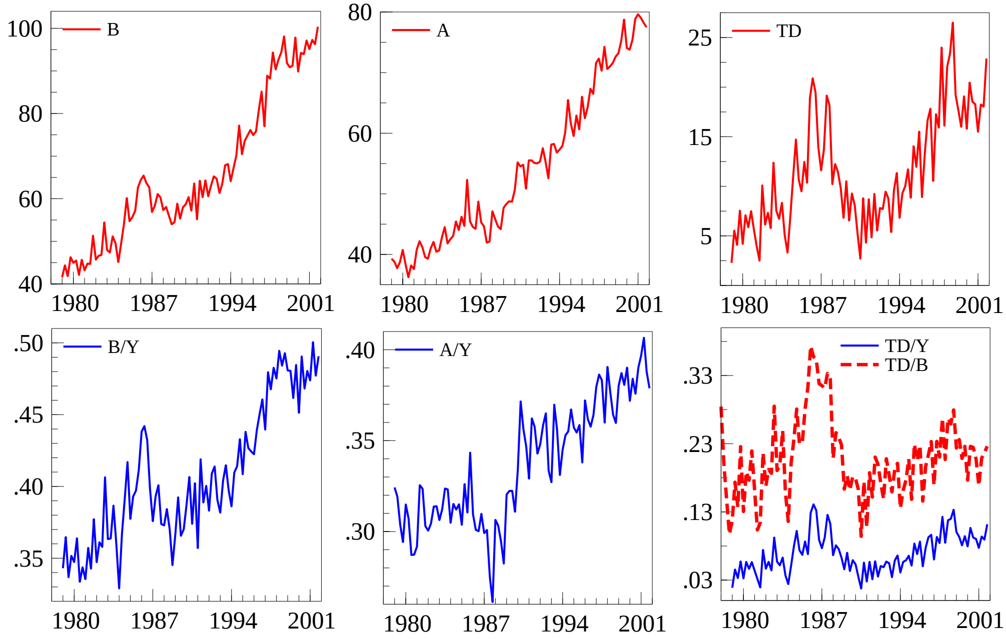

Figure 8: *Import (B) and export (A) of traditional goods and services in the period 1979:1–2001:4. Top row: quarterly data for import, export and the trade deficit (TD) measured in NOK billions at fixed 1999 prices. Bottom row: import, export and the trade deficit measured as a share of Norwegian mainland GDP (Y). The trade deficit is also measured as a share of import, TD/B. The time series of TD/B characterises the evolution over time of the import share that is not financed by (current) export.*

Table 3.A presents our estimates of the income and price elasticities, 1.5 and 0.7 (in absolute values), respectively, which are comparable with estimates from other Norwegian and international studies, see Hinkle and Montiel (1999, p. 355, 475, and 489), Goldstein and Khan (1985), Marquez (1990) and Clarida (1996) for an overview of estimates based on a large number of extensive studies. We also note that our estimates indicate symmetry in income and price elasticities: $\beta_1 = \beta_2$ and $\alpha_1 = \alpha_2$, which is supported by formal tests. It is also interesting to note that this property as well as both the size of income and price elasticities are the same as those presented in Houthakker and Magee (1969) for Norway, who used annual data from the period 1951–1966. This indicates that income and price elasticities of foreign trade have been fairly stable over time.

However, income elasticities that are greater than 1 imply increasing GDP shares for import and export over time, if the real exchange rate is constant or the price elasticities are sufficiently low. Such increases in GDP shares of import and export over time seem to be in line with actual developments in Norway, at least over the past 50 years, cf. Figure 8 and the results in Houthakker and Magee (1969). One explanation could be that import and export both contain factor inputs in contrast to the income measures, mainland GDP in Norway and trading partners' GDP, which measure value added. Hence, an increasing GDP share does not necessarily imply that the GDP share of import adjusted for inputs will also increase. Beside this, when making simulations far into the future, we experienced that the variability of the (equilibrium) real exchange rate and the size of our estimates of price (and income) elasticities prevent GDP shares for import and export from becoming unreasonably large, at least in the short and medium term, i.e. over a time period of about forty years, see next section. Given that we are primarily interested in the near future, we found it unnecessary to adjust our estimates of the income and or price elasticities.

Table 3: Assumptions underlying the basic FEER path

A. Estimates of income and price elasticities

Parameters:	β_1	β_2	α_2	α_2
Estimates:	1.5	1.5	0.7	0.7
Sample period:	1979:1–2001:4			

B. Equilibrium correction models of foreign trade

$$\Delta\widehat{b}_t = \underset{(-2.68)}{-1.14} - \underset{(-2.69)}{0.17}\ [b-(1.5y-0.7r)]_{t-1} + \text{ short run effects}$$

$$\Delta\widehat{a}_t = \underset{(3.23)}{2.81} - \underset{(-3.22)}{0.25}\ [a-(1.5y_f+0.7r)]_{t-1} + \text{ short run effects}$$

Estimation method: FIML

C. Internal and external balance

Trend growth: $\Delta_4\bar{y} = \Delta_4\bar{y}^f = 2$ %; 0.5 % per quarter

Trade deficit: $\overline{TD} = PI = 105$ Bill. NOK/year; 105/4 = 26.25 Bill. NOK/quarters

Note: Trend growth rates for Norway and abroad are approximately equal to the corresponding sample averages. The estimate of NOK 105 billion for permanent income is based on the National Budget for 2003. This is equivalent to 4 per cent of the current value of petroleum wealth (government's share), which is NOK 2616 billion, of which NOK 619 billion is the market value of the Government Petroleum Fund at start-2002. The remainder (NOK 2000 billion) is the current value of the estimated value of the government's share of cash flow from oil and gas production to 2070, when all resources are assumed to be depleted/depreciated. The discount rate and real rate of return are assumed to be equal to 4 per cent per annum.

Table 3.B presents a simplified version of our estimated model of import and export of traditional goods and services which is in log-linear form. We employ this model to derive paths for FEER conditional on different specifications of the state of internal and external balance. This model has fairly good explanatory power over the sample period, despite the fact that it is based on a limited information set determined by the theoretical framework outlined in the previous section. The model has also satisfactory statistical properties, which suggests that it is not obviously misspecified, see Akram (2003) for a comprehensive documentation.

Table 3.C specifies the assumptions regarding internal and external balance. Internal balance is characterised by mainland GDP in Norway and GDP in trading partner countries growing at a trend growth rate of 0.5 per cent per quarter (2 per cent per year). External balance is specified by equating the (quarterly) trade deficit to the permanent income from Norway's net foreign assets at each point in time. Net foreign assets have been set equal to the estimated current net value of total petroleum wealth, which consists of the current net value of the estimated petroleum resources in the seabed and the market value of the Norwegian Petroleum Fund at the end of 2001. The implied permanent income (PI) is estimated at NOK 105 billion per annum, see National Budget 2003. We have chosen to disregard other net foreign assets, as total net foreign assets for Norway have largely comprised petroleum wealth, particularly from the mid-1990s, see Akram (2003) for further details.

4.2.2. FEER and foreign trade in the period 2002–2070

Figure 9 shows paths of the equilibrium exchange rate when trade deficit is financed by the permanent income from petroleum wealth and if we had required trade balance in absence of revenues from petroleum wealth and other net foreign assets. Figure 10 shows movements in import, export and the trade deficit that are consistent with the equilibrium exchange rate, in the former case. The paths of these variables are not only interesting in themselves, but they also cast light on the mechanisms underlying the behaviour of the equilibrium exchange rate over time.

The equilibrium exchange rate conditional on the permanent income is relatively strong in the first few years, but then weakens over time. It moves from values of around 0.90 to 0.95 in the period 2002–2010, but is 1.10 by end–2070. Most of the depreciation occurs in the course of the first 35 years, as the rate of depreciation is greater in the short run than in the long run. Interestingly, the figure suggests that the actual exchange rate in 2002 was at the same level as the estimated equilibrium exchange rate for this period, see Figure 1.

The depreciation of the equilibrium exchange rate over time reflects an increase in the import level relative to permanent income due to economic growth. Figure 10.b shows that permanent income can finance 25 per cent of import in 2002, but that this share declines in line with growth in import and moves towards zero in the long run. After 2035, permanent income can only finance under 10 per cent of import demand. As a share of mainland GDP, permanent income amounts to 13 per cent in 2002 but falls to less than 7 per cent after 2035. Steadily higher export has to compensate for the diminishing importance of permanent income as a (possible) financing source for import in order to ensure external balance. This is brought about via a depreciation in the equilibrium exchange rate as shown in Figure 9.

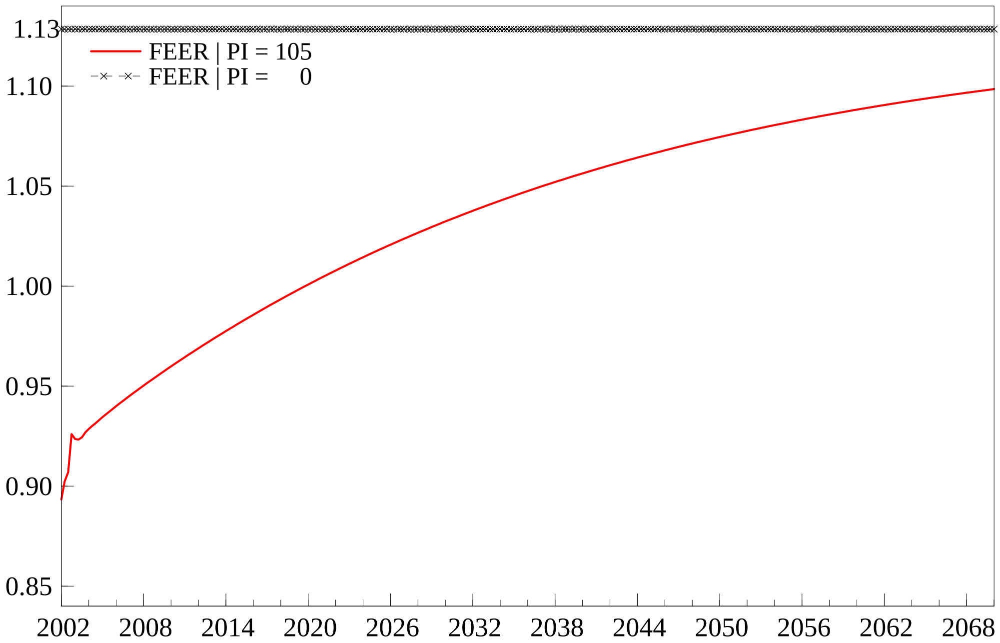

Figure 9: *Fundamental equilibrium exchange rate (FEER) in the period 2002:1– 2070:4. The continuous rising curve plots FEER when the trade deficit equals permanent income at NOK 105 billion, i.e. 26.25 (=105/4) billions per quarter. The straight curve represents FEER when external balance is defined as trade balance at each point in time, i.e. PI = 0.*

In the long run, the equilibrium exchange rate is more or less the same as the level that achieves trade balance where nearly all import is financed by export. Figure 9 shows that the equilibrium exchange rate for a permanent income level of NOK 105 billion per year converges toward the equilibrium exchange rate for trade balance, which is roughly 1.13.[7] This indicates that the Norwegian real exchange rate must depreciate considerably from the level at the start of 2002, for example, if import of traditional goods and services is to be financed solely by export of traditional goods and services.

Figure 10 also depicts the effects of changes in the equilibrium exchange rate on import and export. Figure 10.a shows the annual growth in import. Trend growth of 2 per cent per year contributes partially to import growth of 3 (= 1.5×2) per cent. The depreciation of the equilibrium exchange rate, however, implies that import growth remains under 3 per cent over the whole simulation period. Figure 10.c shows that export expands faster than import, which is a result of the depreciation in the equilibrium exchange rate. The growth differential is less than 1

[7] In general, the estimate of the equilibrium exchange rate depends on the level of the income-determined trade deficit. A number of simulations, however, suggested that reasonable changes in the income-determined trade deficit at the end of 2001, do not lead to numerically large deviations from 1,13, see Akram (2003).

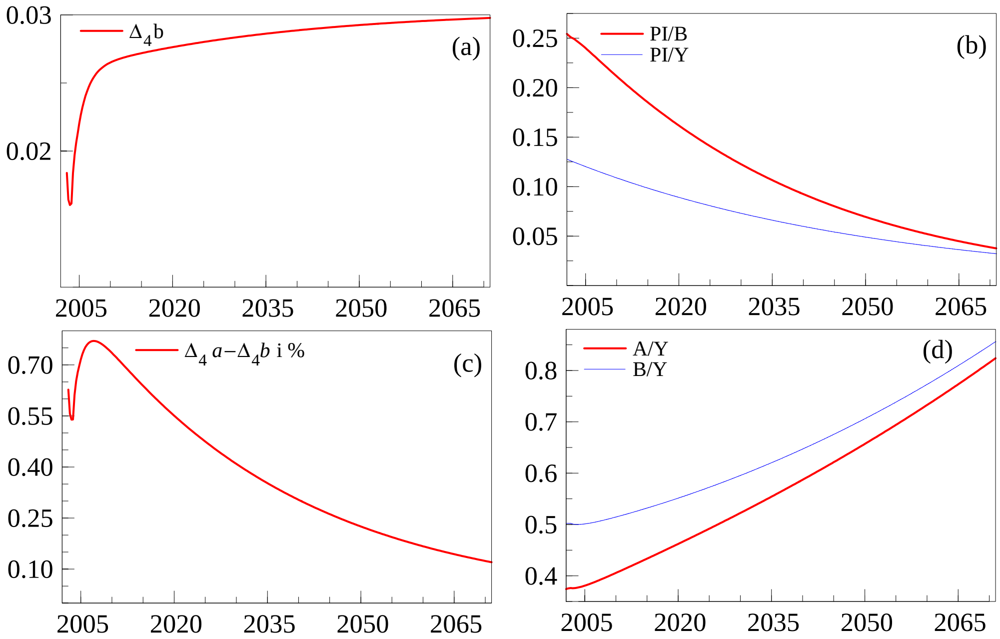

Figure 10: *Paths of import and export that are consistent with FEER|PI = 105 in the period 2002:1–2070:4. (a): annual growth in import $\Delta_4 b$; (b) import share financed by permanent income (PI/B) and trade deficit relative to mainland GDP (PI/Y); (c) percentage growth differential between import and export per year $\Delta_4 b - \Delta_4 a$ and (d) paths of import and export shares relative to mainland GDP, B/Y and A/Y, respectively.*

per cent per year over the whole simulation period and slows in line with the decline in the rate of depreciation. Equal trend growth in Norway and abroad means that export and import grow at same rate in the long term, when the rate of depreciation has become zero. Figure 10.d shows that export as a share of mainland GDP grows more rapidly than the corresponding import share. This means that the initial trade deficit of 13 per cent relative to mainland GDP, which is covered by permanent income, diminishes over time. We see that the export share converges towards the import share in the long run. These shares expand over time as a result of income elasticities that are greater than 1. Growth in the import share is, however, curbed by the depreciation in the equilibrium exchange rate, particularly at the start of the simulation period. This means that the import share only increases from 50 per cent to 55 per cent in the period 2002–2020 and in 2035 is still no higher than 60 per cent. The income effect has a full impact in the long run when the equilibrium exchange rate becomes constant.

4.2.3. Importance of petroleum revenues

Figure 11 shows alternative paths for FEER for the period 2002:1–2070:4. The paths are derived for a permanent income equal to NOK 120, 105 and 90 billion per year, based on oil prices of 20, 17 and 14 dollars, respectively, from 2005 to the end of 2070. It also shows the equilibrium exchange rate conditional on balanced trade, i.e. permanent income of zero. All paths are based on the assumption of annual trend growth of 2 per cent in Norway and abroad.

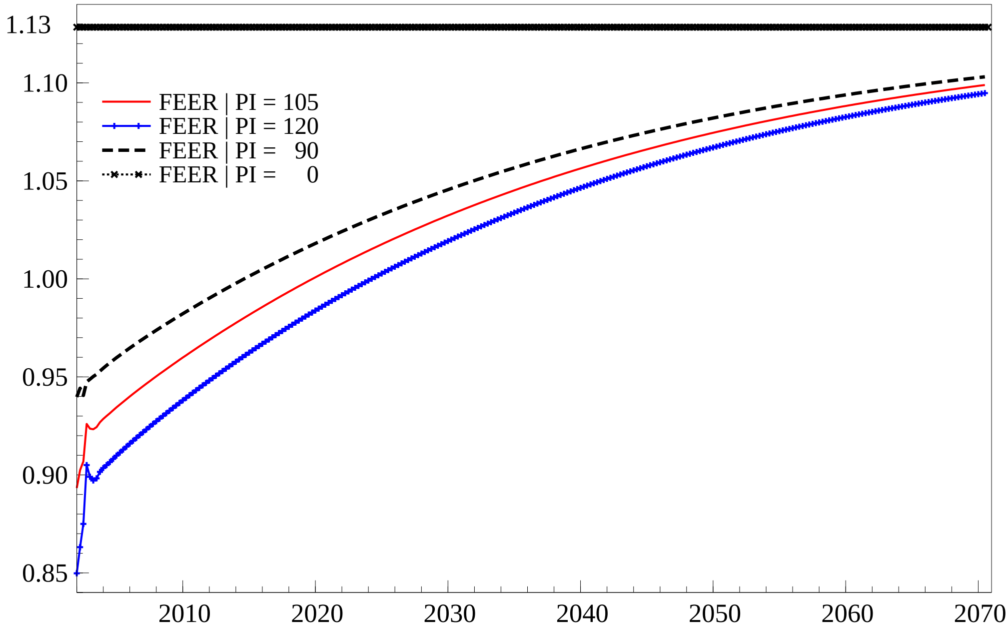

Figure 11: *FEER paths for different values of permanent income (PI), when trend growth in Norway and trading partner countries is assumed to equal 2 per cent per year. The continuous curve in the middle plots the path for FEER when PI equals 105 (NOK billion per year). The lower curve is FEER when PI = 120 and the upper curve is FEER when PI = 90. The straight curve at the top of the chart shows FEER when PI = 0, i.e. when trade balance is enforced.*

An increase in permanent income entails a stronger FEER than would otherwise have been the case over the whole simulation horizon. Higher permanent income is synonymous to a higher sustainable level for the trade deficit, so that FEER has to be stronger in order to bring the trade deficit to the sustainable level. All else being equal, the import share that can be financed with permanent income increases over the whole time horizon. We see that an increase of NOK 25 billion per in year in permanent income or NOK 6.25 billion per quarter serves to strengthen the equilibrium exchange rate immediately by around 5 per cent, from 0.89 to 0.85. A corresponding reduction in permanent income serves to weaken the equilibrium exchange rate by around the same amount, as FEER weakens from 0.89 to 0.94. This suggests an immediate appreciation (depreciation) in the equilibrium exchange rate of 0.8 per cent per NOK billion increase (fall) in permanent income.

Changes in permanent income are of greater importance to FEER in the short run than in the long run, as the importance of permanent income diminishes over time due to growth in import demand. The figure shows that the difference between the various paths for FEER becomes increasingly smaller over time. Thus, in the long run, FEER does not depend on the level of permanent income. Figure 11 indicates that the different FEER paths converge towards the FEER level for permanent income equals zero. In the short and medium term, changes in the level of permanent income may, however, have a considerable effect on FEER.

4.2.4. Importance of economic growth

FEER is constant in the long run if trend growth in the home country and abroad is the same. This long-term level is not only independent of permanent income, but is also independent of the rate of trend growth. The speed with which FEER converges towards this level is, however, influenced by the growth rate as this determines how rapidly import expands relative to permanent income. Growth in import also depends on the income elasticity of import. The higher income growth and/or sensitivity to income is, the faster permanent income will become insignificant in relation to import demand and the faster FEER will fall in order to increase export and curb import growth, so that external balance can be maintained.

Figure 12 shows movements in FEER, conditional on four different trend growth rates that are assumed to be the same in Norway and abroad. This means that income-determined growth in import and export will be equal. Permanent income is assumed to be NOK 105 billion per year in all cases. The speed with which convergence towards long-term equilibrium occurs can be measured by calculating the half-life (H), which indicates how rapidly the difference between the initial value of FEER (here 0.89) and the long-term level of FEER (1.13) is halved, i.e. when the value of 1.01 is achieved. The half-life can be used as a measure of how swiftly Norway must balance its foreign trade without petroleum revenues.

The figure suggests a strongly negative relationship between the growth rate and the half-life. The half-life increase from 20 to 45 years if the growth rate becomes 1 per cent instead of 2 per cent per year. If the growth rate doubles from 2 to 4 per cent per year, the half-life becomes only 8 years. However, if the economy and import do not grow, a fixed import share can be financed indefinitely by permanent income. In this case, FEER remains at its 2002 level and the half-life is infinite. In other words, in order to achieve a permanent appreciation, we have to assume that import demand does not grow over time, so that the import share that is financed by petroleum revenues remains unchanged over time.

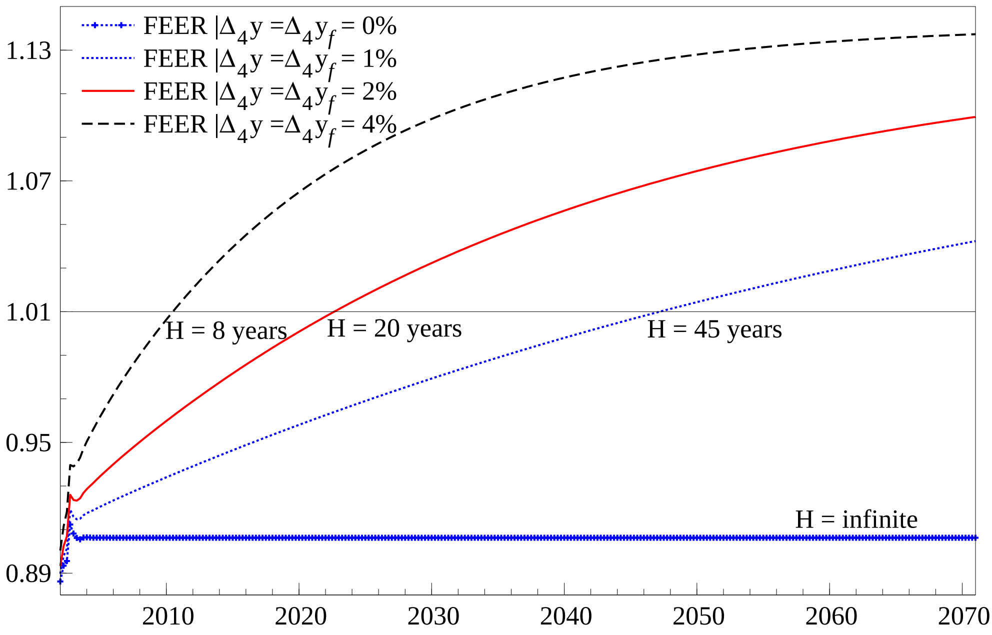

Figure 12: *FEER paths for different growth rates, when the trade deficit equals permanent income at NOK 105 billion per year. It is also assumed that trend growth in Norway and abroad is the same. H denotes the half-life, i.e. how rapidly FEER converges towards its long-term level, the level where the import share that can be financed by permanent income becomes insignificant.*

Changes in the income elasticity of import and export over time will have the same qualitative effect on the half-life as changes in growth rates. A decline in income elasticity will lengthen the half-life, whereas an increase will shorten the half-life, ceteris paribus.

5. Conclusions

We have used the PPP, BEER and FEER approaches to describe and explain movements in the Norwegian real exchange rate and to calculate its equilibrium value. A summary of our findings is given below.

Movements in the Norwegian real exchange rate comply well with predictions based on the theory of purchasing power parity (PPP). The real exchange rate has fluctuated around its estimated equilibrium level, which appears to have remained stable over time. The Norwegian real exchange rate has also shown a tendency to converge relatively rapidly towards the equilibrium level. A given deviation from the equilibrium level is halved in the course of 5–6 quarters, all else being equal. Deviations from equilibrium are eliminated through changes in the nominal exchange rate and prices, where the contribution of nominal exchange rate dominates. There is little to indicate that the contributions of the nominal exchange rate and prices have changed relative to each other, or that either has diminished in the last decade relative to their sizes in the 1970s and 80s, in fact, rather to the contrary. Exchange rates are, however, constantly exposed to shocks so that a move towards the equilibrium level may be reversed. The real exchange rate may therefore deviate from its equilibrium level for a longer period of time than implied by purely partial analyses. By identifying which shocks/variables that are affecting the real exchange rate, it is possible to get a better indication of how persistent a deviation can be. It can also be argued that the equilibrium level of the real exchange rate can be constant for reasons other than those given by the theory of purchasing power parity. By identifying these, it is possible to gain insight into which conditions determine the actual level of the equilibrium exchange rate. The BEER approach allows one to take such considerations into account.

The behavioural equilibrium real exchange rate (BEER) approach explains movements in the Norwegian real exchange rate in the long run using the following variables: the difference between relative prices for n and t-products between Norway and its trading partners, the real oil price and the share of investment in GDP. The equilibrium real exchange rate in the long run has been estimated by making assumptions about the equilibrium levels of these variables. Implicitly, the real exchange rate may deviate from its equilibrium level partly because these variables may deviate from their equilibrium levels. As such deviations are assumed to be temporary, deviations from the equilibrium exchange rate will also be temporary. Other variables that influence the real exchange rate in the short and medium term include the interest rate differential between Norway and its trading partners and growth in public spending in Norway. We have demonstrated that the real exchange rate may be stronger than its equilibrium level for a long period as a result of planned growth in public expenditures in the period ahead. In the short run, we have also observed a tendency for the real exchange rate to continue moving in one direction or the other, even when the shock that caused the initial movement has dissipated.

As regards the fundamental equilibrium exchange rate (FEER) approach, we first derived the FEER with the help of a simple theoretical model for the import and export of traditional goods and services, where it was taken into account that a trade deficit can be sustained with revenues (permanent income) from positive net foreign assets. The empirical analysis was carried out on the basis of this model. Permanent income from net foreign assets was set equal to estimated revenues from Norway's total petroleum wealth in the form of petroleum reserves in the seabed and the Norwegian Petroleum Fund. The empirical analysis showed, among other things, that FEER generally is variable. It has a tendency to weaken over time, even when the income flow from net foreign assets, i.e. permanent income from total petroleum wealth, remains unchanged.

This is because import demand increases over time due to economic growth. Thus the import share that can be financed by permanent income declines steadily. In order to ensure that the trade deficit equals permanent income, the real exchange rate has to depreciate steadily to slow import and boost export. Sufficiently far into the future, the import share that can be financed by permanent income becomes insignificant. Import is then largely financed by export and the equilibrium exchange rate is the same as when permanent income equals zero, i.e. when trade balance is enforced. This equilibrium level will be constant if trend growth in the home country and abroad is constant. The path of FEER over time depends on the sustainable level of the trade deficit and the growth rate at home and abroad. An increase in permanent income, that is as a result of, for example, higher oil prices serves to strengthen FEER more than would otherwise be the case over the whole simulation horizon. Changes in permanent income are, however, of more importance to FEER in the short run than in the long run, as the importance of permanent income diminishes over time. The more rapidly the economy grows, the faster permanent income will become insignificant relative to the size of the growing import level and the sooner Norway will have to balance its foreign trade without petroleum revenues. It is also shown that a permanent appreciation would require that import does not grow over time, so that the import share that is financed by oil revenues remains unchanged over time.

Both the PPP and the BEER approaches suggest an equilibrium exchange rate that is weaker than the observed real exchange rate in 2002. The PPP approach implies an equilibrium exchange rate of 0.975, whereas the BEER approach implies 1.03 conditional on our specification of internal and external balance. The FEER level in 2002 is, however, on a par with the actual exchange rate that year, but depreciates over time and converges towards 1.13 which balances foreign trade with traditional goods and services. However, the different point estimates should be interpreted as being indicative as there is considerable uncertainty attached to the model specifications, parameter estimates and the assumed equilibrium values of the explanatory variables.

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Chapter 5 – How does the exchange rate react to a cost-push shock?

Øistein Røisland and Tommy Sveen

This article analyses how the nominal exchange rate reacts to cost-push shocks. Generally, the effect is uncertain as it depends on how the central bank reacts. The more weight the central bank places on price stability and the steeper prices are, the more likely it is that a cost-push shock will result in a nominal appreciation. With flexible inflation targeting, a cost-push shock is most likely to result in an appreciation in the short term, unless confidence in the central bank deteriorates at the same time.

1. Introduction

The exchange rate is an "asset price" and the price of currency in the market is based on supply and demand. Foreign exchange transactions may be the result of international trade in goods and services. However, the bulk of foreign exchange transactions occur as a result of adjustments in the currency composition of assets and liabilities.

The exchange rate is determined by a large number of factors. In this article we will look at a particular type of disturbance - or shock - that may be of importance to the exchange rate, cost-push shocks. A cost-push shock is defined as a change in inflation that is not a result of pressures in the economy.[1] The wage settlement in 2002 is an example of such a cost-push shock. The final wage settlement was far more expansive than estimated by most forecasters one year earlier.

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[1]We focus on temporary changes in the economy that translate into temporary changes in the rate of inflation.

In order to analyse the effect of a cost-push shock on the exchange rate, we will differentiate between direct and indirect effects. The direct effect can be defined as the effect a cost-push shock would have if monetary policy had not reacted to the shock. The indirect effect comes via the central bank's response. To analyse these effects, we need a model. This model is presented in section 2, whereas in section 3 we discuss the effect of a cost-push shock both in general and with the help of simulations in our model.

2. A simple model

We have assumed that there is an inflation target for monetary policy and that the policy can be represented by the central bank minimising the following loss function:

$$L_t = E_t\left\{\sum_{k=0}^{\infty} \beta^k\left[\left(\pi_{t+k} - \pi^*\right)^2 + \lambda y_{t+k}^2\right]\right\} \tag{1}$$

where π and π^* are the current rate of inflation and the inflation target, respectively, y is the output gap – discrepancy between actual production and production capacity, β is a discount factor and λ measures the importance the central bank attaches to stable production in relation to stable inflation.

Our starting point is a simple model for a small open economy developed by Laurence Ball.[2] It comprises three equations in addition to a measurement function for monetary policy:

$$y_t = -\beta_r r_{t-1} + \beta_e e_{t-1} + \beta_y y_{t-1} + \varepsilon_t \tag{2}$$

$$\pi_t = \pi_{t-1} + \alpha_y y_{t-1} + \alpha_e\left(e_{t-1} - e_{t-2}\right) + \eta_t \tag{3}$$

$$e_t = -\theta_r\left(r_t - r_t^*\right) + \nu_t\,, \tag{4}$$

where r and r^* denote domestic and foreign real interest rates, i.e. nominal interest rates minus

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[2] Laurence Ball (1999), 'Policy Rules for Open Economies'. In John Taylor (ed.), *Monetary Policy Rules*

expected inflation and e is the logarithm for the real exchange rate, i.e. the price for foreign goods measured in NOK relative to the price of Norwegian goods. In addition, the variables ε, η and v are shocks (or disturbances) and the β-, α- and θ parameters are positive constants.

Equation (2) is an IS relationship for a small open economy and describes aggregate demand as a function of the real interest rate, the real exchange rate and of demand in the previous period. In addition, ε is a demand shock - that is a shock in demand in excess of that which is ascribable to the real interest rate and the real exchange rate. The period length is assumed to be one year so that a change in real interest rates or the real exchange rate translate into a change in demand with a one-year lag.

Equation (3) is a Phillips curve for an open economy. It is assumed that there is a considerable degree of persistence and that inflation will remain high unless the authorities cause it to fall. Furthermore, inflation depends on the level of activity – represented by the output gap, y. Pressure in the economy – a positive output gap – leads to higher inflation. In the first instance, high demand for goods and services results in firms increasing prices. And secondly, higher activity normally pushes up the cost level. This is because trade unions will demand higher wage increases and employers will outbid each other in the competition for labour.

Inflation is influenced by the exchange rate, as well as the level of activity. Consumer prices are a combination of prices for domestically produced and imported goods and services. Changes in the exchange rate will therefore affect consumer prices, in that prices for imported goods will change. This will in turn affect prices for domestically produced goods as a result of competition and changes in firms' costs - due to changes in prices for imported intermediate goods and changes in wages as a result of changes in consumption-based real wages.

The variable η is the cost-push shock in the model and shows the rise in inflation at a given level for the output gap and real exchange rate. This most obvious shock would be an increase in wages over and above that indicated by the activity level, but it could also be caused by an increase in international commodity prices that pushes up enterprises' production costs.

Equation (4) determines the real exchange rate. A higher real interest rate (differential) leads to a stronger real exchange rate, i.e. a real appreciation. The real exchange rate will also be affected by changes in the risk premium – which are represented by the variable v.[3]

We use the same calibration - i.e. the same values for the parameters - as Ball. The degree of persistence in the output gap (β_y) is assumed to be relatively high and is set at 0.8. This means that the half-life for a change in the output gap will be just over three years. The total effect of a 1 percentage point increase in interest rates is a 1 per cent fall in production. The effect via the real interest rate is greatest ($\beta_r = 0.6$) and the effect via the real exchange rate is somewhat weaker ($\beta_e\theta_r = 0.4$). The slope on the Phillips curve $\alpha_y = 0.4$ indicates that an increase in the output gap of one percentage point would give a 0.4 percentage point increase in inflation. It is further assumed that an appreciation of one per cent would result in a 0.2 percentage point reduction in inflation. A 1 percentage point increase in the interest rate differential is assumed to give an appreciation of $\theta_r = 2$ and thus $\beta_e = 0.2$.

We can now give the following stylised review of the effect of a 1 percentage point increase in real interest rates. Initially, the real exchange rate will appreciate by 2 per cent. One year after the rise in interest rates, production will fall by 1 per cent and inflation by 0.4 percentage point. Two years after the rise, the decline in production will result in a further fall in the rate of inflation so that the total effect after two years will be a 0.6 percentage point reduction in inflation.

3. The effect of a cost-push shock

We will now look at the effect of a cost-push shock on the exchange rate in a situation where the economy is in balance to start with. A robust result in many different models is that the central bank responds to a cost-push shock by raising real interest rates. This is also the case in the model above; the cost-push shock pushes up inflation for a given level of production. As

[3] Strictly speaking, this representation is not consistent with uncovered interest parity. In the next section we will also discuss the effect of a cost-push shock when uncovered interest parity is maintained.

long as the central bank places importance on stability in both inflation and production, it will not allow the whole effect of a cost-push shock to translate into higher inflation. Therefore, it will dampen the effect on inflation by allowing a fall in production. And for production to fall, real interest rates must be increased – in other words, the *nominal* interest rate has to increase more than the isolated effect of the cost-push shock on inflation. The central bank will follow what is called the "Taylor principle". The optimal increase in real interest rates depends on how much importance the central bank places on production stability – described here by the weight λ. The higher the weight on inflation, the more real interest rates have to be increased. Under an inflation targeting regime we would get the following results:

Result 1: *A cost-push shock would lead to higher real interest rates*

When discussing the effect on the nominal exchange rate, it is appropriate to start by looking at the effect on the *real* exchange rate. In the model described above, a 1 percentage increase in real interest rates gives a real appreciation of θ per cent. An alternative to equation (4) is uncovered interest parity, which says that the expected return will be the same between different currencies. If uncovered interest parity applies in nominal terms, it can be proved that it also applies for real variables, that is, we have the following relationship:

$$(5) \qquad e_t = E_t e_{t+1} - \left(r_t - r_t^*\right) + \nu_t ,$$

where E is an expectations operator so that $E_t\, e_{t+1}$ is the expected real exchange rate in the period t+1, given the information in period t, and the variable υ is the risk premium. Because uncovered interest parity is included in many theoretical models, we will base the following discussion on equation (5). The qualitative results are, however, the same whether we use equation (4) or (5). Finally, model simulations will be based on the original Ball model, where equation (4) is included.

If we solve equation (5) successively and at the same time assume that purchasing power parity applies in the long run, we find that the real exchange rate today can also be written as

$$(6) \qquad e_t = -E_t \left\{ \sum_{k=0}^{\infty} \left(r_{t+k} - r_{t+k}^{*} \right) - \nu_{t+k} \right\}$$

i.e. the real exchange rate today depends on expectations regarding the future path for the real interest rate differential and risk premium. Let us assume that the cost-push shock does not affect the risk premium, real interest rates abroad or expectations regarding these variables. Then we can express the immediate change in the real exchange rate resulting from a cost-push shock as follows:

$$(7) \qquad \frac{\Delta e_t}{\Delta \eta_t} = -\frac{\Delta \sum_{k=0}^{\infty} r_{t+k}}{\Delta \eta_t} < 0$$

where the sign depends on result 1 above. We then have:

Result 2: *A cost-push shock gives an immediate real appreciation*

Now we will look at the effect on the *nominal* exchange rate. Note that $e = s + p^* - p$, where s is the nominal exchange rate and p and p^* are the domestic and foreign price levels, respectively. If we keep foreign prices constant, we arrive at $\Delta e = \Delta s - \Delta p$, which gives

$$(8) \qquad \frac{\Delta s_t}{\Delta \eta_t} = \frac{\Delta p_t}{\Delta \eta_t} - \frac{\Delta \sum_{k=0}^{\infty} r_{t+k}}{\Delta \eta_t}$$

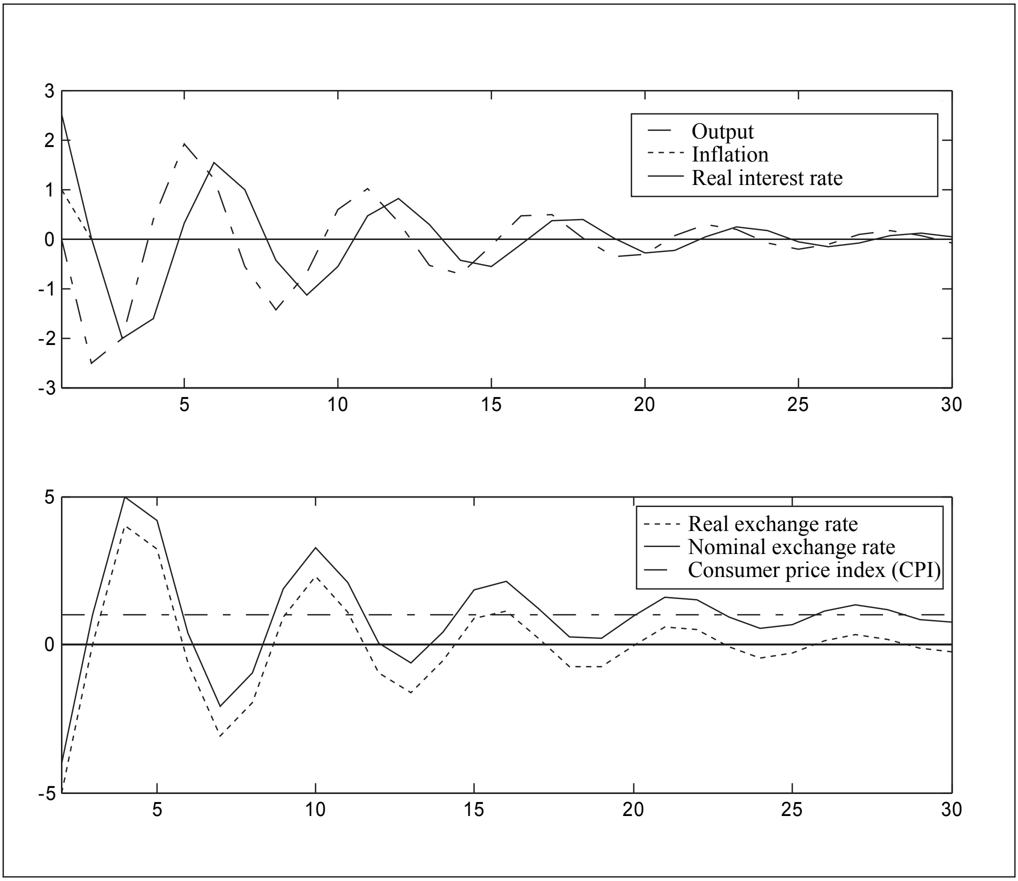
In the model in section 2, $\frac{\Delta p_t}{\Delta \eta_t} = 1$, as it takes one period before monetary policy affects inflation. If, for example, the exchange rate channel works faster, the effect will be less. It is, however, reasonable to assume that the term $\frac{\Delta p_t}{\Delta \eta_t}$ is positive, as the central bank allows a slight increase in inflation. The reason for this is partly that emphasis is placed on the real economy and partly that monetary policy influences prices with a time lag. Some of the shock therefore slips in as a change in the price level. There are thus two forces pulling in different directions. A higher price level, in isolation, results in a weaker nominal exchange rate, whereas higher real interest rates result in a stronger exchange rate.

Result 3: *The effect of a cost-push shock on the nominal exchange rate is uncertain*

In Charts 1 and 2, we have plotted the effect of a cost-push shock in the model with two different assumptions regarding the weight of the output gap (λ). Chart 1 shows the effect with strict inflation targeting (SIS), in other words, if $\lambda = 0$; whereas Chart 2 shows the effect with flexible inflation targeting (FIS) – where $\lambda = 1$. In the first case, we see that inflation rises initially, but then stabilises from and including period 2. The central bank achieves this by initiating a relatively sharp real appreciation so that inflation falls as a result of the decline in imported inflation. Parallel with the fall in inflation, the increase in real interest rates and the real appreciation lead to a fall in production. In order to avoid this in turn translating into even lower inflation, the interest rate hike must be reversed and real interest rates must be set at a lower level than normal. This will give a real depreciation that is just sufficient to offset the effect on inflation of a reduction in demand. The result of the strict inflation targeting is thus relatively substantial fluctuations in the other variables. As far as the exchange rate is concerned, we see that the long run effect is a nominal depreciation (equal to the increase in consumer prices) – whereas the real exchange rate reverts to its initial level. The immediate effect is, however, both a real and a nominal appreciation. In Chart 1 we can clearly see the two forces pulling in different directions. Consumer prices increase and there is a real appreciation.

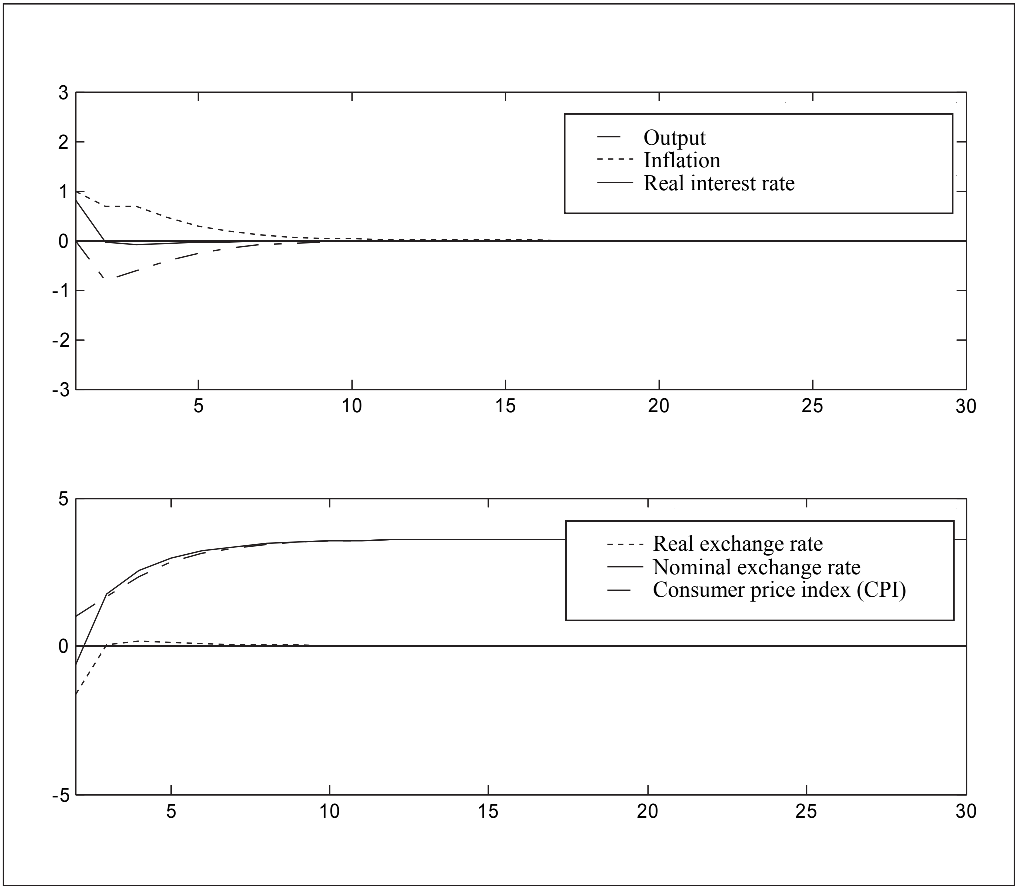
In the model above, it takes one period before monetary policy influences inflation. If the central bank is able to control inflation in the very short term, only the real interest rate effect has an impact on the exchange rate. In which case the effect is unambiguous: the nominal exchange rate will appreciate in the short term with flexible inflation targeting.

Chart 1: The effect of a cost-push shock (SIS - λ = 0)



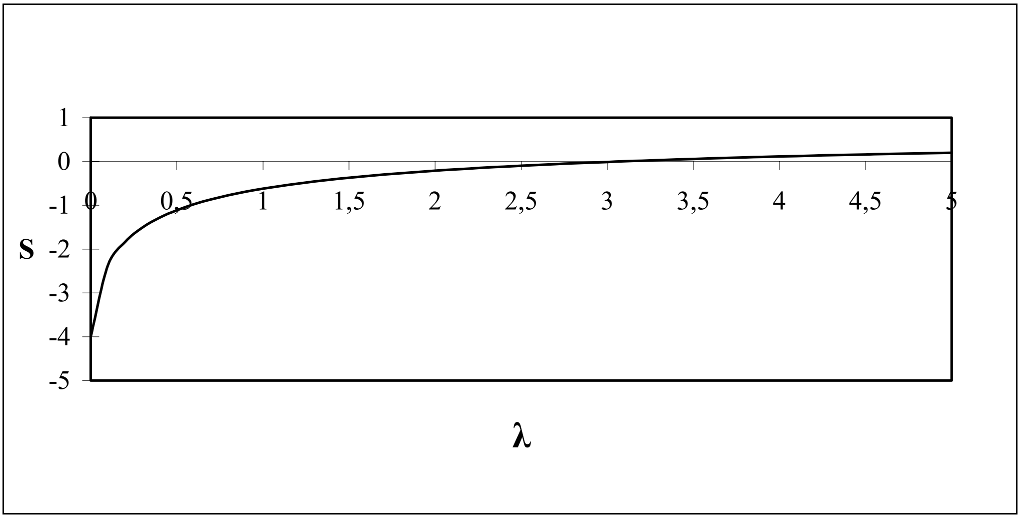
Let us now look at the effect of a cost-push shock with flexible inflation targeting. In Chart 2, we let the central bank place weight on variation in both production and inflation, thus λ = 1. Not surprisingly, it takes longer for inflation to return to the inflation target. The accumulated effect on the price level is thereby greater and the effect is a more marked nominal depreciation in the long term. We also see that there is less change in real interest rates, so that the real appreciation is smaller. The result is a smaller fall in production. And the immediate nominal appreciation is also less.

Chart 2: Effect of a cost-push shock (FIS - λ = 1)



In the long term, the cost-push shock does result in a nominal depreciation, given that the real equilibrium exchange rate does not change. The size of the nominal depreciation depends on how much emphasis monetary policy places on stabilising the output gap. In the short term, however, the effect on the nominal exchange rate is uncertain and will depend on two factors. First, the more importance the central bank attaches to the real economy, the more likely depreciation is. In Chart 3, we have plotted the relationship between the immediate effect on the nominal exchange rate and the weight of the output gap (λ). A higher weight on the output gap reduces the immediate nominal appreciation and if the weight on the output gap is sufficiently large, we will get a nominal depreciation. The reason for this is that the increase in the price level is greater and the rise in real interest rates is correspondingly lower.

Chart 3: Relationship between nominal exchange rate and λ



The more flexible prices are, the more likely an immediate nominal depreciation is. If prices are "completely" flexible, monetary policy will be neutral - so that real interest rates will remain unchanged - and the nominal depreciation will be immediate. In more realistic models, however, there is reason to believe that the real interest rate effect will dominate in the short term, causing the nominal exchange rate to appreciate. This is confirmed by the model analysed above. It is also the result presented in an article on inflation targeting in a small open economy by Lars Svensson. The nominal exchange rate will appreciate in the very short term with both flexible and strict inflation targeting, though the appreciation will be smaller with a flexible regime.[4]

If the central bank's target is to stabilise the price level rather than inflation, the likelihood of an immediate nominal appreciation increases. This also applies if there is a time lag in the effects of monetary policy - as in the model above. The reason for this is that the central bank in this case will steer the price level – and not inflation - back to its original level. Thus the change in real interest rates will be sharp.

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[4] See charts 2 and 3 p. 173-74 in Svensson (2000), "Open-economy inflation targeting", *Journal of International Economics 50*, 155-183.

Our focus is on temporary changes in the economy that translate into temporary changes in the rate of inflation. But the economy can also be exposed to permanent changes. An example of such a disturbance could be when real wage growth increases at a given level of unemployment. This will increase equilibrium unemployment so that wage growth in turn is linked to productivity growth in the economy. The central bank will then increase real interest rates in order to bring unemployment to the equilibrium level. Parts of the shock will still slip in as a change in the general price level, which, in isolation, gives a nominal depreciation. Contrary to temporary shocks, an increase in equilibrium unemployment may result in a real appreciation in the long run, as the supply of domestically produced goods and services, in isolation, will fall as a result of the rise in unemployment. Thus the relative price of the country's goods and services will rise, thereby leading to a real appreciation in the long run. As result, the nominal depreciation will be smaller in the long run. In the short term, however, in this scenario as well, two forces will pull the nominal exchange rate in different direction, which makes the total effect somewhat uncertain.

4. Conclusion

We have shown that the immediate effect of a cost-push shock on the nominal exchange rate is uncertain. A positive cost-push shock results in a higher price level, which pulls in the direction of depreciation. The monetary policy response implies (expectations of) higher real interest rates, which pulls in the direction of an appreciation. Even though the net effect is theoretically uncertain, the latter effect seems to dominate in realistic models. The stronger exchange rate resulting from the cost-push shock is, however, temporary. Gradually the exchange rate will fall and in the long run will move towards a level that is lower than that before the cost-push shock took effect.

In this article, a cost-push shock has been interpreted as a purely exogenous cost-push shock. If the cost-push shock is instead a result of improved productivity, the results will be modified. We have also assumed that purchasing power parity will be maintained in the long run, i.e. that the real exchange rate will move towards a constant equilibrium level. Differences in productivity trends between countries may, however, entail that this assumption does not hold. We have chosen not to include any such structural trends in this analysis.

Chapter 6 – To what extent can movements in the krone exchange rate be explained by the interest rate differential?

Arne Kloster, Raymond Lokshall and Øistein Røisland

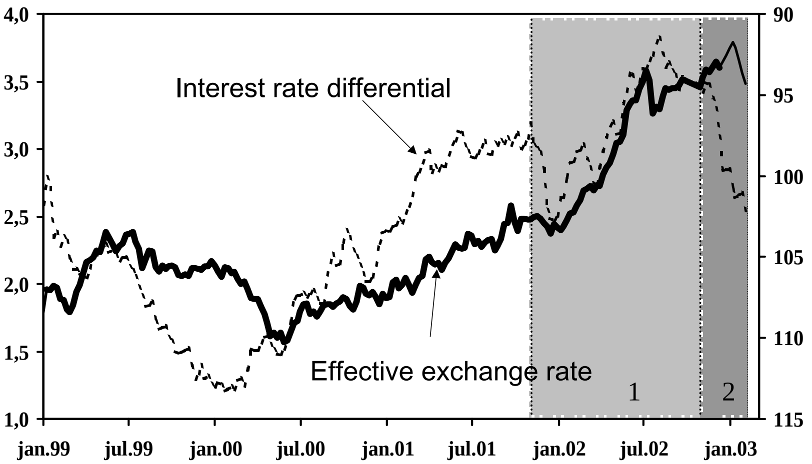
This article analyses, within the framework of uncovered interest parity, the extent to which movements in the krone exchange rate since November 2001 can be ascribed to the interest rate differential. We find that changes in the interest rate differential can explain some of the movements in the exchange rate, but that other factors have also played a role. Among other things, it appears that the risk premium on investments in Norwegian krone was reduced through the same period that the Norwegian krone appreciated.

1. Background

The Norwegian krone strengthened considerably from the start of 2001, but then weakened again slightly. In this period, exchange rate movements have largely coincided with changes in the interest rate differential, see Chart 1. It may therefore seem obvious to conclude that movements in the krone exchange rate can to a large extent by explained by the interest rate differential.

However, the fact that changes in the krone exchange rate have coincided with the trend in the interest rate differential in *qualitative* terms does not necessarily mean that the interest rate differential can explain *the extent* of these changes. In order to examine how much of the exchange rate movements can be ascribed to the increase in the interest rate differential alone, we have divided the period into two sub-periods: 1) 1 November 2001 to 4 November 2002, and 2) 4 November 2002 to 27 March 2003. This particular division of the period is in part due to available data. But it is also of professional interest, as Period 1 is primarily characterised by an appreciation of the krone and an increase in the interest rate differential, whereas Period 2 is characterised by the opposite (if to a somewhat lesser extent).

Chart 1. Effective exchange rate and the interest rate differential (12 month)



In this article we will analyse the relationship between the krone exchange rate and the interest rate differential within the theoretical framework of uncovered interest parity. This does not necessarily mean that we think that uncovered interest parity is a good model for the exchange rate. The theory of uncovered interest parity does, however, give us a tool with which to analyse and decompose changes in the krone exchange rate.

Uncovered interest parity is normally used to glean information about market expectations regarding exchange rate movements. Normally, however, movements in the exchange rate are different. One reason may be that the market has changed its expectations regarding future interest rates at home and abroad. If, for example, market expectations of future interest rate differentials are adjusted upwards, this will, in isolation, contribute to a stronger trend in the exchange rate than that originally anticipated by the market. The advantage of the method we have chosen to use is that it takes account of what the interest rate differential was originally and how market expectations of future interest rate differentials have changed through the period. We show that much of the appreciation in the krone exchange rate from 2001 to 2002 can be explained by an upwards adjustment in market expectations of future interest rate differentials.

The method is presented in the section below. This section requires some knowledge of the use of model-consistent expectations. However, it is not necessary to have an understanding of all the technical aspects of the calculations to understand the results and interpretations presented later in the article.

2. Uncovered interest parity

Uncovered interest parity (UIP) says that the expected return shall be the same regardless of the currency in which you wish to invest. The theory builds on the assumption that participants in the foreign exchange market are risk neutral. It is, however, quite usual in theoretical literature to extend the pure UIP context with a (stochastic) risk premium. As changes in the risk premium are also discussed in this article, it seems natural to include it. The logarithmic form of UIP is then written as follows

$$v_t = E_t v_{t+1} - (i_t - i_t^*) + z_t, \tag{1.1}$$

where v_t is the logarithm of the exchange rate in the period t (an increase equals a depreciation), $E_t v_{t+1}$ is the expected exchange rate in the next period, i is the domestic interest rate level, i^* is the foreign interest rate level and z_t is the risk premium. Pure UIP, when the expected return is the same between different currencies, means that $z_t = 0$. If $z_t \neq 0$, the equation indicates that the expected *risk-adjusted* return will be the same between different currencies. If equation (1.1) is solved successively, you will find

$$v_t = -\sum_{j=0}^{n-1} E_t(i_{t+j} - i_{t+j}^*) + \sum_{j=0}^{n-1} E_t z_{t+j} + E_t v_{t+n}. \tag{1.2}$$

Consequently, the difference between the actual exchange rate in the period $t+k$ and the exchange rate in the period $t+k$ that was expected k periods earlier, is expressed by

$$v_{t+k} - E_t v_{t+k} = -\sum_{j=k}^{n-1}(E_{t+k}(i_{t+j} - i^*_{t+j}) - E_t(i_{t+j} - i^*_{t+j}))$$
$$+\sum_{j=k}^{n-1}(E_{t+k}z_{t+j} - E_t z_{t+j}) + (E_{t+k}v_{t+n} - E_t v_{t+n}) \qquad (1.3)$$

Here, the term $\sum_{j=k}^{n-1}(E_{t+k}(i_{t+j} - i^*_{t+j}) - E_t(i_{t+j} - i^*_{t+j}))$ denotes changes in expectations regarding future interest rate differentials – the forward rate differential – (to the period *t+k+n-1*), the term $\sum_{j=k}^{n-1}(E_{t+k}z_{t+j} - E_t z_{t+j})$ denotes changes in expectations regarding the risk premium and the term $(E_{t+k}v_{t+n} - E_t v_{t+n})$ is changes in expectations regarding the exchange rate level in the period *t+n*.

It is normal to interpret changes in forward rate differentials at the long end of the market as changes in relative inflation expectations and not as changes in long-term real interest rates. It may therefore be appropriate to write UIP in its "real form":

$$e_t = E_t e_{t+1} - (r_t - r^*_t) + z_t, \qquad (1.4)$$

where $e = v + p^* - p$ is the real exchange rate, $r_t = i_t - E_t(p_{t+1} - p_t)$ is domestic real interest rates and $r^*_t = i^*_t - E_t(p^*_{t+1} - p^*_t)$ is foreign real interest rates. p_t is the logarithm of the price level, so that $E_t(p_{t+1} - p_t)$ is expected inflation. Note that equation (1.4) follows directly from (1.1), so that nominal UIP and real UIP are completely equivalent. If we solve (1.4) progressively, we arrive at an expression that corresponds with (1.2):

$$e_t = -\sum_{j=0}^{n-1} E_t(r_{t+j} - r^*_{t+j}) + \sum_{j=0}^{n-1} E_t z_{t+j} + E_t e_{t+n}. \qquad (1.5)$$

or alternatively

$$v_t = p_t - p_t^* - \sum_{j=0}^{n-1} E_t(r_{t+j} - r_{t+j}^*) + \sum_{j=0}^{n-1} E_t z_{t+j} + E_t e_{t+n} \tag{1.6}$$

According to UIP, the nominal exchange rate is therefore determined by the current differential between domestic and foreign price levels, expected real interest rate differentials, the risk premium and expected long-term real exchange rate.[1] As the price ratio with other countries is more or less fixed in the short term, short-term changes in the exchange rate will primarily reflect changes in the final three terms. It is therefore changes in the real interest rate differential and not changes in the nominal interest rate differential that affect the exchange rate in the short term.

However, inflation expectations and thereby real interest rates cannot be observed directly. We therefore have to make some assumptions. One approach would be to assume that inflation expectations are fixed. The change in the real interest rate differential is then equal to the change in the nominal interest rate differential. This would be relevant if confidence in the inflation target is stable.

Brigden et al. (1997)[2] divide the interest rate differential into a nominal part and a real part. They assume that all changes in the forward rate differential for horizons of more than *p* years only represent inflation expectations. Until this point, it is assumed that changes in the forward rate curve comprise both changes in expected real interest rate differentials and inflation expectations. More specifically, the inflation expectation component within the p-horizon is assumed to be expressed by

$$INF = \left(\frac{p}{2}\right)\Big(E_{t+k}(i_{t+k+p} - i_{t+p}^*) - E_t(i_{t+k+p} - i_{t+k+p}^*)\Big), \tag{1.7}$$

[1] For a discussion about long-term real exchage rates, see the articles by Akram et al.and Torvik in this Occasional Paper.
[2] A. Brigden, B. Martin and C. Salmon: "Decomposing exchange rate movements according to the uncovered interest rate parity condition". *Quarterly Bulletin,* November 1997.

so that changes in the forward rate curve entail the following changes in the real forward rate differential:

$$\begin{aligned} REAL = &\sum_{j=k}^{n-1} (E_{t+k}(i_{t+j} - i^*_{t+j}) - E_t(i_{t+j} - i^*_{t+j})) \\ &-\left(\frac{p}{2}\right)\left(E_{t+k}(i_{t+k+p} - i^*_{t+k+p}) - E_t(i_{t+k+p} - i^*_{t+k+p})\right). \end{aligned} \tag{1.8}$$

Brigden et al. assume that *p=6*, i.e. that changes in the forward curve from six years or more represent inflation expectations alone.

As it is not obvious which assumptions it is natural to include regarding inflation expectations, we have used both the assumption of unchanged inflation expectations and Brigden et al.'s assumption.

3. Results

3.1 Appreciation period

In the period from 1 November 2001 to 4 November 2002 the effective krone exchange rate, measured by the trade-weighted exchange rate index, appreciated by 8.6 per cent. This was accompanied by an increase in the interest rate differential, as a result of higher domestic interest rates and lower interest rates abroad. How much of this appreciation can then be ascribed to the increase in the interest rate differential? It is useful to divide movements in the exchange rate into two components: the change that the market *expected* at the start of the period and the change that occurred through the period that was not expected at the start of the period, i.e. "news".

Actual change in the exchange rate
= (2) expected movements
+ (3) "news"

If strict UIP applies, the expected change in the exchange rate was equal to the one-year interest rate differential at 1 November 2001, which was 2.9 per cent. This implies then that the market expected a 2.9 per cent *depreciation* of the krone. According to equation (1.3) there are three types of "news" that can affect the exchange rate: a) unexpected changes in the interest rate differential, b) unexpected changes in the risk premium and c) unexpected changes in the long-term exchange rate. For the moment we will disregard b) and c) and concentrate on unexpected changes in the interest rate differential.

If expectations regarding inflation, the risk premium and the long-term exchange rate remain unchanged, the appreciation of the exchange rate will be equal to accumulated changes in forward rate differentials, i.e. the area below the bottom curve in Chart 2. The accumulated change in forward rate differentials from 1 November 2001 to 4 November 2002 is 4.9 percentage points. Thus, "news" in terms of the interest rate differential through the period should, in isolation, indicate a 4.9 per cent appreciation of the krone cent in relation to the exchange rate level that was expected one year earlier. As the exchange rate firmed by 8.6 per cent in this period, when according to (strict) UIP it was expected to fall by 2.9 per cent, the accumulated increase in forward rate differentials would have to have been 8.6+2.9=11.5 percentage points in order to fully explain the change in the exchange rate. But as the increase was only 4.9 percentage points, it follows that the increase in the interest rate differential in this period can only explain just under half of the appreciation of the krone. If we assume that

Chart 2. Forward interest rates

1. November 2001 and 4. November 2002

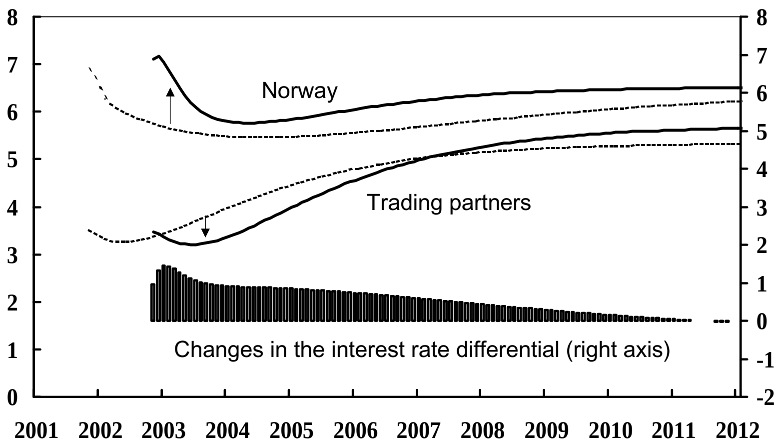


Table 1. Change in trade-weighted exchange rate index from 1 November 2001 to 4 November 2002

Per cent, percentage points in italics.

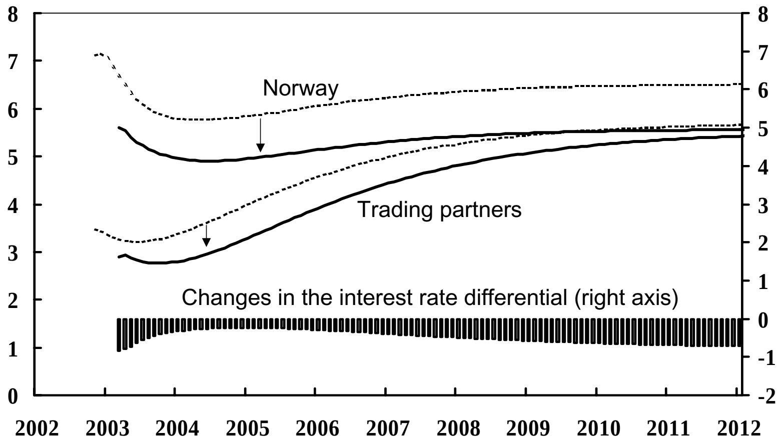
Actual exchange rate movements	(1)	8.6
Of which:		
Expected	(2)	- 2.9
"News"	(3)=(1)-(2)	11.5
Accumulated change in forward rate differentials	(4)	4.9
Of which:		
Real component	(5)	3.6 - 4.9
Inflation expectations	(6)=(4)-(5)	0 – 1.3
Contribution from interest rate differential	(7)=(2)+(5)	0.7 – 2.0
Residual: Unexpected changes in risk premium and long-term exchange rate	(8)=(1)-(7)	6.6 – 7.9

some of the increase in forward rate differentials was ascribable to higher inflation expectations, the interest rate differential explains even less of the appreciation. With the assumptions of Brigden et al., the increase in nominal forward rate differentials gives a 3.6 per cent increase in the accumulated forward *real* rate differential.

The results are summarised in Table 1. The interval in the lower half of the chart is presented as a result of the two alternative assumptions regarding changes in inflation expectations. If we apply strict UIP, we find that between 6.6 and 7.9 percentage points of the total appreciation of 8.6 per cent is due to factors other than the interest rate differential. As we will discuss in section 4, it is uncertain whether the market expected a 2.9 per cent fall in the krone exchange rate, in line with the interest rate differential at 1 November 2001. If there was a posi-

Chart 3. Forward interest rates

4. November 2002 and 27. March 2003



tive risk premium on investments in NOK, the market expected a smaller depreciation than this. A greater share of the appreciation in the exchange rate would then be explained by the increase in the interest rate differential. If, for example, we assume that the market expected the exchange rate to remain unchanged, which it is not entirely unrealistic to assume, the increase in the interest rate differential would explain around half of the appreciation in the exchange rate.

3.2. Depreciation period

In the period from 4 November 2002 to 27 March 2003, the krone depreciated by 4 per cent. Interest rate levels and expectations were reduced in both Norway and abroad, but forward rates in Norway fell more than abroad, thus narrowing the interest rate differential with other countries, see Chart 3.

Pure UIP (z_t = 0) implies that the market expected a depreciation in line with the interest rate differential at 4 November 2002, i.e. 1.2 per cent. Accumulated forward rate differentials fell by 4.5 per cent through the period. If we apply the assumption of unchanged inflation expectations, UIP indicates that movements in the interest rate differential should have resulted in a depreciation in the exchange rate of 1.2+4.5=5.7 per cent, i.e. a greater depreciation than actually occurred. However, a substantial part of the decline in forward rate differentials occurred in the 5 – 10-year range (see Chart 3). There is reason to believe that much of this fall is due to liquidity conditions at the long end of the bond market and therefore cannot be ascribed to pure interest rate or inflation expectations. Thus there is reason to ignore the decline in this part of the forward rate curve. The assumptions of Brigden et al*.,* however, do this *de facto*, as they ascribe changes in long-term forward rates to inflation expectations alone. On the basis of their assumption, the decline in the nominal forward rate differential implies a decline in the *real* forward rate differential of 0.63 percentage point, i.e. a 0.6 per cent fall in the exchange rate in addition to the expected depreciation. This assumption possibly gives too weak a depreciation, whereas the assumption of unchanged inflation expectations exaggerates the fall, so that the most realistic figure lies somewhere in between. The results are summarised in Table 2.

Table 2. Changes in trade-weighted exchange rate index from 4 November 2004 to 27 March 2003

Per cent, percentage point in italics

Actual exchange rate change	(1)	- 4.0
Of which:		
Expected	(2)	- 1.2
"News"	(3)=(1)-(2)	- 2.8
Accumulated change in forward rates		
Of which:	(4)	- 4.5
Real component	(5)	- (0.6 – 4.5)
Inflation expectations	(6)=(4)-(5)	- 3.9 – 0.0
Contribution from interest rate differential	(7)=(2)+(5)	- (1.8 – 5.7)
Residual: Unexpected changes in risk premium and long-term exchange rate	(8)=(1)-(7)	- 2.2 – 1.7

4. Risk premium on the Norwegian krone

The risk premium on the Norwegian krone is defined as the expected excess return on investments in NOK relative to foreign currencies. Solving equation (1.1) for z_t gives

$$z_t = i_t - i_t^* - (v_{t+1}^e - v_t) \tag{1.9}$$

A positive risk premium could, for example, entail that a positive interest rate differential on investments in NOK is not offset by an expected depreciation of the krone exchange rate. A reduction in the risk premium may be the result of a narrowing of the interest rate differential without any change to the expectations of a depreciation. A large expected depreciation and unchanged interest rate differential also entails a lower risk premium.

In the previous section we saw that changes in the forward rate differential could not fully explain movements in the krone exchange rate. For example, the krone exchange rate firmed more for a period than the increase in the forward rate differential, in isolation, would indicate. This deviation may be explained by changes in expectations regarding the level of the krone exchange rate in the long term (up to 10 years hence) and/or a lower risk premium. That which cannot be ascribed to changed expectations regarding the future level of the krone exchange rate, must be ascribed to changes in the risk premium.

We can glean information about the risk premium on the Norwegian krone and any changes in the premium by looking at the expected future krone exchange rate, the current exchange rate and interest rates in Norway and abroad, see equation (1.9). Interest rates and currencies are traded in the money and foreign exchange markets daily and prices can be easily observed. However, the expected exchange rate at a future point in time cannot be observed directly.

An expression for expected future exchange rates can be obtained by asking forecasters and analysts what they think the exchange rate will be at a future point in time. Consensus Economics Inc. carry out such surveys each month and report the average value for a number of currencies in their publication.[3] The horizons are three months, one year and two years. We can use the currencies given in Consensus Forecasts to establish the expected krone exchange rate against a number of currencies. The effective krone exchange rate (trade-weighted exchange rate) and interest rates for trading partners can be established by looking at the weighted average for the exchange rate and interest rates in the eight most important trading partner countries. Here we will look at the expected krone exchange rate in one year's time and at 12-month money market rates.

Chart 4 shows the development in the risk premium over a one-year horizon and the 12-month interest rate differential vis-à-vis our trading partners from June 1998 to March of this year. The interest rate differential vis-à-vis our trading partners was positive for the entire period. The risk premium was positive until the start of 2002. In this period, the positive interest rate differential was not offset by a sufficiently large expected depreciation and there was an expected positive excess return on investment in NOK. There were expectations of an appreciation until September 2000. This made the expected excess return greater than the interest rate differential.

The risk premium has been reduced since the start of 2000 and has generally been negative since the start of 2002. A negative risk premium means that the expected depreciation more than offsets the positive interest rate differential. A smaller return is then expected on investments in NOK than in foreign currency.

A participant may accept an expected smaller relative return on one investment if this investment helps to reduce the total risk for all the investments the participant has made. The reduction in the risk premium on Norwegian krone may be linked to the fact that the krone has functioned as a hedge against other risks in the financial markets. Several market participants have pointed to the krone as a "safe-haven currency" in relation to the danger that the increased risk of war might have a major impact on the oil price.[4]

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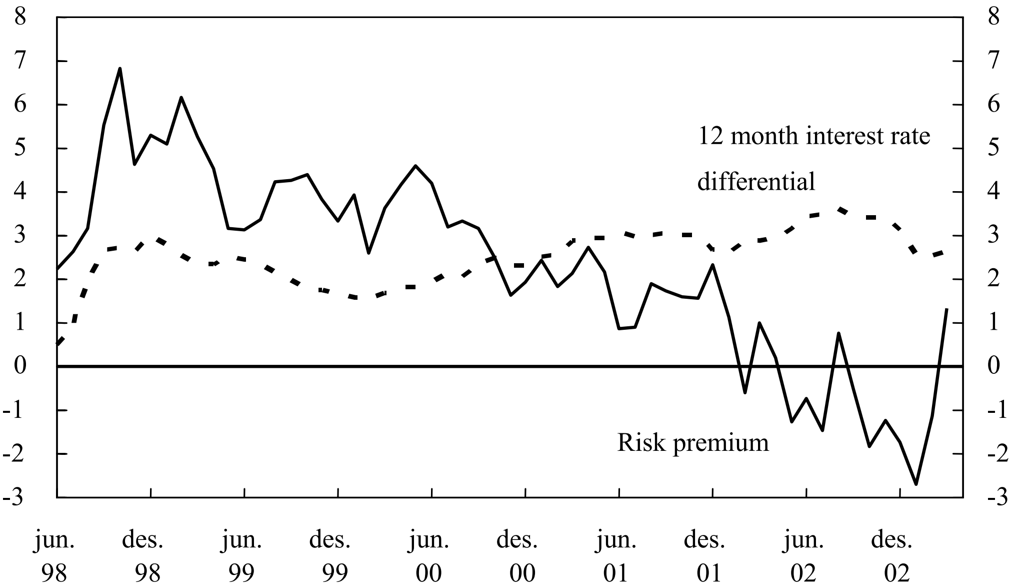
[3] Data from Consensus Forecasts for Norway is available from June 1998.
[4] For a more detailed analysis of factors that may have contributed to the reduction in the risk premium, see the article by Naug in this issue of Occasional Papers.

Chart 4. Risk premium

June 1998 – March 2003



Figures from Consensus Forecasts, together with interest rate differentials and spot exchange rate, indicate that the risk premium for investment in NOK has fallen. The risk premium now appears to be low. With the analysis framework of the previous section, a reduced risk premium serves, in isolation, to strengthen the exchange rate. This appreciation is then in addition to the appreciation resulting from the increase in the interest rate differential alone.

In November 2001, our indicator for the risk premium was around 2 percentage points. Even though the interest rate differential was around 3 percentage points, this may indicate that the expected depreciation of the krone was only around 1 per cent in the period to November 2002. From November 2001 to November 2002, the forward rate differential widened by 5 percentage points. Within the analysis framework of the previous section this is equivalent, in isolation, to a 5 per cent appreciation of the krone exchange rate. In the same period, the risk premium on a one-year horizon fell by around 3 percentage points. If the change only applies to the one-year horizon, this reduction indicates, in isolation, a 3 per cent increase in the krone exchange rate. The total effect of a higher forward rate differential and a lower risk premium may indicate an appreciation of the krone exchange rate of around 8 per cent. If the risk premium stood at around 2 percentage points to begin with, the unexpected appreciation of the krone exchange rate was 9.5 per cent over the period. If the change in the risk premium is expected to be more long-term, the effect on the krone exchange rate is greater.

The analysis here presumes that the estimates for future krone exchange rates presented in Consensus Forecasts reflect market participants' actual expectations regarding future exchange rates. However, the estimates are given by forecasters and analysts in various institutions and not by market participants themselves. Even though expectations may deviate, the deviation over time is not likely to be that great. There may also be variations in how often estimates from the different institutions are updated. If the estimates are not updated frequently and the spot exchange rate changes substantially, this may appear as changed expectations about exchange rate movements even though no new evaluation of future exchange rate movements has been made. By observing the risk premium over a longer period, these effects are also likely to be minor.

5. Conclusions

In this article, we have decomposed exchange rate and interest rate movements within the framework of uncovered interest parity. We have looked at two periods in particular: 1 November 2001 to 4 November 2002, and 4 November 2002 to 27 March 2003. The first period is characterised by an appreciation of the krone and an increase in the interest rate differential. The second period is characterised by a fall in the exchange rate and a decline in the interest rate differential. In the first period we find that the interest rate differential can only explain up to half of the appreciation of the krone. According to our theoretical framework, the remainder of the appreciation is due to a combination of a reduction in the risk premium on investments in NOK and expectations of a stronger long-term real exchange rate for the krone. In the second period, the entire fall in the exchange rate can potentially be explained by the narrowing of the interest rate differential in the period. This estimate is, however, very sensitive to which assumptions are made regarding the relevance of long-term forward rate differentials to the krone exchange rate.

Even though the risk premium is not directly observable, we have made an indicator by using exchange rate expectations collected from surveys by Consensus Forecasts. Based on this information, it appears that the risk premium fell substantially during the period when the krone firmed. This may be connected to the fact that the krone was to a certain extent regarded as "a safe haven", as, for example, it provides investors with some hedge against losses in the event of an increase in the oil price.

Chapter 7 – Factors behind movements in the krone exchange rate – an empirical analysis[1]

Bjørn E. Naug

The effective krone exchange rate appreciated considerably from May 2000 to January 2003. This article analyses factors behind the appreciation using an estimated model of the krone exchange rate (trade-weighted exchange rate index) based on monthly data. We find that the appreciation is related to (i) a strong rise in the interest differential against other countries from spring 2000 to November 2002 and (b) the fact that this differential was positive and high throughout the entire appreciation period. The wider interest differential may explain around 40 per cent of the appreciation from May 2000 to January 2003. The positive interest differential caused the krone to strengthen as a result of the fall in international stock markets and expectations of lower fluctuations between the major currencies. This effect may explain more than half of the appreciation. The appreciation in 2002 is also related to the sharp increase in the oil price and the krone's status as a safe-haven currency during the unrest in the Middle East. Changes in the interest differential have the largest effect on the krone when share prices have fallen sharply over a six-month period and when only narrow fluctuations are expected between the major currencies. In such a situation, investors are cautious and sceptical of the possibility of achieving (substantial) capital gains in the stock and currency markets. They then place more emphasis on interest differentials than when share prices have risen strongly and the major currencies are expected to fluctuate widely. As share prices and expected fluctuations between the major currencies fell over the appreciation period, this means that the krone became more sensitive to interest rate changes during that period.

[1] I would like to thank Jan F. Qvigstad, Dagfinn Rime, Ida W. Bache, Ragnar Nymoen, Øistein Røisland and Tom Bernhardsen for constructive comments and discussions. The views expressed in this article are those of the author alone.

1. Introduction

The krone exchange rate appreciated considerably from May 2000 to January 2003, particularly in 2002. The appreciation is often linked to the strong rise in the interest differential against other countries through the appreciation period. However, Kloster et al. (2003, Chapter 6 of this Occasional Paper) find that the higher interest differential cannot explain more than half of the appreciation from November 2001 to November 2002. The remainder of the appreciation in that period must then be explained by a shift in exchange rate expectations and/or a fall in the risk premium on krone investments. This is expressed in the formula for uncovered interest parity (UIP) with a risk premium (equation 1.1 in Kloster et al. 2003):

$$(1) \quad v_t = E_t v_{t+1} - (i - i^*)_t + z_t,$$

where v_t is the logarithm of the exchange rate in period t (a higher rate means that the krone depreciates), $E_t v_{t+1}$ is market expectations of the exchange rate in the next period based on the information available in period t, i and i^* are interest rates on Norwegian and foreign securities respectively (with maturity in the next period) and z_t is the risk premium in period t.

Equation (1) shows that the krone appreciates when the interest differential ($i - i^*$) widens and when the risk premium z_t or the expected exchange rate $E_t v_{t+1}$ falls. The risk premium and the expected exchange rate may change if agents receive new information or adjust their assessment of old information. An increase in the interest differential will generate expectations of a depreciation if $v_t = E_t v_{t+1}$ to start with and if z_t is unaffected.

The variables $E_t v_{t+1}$ and z_t in (1) can change rapidly, are unobservable and depend on different conditions in different periods. Hence it is difficult to construct exchange rate models that are stable over time and that explain short-term fluctuations in the exchange rate, as illustrated by these statements by leading exchange rate researchers:

> *"To repeat a central fact of life, there is remarkably little evidence that macro-economic variables have consistent strong effects on floating exchange rates."*
> (Frankel and Rose 1995).

"No structural model can reliably explain major currency exchange-rate movements after the fact, much less predict them." (Rogoff 2002).

"The explanatory power of (empirical exchange rate models) diminishes as the estimation period or forecast horizon is extended. Continued forecasting success typically requires regular updates of model specification and parameter estimates." (Meese 1990).

We try, however, to estimate a model of the trade-weighted exchange rate index[2] (TWI) that can explain exchange rate movements in recent years. The analysis is based on monthly data for the period 1999.1 - 2003.1. From 1994 to 1998, the interest rate and interventions were used to maintain a stable krone against European currencies. Thus, it is doubtful whether exchange rate movements after 1998, when changes in the risk premium and exchange rate expectations have impacted fully on the krone in the short run, can be explained by a model that is (partly) based on data from before 1999.[3] In order to capture effects of variation in the risk premium and exchange rate expectations, we include factors that have been highlighted by analysts and market participants in discussions of the appreciation from 2000.5 to 2003.1. The preferred model includes effects of the oil price, the interest differential against other countries, movements in US share prices and an indicator of expected variability between the three major currencies. It was presented in Inflation Report 1/03 from Norges Bank. The cut-off date for that report was 28 February 2003. We also test the model's post-sample properties.

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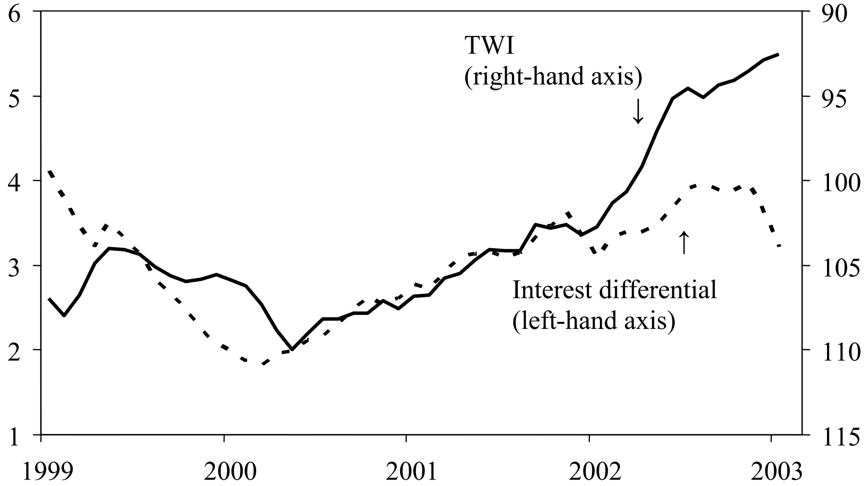
[2] The index measures the price of Norwegian kroner in the currencies of Norway's 25 most important trading partners (indices for the respective currencies are weighted together using OECD's competition weights for Norway); see Norges Bank's website for more information.

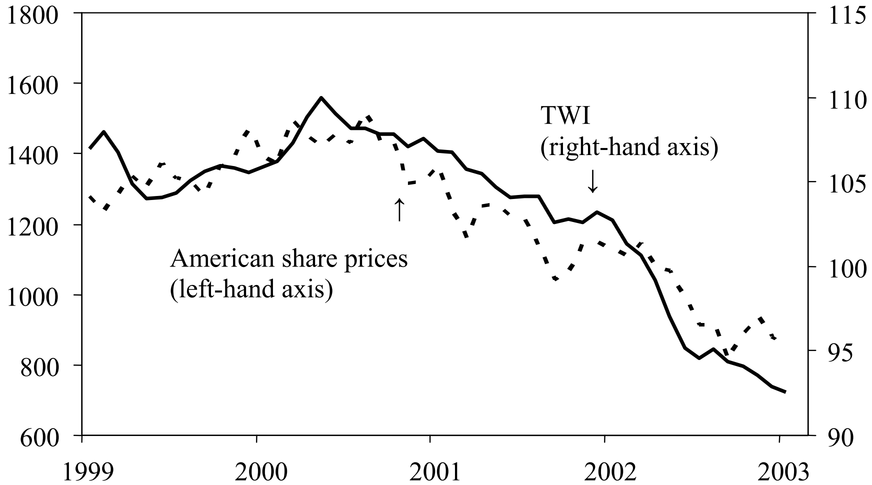
[3] Akram (2000) reports models of NOK/ECU where a wider interest differential coincides with a weaker krone from 1991.11 to 1998.11 (monthly data). The interpretation is that a wider interest differential in that period reflected increased expectations of a depreciation, which affected the krone. Bernhardsen and Røisland (2000) find similar results in models of NOK/DEM estimated on monthly data for the periods 1993.1 - 2000.7 and 1997.1 - 2000.7; they do not find significant interest rate effects in models of the trade-weighted exchange rate index estimated over these periods. The model in Bjørnland and Hungnes (2003) indicates that higher Norwegian interest rates coincided with a weaker krone in the short run in the period 1983.1 - 2002.2 (quarterly data); but the long-run effect is negative. The model includes a dummy that captures the sharp appreciation in the second quarter of 2002. Equation 5 in Akram (2003, Chapter 4 of this Occasional Paper) implies that a higher real interest differential resulted in a stronger real exchange rate in the period 1972-2001. The equation explains 2/3 of the real appreciation from spring 2000 to end-2001 (see Chart 5 in the article).

Chart 1. Trade-weighted exchange rate index[1)] (TWI) and 3-month interest differential against other countries



1) A rising curve denotes an appreciation of the krone

Chart 2. Trade-weighted exchange rate index[1)] (TWI) and US share prices[2)]



1) A falling curve denotes an appreciation of the krone

2) The S&P 500 index

2. What have analysts and market participants said about the appreciation of the krone?

Analysts and market participants have highlighted several factors that contributed to the appreciation of the Norwegian krone (NOK) from May 2000 to January 2003:[4]

- The interest differential against other countries widened considerably from spring 2000 to November 2002. This generated more interest for the Norwegian krone. Chart 1 shows that the trade-weighted exchange rate index was strongly correlated with the short-run interest differential (3-month)[5] from May 2000 to end-2001. The chart also indicates that we have to look to factors other than the interest differential in order to explain the sharp appreciation in 2002, see the results in Kloster et al. (2003).
- As a result of the fall in share prices from 2000 to 2002, many investors became cautious and sceptical of the potential returns in the stock market. Thus, as share prices fell, they wanted to invest a larger share of their portfolios in interest-bearing securities. In this situation, the Norwegian krone was attractive as the interest differential was positive and high. The krone was strongly correlated with US share prices (measured by S&P 500 index) during the sample period, see Chart 2.
- The prices of currency options for the USD/EUR, USD/JPY and EUR/JPY exchange rates fell significantly through the period May 2000 - December 2002. This means that investors expected smaller and smaller fluctuations between the major currencies in that period. Thus the expected potential for achieving capital gains in the currency market also diminished. Many investors therefore gradually placed more importance on interest differentials than previously and invested a larger share of their portfolios in high-interest currencies such as the Norwegian krone. Expectations of increased stability between major currencies may also have yielded expectations of narrower fluctuations in the krone exchange rate. This may in turn have served to increase the risk-adjusted return for foreign investors of investing in Norwegian interest-bearing securities. Chart 3 shows the krone exchange rate and an option-based indicator, *GHI*, which

[4] Most of these factors are also discussed in Juel et. al. (2002).

[5] The foreign interest rate is a weighted average of three-month rates in Norway's 25 most important trading partner countries (the interest rates are weighted using OECD's competitiveness weights for Norway).

measures market expectations of short-run volatility between the major currencies.[6] The indicator falls when expected volatility declines. The chart shows that *GHI* was positively correlated with the trade-weighted exchange rate index in the sample period.

- The oil price rose sharply from end-2001 to January 2003. A higher oil price boosts the petroleum wealth and thereby increases the need for a real appreciation (stronger equilibrium exchange rate), see Akram et al. (2003, Chapter 3 of this Occasional Paper). As long as agents are confident that the inflation target will be reached, the appreciation will largely occur through an appreciation of the nominal exchange rate.[7] Expectations of a stronger krone generate higher demand for the krone (and thereby a stronger exchange rate) today, see equation (1). Chart 4 indicates that the higher oil price was an important factor behind the appreciation from end-2001 to January 2003.
- The unrest in the Middle East from February-March 2002 and into 2003 made investors even more cautious and they wanted to hedge against the risk of a sharp rise in the oil price. This resulted in a lower risk premium on investments in NOK, and therefore an increase in demand for the krone, as the interest differential was high and the krone can be expected to appreciate when the oil price rises (see also Kloster et al. 2003).
- When new fiscal guidelines regarding the use of oil revenues was introduced in March 2001, it was argued that the real exchange rate should appreciate, see Torvik (2003, Chapter 2 of this Occasional Paper). This caused the risk premium on NOK-investments to fall: agents viewed it as less likely than before that the nominal exchange rate would depreciate in the short run. The risk premium may have been further reduced by statements from Norges Bank[8] regarding the need for real appreciation and the outlook for a nominal appreciation, see Johansen (2002) and NOU (2003: 13, section 5.5.2).

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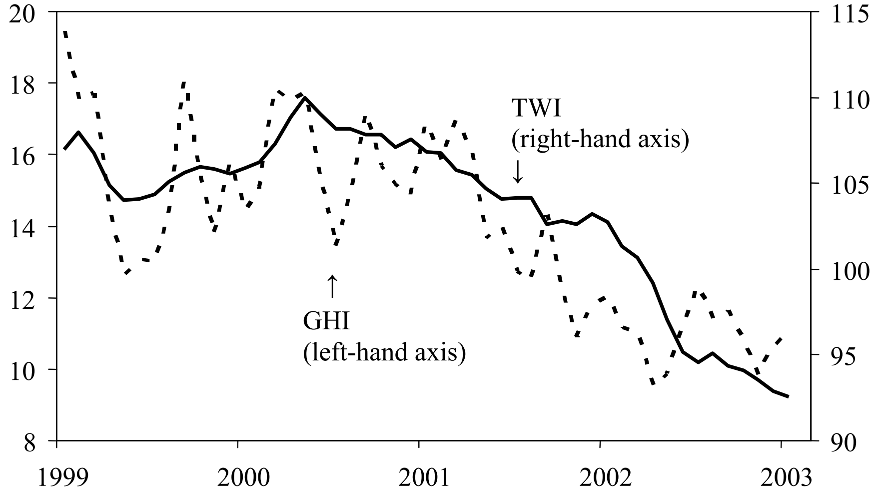
[6] The acronym *GHI* stands for Global Hazard Indicator. *GHI* comprises the implicit volatility in one-month option contracts for the USD/EUR, USD/JPY and EUR/ JPY exchange rates. The implicit volatility is directly related to the option price. It measures market expectations of exchange rate volatility. The *GHI*-formula was developed by Brousseau and Scacciavillani (1999). The variable is also described in Bernhardsen and Røisland (2000). They find significant short-run effects of *GHI* in models of NOK/DEM and the trade-weighted exchange rate index estimated on monthly data for the periods 1993.1 - 2000.7 and 1997.1 - July 2000.7.

[7] A rise in the oil price also generates higher demand for the krone in that the value of exports increases. However, this effect is to some extent offset by higher allocations to the Government Petroleum Fund. Bjørvik et al. (1998) and Akram (2000) discuss the relationship between the krone and the oil price when monetary policy seeks to maintain a stable krone.

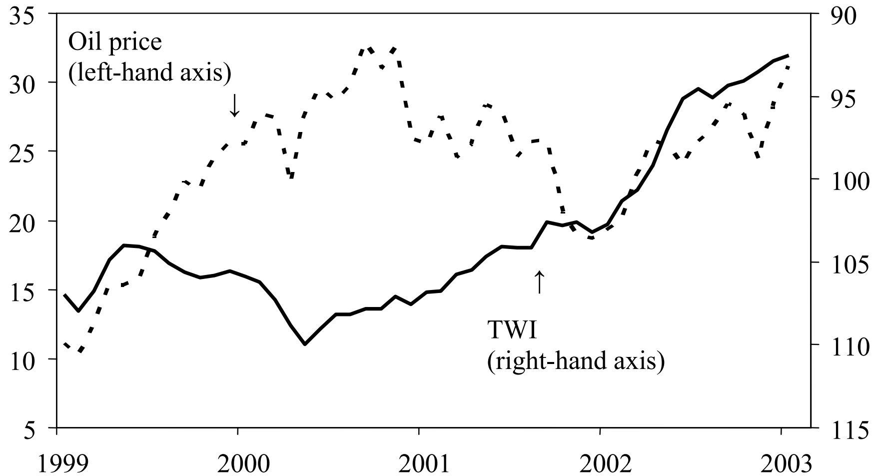
[8] See Inflation Report 2/02 (p. 4) and “Economic perspectives”, Economic Bulletin 1/02 (p. 3).

Chart 3. Trade-weighted exchange rate index[1)] (TWI) and indicator of fluctuations between major currencies (GHI)



1) A falling curve denotes an appreciation of the krone

Chart 4. Trade-weighted exchange rate index[1)] (TWI) and the oil price[2)]



1) A rising curve denotes an appreciation of the krone

2) Brent Blend, USD per barrel

In the next section we evaluate the importance of these factors by estimating a model of the TWI. We use the model to discuss how the krone responds to changes in the explanatory factors and to decompose the appreciation from 2000.5 to 2003.1. In Section 4 we evaluate how well our model explains the development in the krone from 2003.1 to 2003.11.

3. An econometric model of the trade-weighted exchange rate index[9]

We started with a flexible dynamic model that included effects of *GHI*, the oil price, US share prices and the interest differential against other countries at the short end (3 months) and the long end (12 months) of the market[10]. We also included a stochastic trend[11] to capture effects of unobserved variables that may have affected the risk premium or exchange rate expectations, particularly effects connected to unrest in the Middle East, statements from Norges Bank and the introduction of new fiscal guidelines in March 2001. We then simplified the general model by setting restrictions on the coefficients that were not rejected by the data and that eased the interpretation of the dynamics. The long-run interest differential was excluded as it was insignificant in models that also included the short-run interest differential (the short-run differential was significant in all models). Furthermore, the trend was reduced to a constant without any significant loss of fit. In other words, we found no (statistically significant) effects from the fear of war, the introduction of new fiscal guidelines and statements from Norges Bank over and above those that are captured by the variables in the model (we reached the same conclusion using dummies to capture such effects). The fear of war fuelled a sharp increase in the oil price in 2002 and the interest rate may have been affected by statements from Norges Bank and the introduction of new fiscal guidelines in 2001.

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[9] The analysis was carried out using Stamp 6.2 (Koopman et al. 2000) and PcGive 10.1 (see Hendry and Doornik 2001).

[10] The foreign interest rates are weighted averages of rates at the short and long end of the market in trading partner countries (see note in connection with Chart 1). It is questionable whether this is the best way to measure foreign interest rates. A number of investors borrow in low interest currencies in order to invest in high interest currencies ("carry-trade"). The extent to which these investors trade in NOK or not depends on (changes in) the interest differential between Norway and (other) countries with relatively high interest rates. We will test for such effects in a follow-up analysis.

[11] A stochastic trend is more flexible than a linear (deterministic) trend and can capture effects of omitted variables. The formula is described in Koopman et al. (2000).

Table 1. A model of the trade-weighted exchange rate index

$$\Delta v_t = \underset{(6.70)}{1.711} + \underset{(1.73)}{0.192}\,\Delta v_{t-1} - \underset{(6.50)}{0.330}\,v_{t-1} - \underset{(6.03)}{0.042}\,oil_t + \underset{(2.63)}{0.020}\,\Delta ghi_t$$

$$- \underset{(3.67)}{0.019}\,\Delta(i - i^*)_t - \underset{(6.01)}{0.043}\,\Delta_2(i - i^*)_{t-1} - \underset{(6.71)}{0.053}\,\Delta_2(i - i^*)_{t-3}$$

$$- \underset{(7.67)}{0.064}\,(i - i^*)_{t-5} + \underset{(2.98)}{0.012}\,\Delta_6 share_t\cdot(i - i^*)_t + \underset{(6.12)}{0.018}\,[ghi\cdot(i - i^*)]_{t-1}.$$

$R^2 = 0.76$, $\sigma = 0.0042$, $DW = 1.94$

The long-run solution of the model is:

$$v_t = 5.2 - \underset{(12.14)}{0.193}\,(i - i^*)_t + \underset{(3.53)}{0.035}\,\Delta_6 share_t\cdot(i - i^*)_t + \underset{(7.46)}{0.056}\,ghi_t\cdot(i - i^*)_t - \underset{(6.78)}{0.126}\,oil_t.$$

Estimation period: July 1999 – January 2003 (monthly data).

Estimation method: Ordinary least squares.

Absolute t-values are given in brackets under the estimates.

Δ indicates change in the variable X: $\Delta X_t = (X_t - X_{t-1})$, $\Delta_2 X_t = (X_t - X_{t-2})$ and $\Delta_6 X_t = (X_t - X_{t-6})$.

The variables and test statistics are defined by:

v	= Logarithm of the trade-weighted exchange rate index
oil	= Logarithm of the oil price (Brent Blend measured in USD)
ghi	= Logarithm of the global hazard indicator *GHI*
i	= Three-month money market rate in Norway (per annum)
i^*	= Three-month money market rate for our 25 most important trading partners
$share$	= Logarithm of the S&P 500 index
R^2	= Share of variation in left-hand variable explained by the model
σ	= Standard deviation of regression residuals
DW	= Durbin Watson statistic

Share prices are measured at the end of each month. The other variables are measured as a monthly average.

The preferred model is reported in Table 1. It is an equilibrium correction model of the (log of) the trade-weighted exchange rate index. The change in the exchange rate in month t (Δv_t) depends on the change in the exchange rate (Δv_{t-1}) and exchange rate level (v_{t-1}) in the previous month and the variables described above. The coefficient of Δv_{t-1} implies that the exchange rate depreciates by 0.19 per cent in month t if it depreciated by 1% in the previous month, all else being equal. Hence, the krone tends to continue depreciating if it depreciated in the previous month (with the opposite being the case if it appreciated). This effect may reflect herd behaviour (see Rime 2003, Chapter 8 of this Occasional Paper) and that many market participants use technical analysis. The coefficient of v_{t-1} says that the krone depreciates (appreciates) by 0.33 per cent in month t if the exchange rate in month $t-1$ was 1 per cent stronger (weaker) than the "equilibrium" exchange rate resulting from the model. This "equilibrium" rate is determined by the estimated long-run solution (see Table 1) and thus depends on the explanatory factors included in the model. The equilibrium correction comes about because investors want to sell the krone if it is (perceived to be) too strong relative to its "equilibrium" rate (the opposite being the case if the krone is too weak).

The model explains 76 per cent of the variation Δv_t; the average difference between the actual and simulated exchange rate is 0.4 per cent. Chart 5 illustrates that the model fits well over the estimation period July 1999 - January 2003[12]. It has reasonably stable coefficients and it passes standard tests of normality, autocorrelation and heteroscedasticity (not shown).

The long-run solution contains effects of the oil price, the short run interest differential and terms where the interest differential enters multiplicatively with (the logarithm of) *GHI* and the change in (the log of) US share prices over 6 months ($\Delta_6 share_t$). The multiplicative terms have the following implications:

- A change in the interest differential has stronger effect on the krone the weaker the trend in share prices has been over the past six months and the less that major currencies are expected to fluctuate. In periods with low *GHI* and a strong negative value of $\Delta_6 share_t$, investors will normally be (i) sceptical of the possibility of achieving (large) capital gains in the stock and currency markets and (ii) cautious because they have ex-

[12] We omit 1999.1 - 1999.6 as $(i - i^*)$ enters with long lags (see discussion of sample above).

perienced substantial losses on shares and because the future is deemed to be highly uncertain when share prices fall sharply. They will then place more importance on interest differentials between countries than when share prices are rising and the major currencies are expected to fluctuate widely. A higher interest differential gives a stronger krone in the short and long run for all values of GHI_t and $\Delta_6 share_t$ in the estimation period.

- The krone appreciates as a result of a fall in share prices and smaller exchange rate fluctuations abroad as long as the interest differential is positive. The effect is larger the higher the interest differential is. If the differential is positive and high, as it was through the entire sample period, the Norwegian krone is viewed as attractive by investors who are looking for alternatives to shares and short-run investments in the major currencies, see section 2. These investors move out of the krone again when the interest differential narrows (strongly), when the stock market abroad picks up again or when expected fluctuations between the major currencies widen, see section 4 below.

Chart 5. Actual and simulated value of the exchange rate (static simulation)

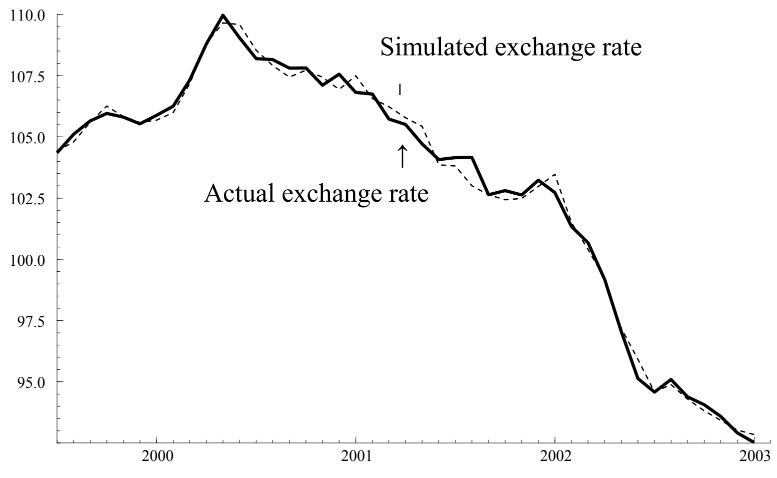


Table 2. Percentage change in the krone exchange rate resulting from isolated shifts in the explanatory variables[1)]

	Months after change				
	0	5	9	12	48
Increase in interest rate diff. by 1 pp.[2)]	–2.0	–3.5	–6.0	–6.1	–6.1
Increase in *GHI* by 10%[3)]	0.2	1.7	1.8	1.8	1.8
Increase in share prices by 10%[3)]	0.4	1.1	0.1	0.0	0.0
Increase in the oil price by 10%	–0.4	–1.2	–1.3	–1.3	–1.3

1) The entire change occurs in one month.
2) The variables ghi_t and $\Delta_6 share_t$ are assumed to be at the levels recorded in January 2003 throughout the entire period.
3) The interest differential $(i - i^*)_t$ is assumed to be at the level recorded in January 2003 throughout the entire period.

Table 2 shows the estimated movement in the exchange rate as a result of isolated changes in the explanatory variables. The estimates on the first line indicate that the krone appreciates by 2.0 per cent in the first month and by 6.1 per cent in the long run if the interest differential increases permanently by one percentage point and GHI_t and $\Delta_6 share_t$ remain unchanged at the levels recorded in January 2003; most of the effect has come through after three quarters. When interpreting this result, one must bear in mind that agents don't know how long a change in the interest differential will last. Since the interest differential is stationary, agents will not perceive a change in the differential to be permanent. Under UIP with a constant risk premium, the krone will appreciate rapidly when the interest differential increases (temporarily) and then depreciate gradually, in line with exchange rate expectations. The initial appreciation is stronger the more persistent the change in the interest differential is perceived to be. In Table 2, the gradual adjustment in the first three quarters may reflect that agents gradually expect the change in the interest differential to be more persistent in this period. It may also reflect herd behaviour, use of technical analysis and that some (non-professional) investors react slowly to changes in the interest differential[13]. The lack of overshooting may reflect that the largest market participants have a relatively short horizon: they reckon on selling their positions in Norwegian kroner before the (expected) depreciation happens. This in turn may be due to the gradual adjustment noted above and that the exchange rate is subject to new

[13] Many small foreign investors bought Norwegian interest-bearing securities in 2002 due to the high interest differential (it had been high for a long time).

shocks continuously. Under these conditions, agents may expect the krone to remain stable or to continue appreciating in the short term even though the UIP hypothesis says otherwise (see Rime 2003, Section 3 for further discussion). The adjustment in Table 2 is consistent with results from international studies, see e.g. Froot and Thaler (1990), Wadwhani (1999), Rødseth (2000, p. 60) and Sarno and Taylor (2002, p. 12).

The second line in Table 2 shows that the krone depreciates by 0.2 per cent in the short run and by 1.8 per cent in the long run if *GHI* increases permanently by 10 per cent and the interest differential remains at the level recorded in January 2003 (*GHI* fell by 38 per cent from 2000.5 to 2003.1). The short-term effect is independent of the interest differential. If share prices increase by 10%, the krone will weaken by 0.4 per cent in the short run and by 1% after 3-5 months, if the interest differential remains at the level recorded in January 2003. A change in share prices has no long-run effect on the krone as long as *GHI* remains unchanged. In the sample period, however, a fall in share prices was followed by a corresponding percentage fall in *GHI* (the opposite being the case if share prices increase), see the model of *GHI* in Table 3. This result may reflect that investors become more cautious when share prices fall: increased caution can give rise to expectations of less stock market and currency speculation, which in turn may yield expectations of smaller fluctuations between the major currencies.

Table 3. A model of *GHI*

$$\Delta ghi_t = -2.151 - \underset{(3.99)}{0.476}\, ghi_{t-1} + \underset{(3.55)}{0.477}\, share_{t-2}$$

$R^2 = 0.29$, $\sigma = 0.089$, $DW = 1.82$

The long-run solution of the model is:

$$ghi_t = -4.5 + \underset{(4.51)}{1.002}\, share_t$$

Estimation period: July 1999 - January 2003 (monthly data)

Estimation method: Ordinary least squares.

Absolute *t*-values are given in brackets under the estimates.

The variables and statistics are defined in Table 1.

The last line in Table 2 shows that the krone appreciates by 0.4 per cent in the short run and 1.3 per cent in the long run if the oil price increases permanently by 10 per cent and the other variables remain unchanged. The long-run effect is reduced to 0.7 if the estimation is instead stopped in January 2002.[14] This indicates that the estimate of 1.3 contains effects of the krone functioning as a geopolitical safe-haven currency from February-March 2002 and into 2003. In subsequent research we will attempt to capture this effect in a better way.

Table 4. Effect of changes in the interest differential at different times. Percentage change in the exchange rate after one year when the interest differential increases by 1 percentage point

March 00[1)]	Sept. 00[1)]	March 01[1)]	Sept. 01[1)]	March 02[1)]	Sept. 02[1)]	Jan. 03[1)]
–2¾	–3¾	–4½	–5	–5¾	–6¾	–6

1) The shift presupposes that ghi_t and $\Delta_6 share_t$ remain at the levels recorded in this month throughout the entire period.

As mentioned, the model in Table 1 implies that the krone responds more to interest rate changes the weaker the movements in share prices have been in the past six months and the less major currencies are expected to fluctuate. As share prices and expected fluctuations between the major currencies declined over the sample (see Charts 2 and 3), this means that the krone became more sensitive to changes in the interest differential during that period. Table 4 reports the long-run interest rate effect at different times during the sample period. The estimates indicate that the interest rate effect increased strongly from March 2000 to September 2002. In March 2000, share prices had risen substantially in the previous six months and the major currencies were expected to fluctuate widely. Investors then sought to achieve gains through speculation in the stock and currency markets and were not particularly concerned with interest differentials between countries. Hence, changes in the interest differential had relatively weak effect on the krone exchange rate. In September 2002, however, share prices had fallen sharply the previous six months and the major currencies were expected to be relatively stable. Investors were thus cautious and sceptical of the potential for returns from speculation in stocks and the major currencies; they paid considerable attention to interest differentials. Interest rate changes therefore had a strong effect on the krone. The interest rate effect decreased from September 2002 to January 2003. This reflects that $\Delta_6 share_t$ was higher in January 2003 than in September 2002.

[14] Bernhardsen and Røisland (2000) find roughly the same effect for the period 1993 - 2000.

Table 5 decomposes the appreciation of the krone in the periods May 2000 - January 2003 and December 2001 - January 2003. We combine the contributions from share prices and expected exchange rate fluctuations abroad, see discussion above. Moreover, we assume that the estimated oil price effects to some extent capture the effects of the krone functioning as a geopolitical safe-haven currency in 2002.

Table 5. Contributions to the appreciation of the krone[1)]

	Period	
	May 2000 – January 2003	December 2001– January 2003
Effects linked to the interest differential	95%	65%
• Wider interest differential	40%	30%
• Fall in shares and FX fluctuations abroad[2)]	55%	35%
Effects of higher oil price and unrest in Middle East	5%	35%

1) The figures have been rounded.
2) These factors contributed because the interest differential was positive.

The model indicates that a wider interest differential may explain around 40 per cent of the appreciation from May 2000 to January 2003. The positive interest differential caused the krone to strengthen as a result of the fall in international stock markets and expectations of lower fluctuations between the major currencies. This effect explains around 55 per cent of the appreciation. Higher oil prices and unrest in the Middle East did not contribute much to the appreciation of the krone when looking at the period May 2000 to January 2003 as a whole. These conditions may, however, explain more than one third of the appreciation from December 2001 to January 2003. The wider interest differential explains roughly 30 per cent of the appreciation in this period, whereas 35 per cent of the appreciation is ascribable to the fall in share prices and diminishing variability between the major currencies (combined with a positive interest differential).

4. Can the model explain the exchange rate movements in 2003?

The model in Table 1 was estimated with data up to January 2003. From January to July 2003, the krone depreciated by 11% against the trade-weighted exchange rate index. It then remained reasonably stable from July to November. The model predicts a depreciation of 9% from January to July when we use observed values of the explanatory factors (but use the calculated values of the exchange rate) in the forecast period, see Chart 6.[15] According to the model, the depreciation is mainly due to a narrowing of the interest differential by 2.7 percentage points from November 2002 to July 2003 (it decreased a further 0.6 pp. from July to September and then remained relatively stable to November). The model also explains the depreciation by an increase in *GHI* by 16% from November to May, a fall in the oil price by 21% from February to May and an increase in US share prices by 18% from the start of February to the end of July.

Chart 6 shows that the forecasts errors for May and August are small, but that the other forecast errors are large compared to the deviations between actual and fitted values in Chart 5. This illustrates that it is difficult to explain historical movements in the exchange rate and to predict future movements (well) with one and the same model, see the discussion in Section 1.

Our model under-predicts the depreciations from January to April and from May to July. The following conditions may explain these under-predictions:

- Signals from Norges Bank regarding interest rate cuts (in order to weaken the krone)[16] appear to have been an important factor behind the depreciations. These signals probably had stronger short-run effects on the krone than those resulting from our model (where such signals only have an effect via the three-month money market rate).
- The krone's role as a geopolitical safe-haven currency ceased when war in Iraq was imminent in February-March 2003, thereby increasing the risk premium on krone

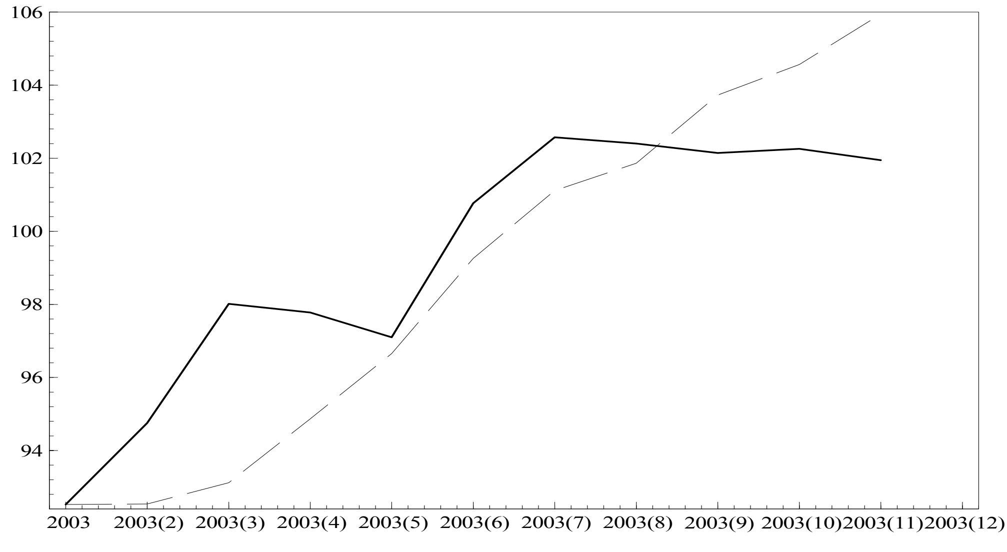
[15] We also include an impulse dummy for 2003.1 (the last observation in the sample period). The coefficient of the dummy has a *t*-value of -1.02.

[16] See the speeches "Economic perspectives" (held on 20 February) and "Financial stability, asset prices and monetary policy" (held on 3 June), published in Economic Bulletin 1/03 and 2/03 respectively.

investments (see Kloster et al. 2003, Chart 4).The model does not include explicit effects of the krone functioning as a geopolitical safe-haven currency in 2002; the effect is only captured by the oil price variable. Thus, the estimated oil price effect is probably stronger than the effect that applies when the krone does not function as a safe-haven currency. The oil price rose by 16% from December 2002 to February 2003.

- The depreciations (at least the first one) accelerated because important market participants used stop-loss strategies: they sold (their positions in) the Norwegian krone when the exchange rate fell to predetermined levels. The use of such strategies means that changes in the explanatory factors can influence the krone more rapidly when changes imply a depreciation than when they lead to an appreciation. Our model does not take this into account.

Chart 6. Actual (—) and predicted (---) values of the exchange rate (dynamic simulation)



While the exchange rate was relatively stable from August to November, our model predicts a strong depreciation (the deviation between the actual and the predicted value in November is 4%). The model predicts a depreciation because it contains strong and slowly working effects of the interest differential and because the interest differential decreased substantially in 2003. The forecast errors for September-November indicates that changes in the interest differential (all else equal) had a stronger effect on the krone in the estimation period (where the differential was above 1.8 in all months) than in the second half of 2003 (where the differential was *below* 1.8 in all months and as small as 0.5-0.6 in September-November). This may reflect that carry traders are interested in the krone as long as the interest differential is high; changes in the differential may not matter for these traders when the differential is low. Analysts and market participants did not focus on the interest differential in the period August - November 2003; some argued that further reductions in the differential would have limited effects on the krone.

5. Conclusion

In this article we have modelled the trade-weighted exchange rate index on monthly data for the period January 1999 to January 2003. We draw the following conclusions from the analysis:

- The appreciation of the krone from May 2000 to January 2003 can largely be ascribed to (i) a strong rise in the interest differential against other countries from spring 2000 to November 2002 and (b) the fact that the this differential was positive and high throughout the entire appreciation period.
- The fall in share prices abroad and reduced (expected) fluctuations between the major currencies contributed considerably to the appreciation of the krone. These factors contributed because the interest differential was positive.
- The rise in the oil price through 2002 and into 2003 made a substantial contribution to the appreciation from December 2001 to January 2003. This effect was amplified by the krone’s functioning as a safe-haven currency in connection with the unrest in the Middle East from February-March 2002 to the end of the appreciation period.
- Changes in the interest differential have the strongest effect on the krone when share prices have fallen sharply (recently) and the major currencies are only expected to fluctuate marginally. As share prices and expected fluctuations between the major currencies fell over the appreciation period, the krone exchange rate became more sensitive to interest rate changes over that period.
- Changes in share prices and exchange rate fluctuations abroad have a stronger effect on the krone the higher the interest rate is. The krone can therefore be highly volatile when Norway is in a different cyclical phase than other countries.

The model predicts most of the depreciation from January to July 2003. It misses much of the short run fluctuations in this period, however, and it cannot explain why the krone was relatively stable from July to November. As a continuation of this work, we will attempt to estimate a model that can explain more of the exchange rate movements since January 2003.

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Chapter 8 - What can financial economics teach us about exchange rates?

Dagfinn Rime[1]

This article looks at two new directions in financial economics - behavioural finance and the microstructure approach to foreign exchange - in order to cast light on mechanisms driving exchange rate movements. Changes in the Norwegian krone exchange rate during 2002 and 2003 are used as an example. The conclusion is that deviations from the "equilibrium exchange rate" may be persistent, and that it is reasonable to assume (in contrast to standard macroeconomic assumptions) that participants in the foreign exchange market have different information sets, and that this can affect the determination of the exchange rate.

1. Introduction

An exchange rate is the price of one country's money, for example euro, measured in another country's currency, for example, Norwegian krone. One would therefore expect that exchange rates depend on fundamental macroeconomic conditions (so called fundamentals), such as interest rates, inflation, economic growth, etc., in the two countries in question. Interest rates indicate the return on financial assets in the respective currencies. Inflation means that money loses its purchasing power. Economic growth says something about increases in the demand for money, among other things, for transaction purposes. This applies to both the foreign currency and to the Norwegian krone. Despite the fact that an exchange rate in many ways is a simple concept, international research has unfortunately shown that it is very difficult to find stable relationships between the exchange rate and economic variables. This also applies to movements in the krone exchange rate in recent years. The Norwegian krone appreciated sharply through 2002, by around 10 per cent against the euro, and has since (May 2003) de-

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preciated by around 10 per cent. This chapter will attempt to cast light on mechanisms in the foreign exchange market in terms of financial economics. Hopefully this might also shed some light on the fluctuations of the Norwegian krone.

The fact that it is difficult to explain exchange rate movements is, however, not as odd as it first may seem. The value of a foreign exchange investment depends on future exchange rates. The exchange rate is therefore determined by market participants' expectations regarding future exchange rates. After all, we invest in order to get a return in the future. These expectations are based on information. If the information is such that we expect that the exchange rate will be stronger (appreciate) in the future, it is in our interest to buy e.g. Norwegian krone. If a sufficient number of people expect the krone to appreciate, demand for Norwegian krone will increase and the current price of the krone will rise. Moreover, participants have to take risk into consideration. If an investment is deemed to be very risky, the investor is not that interested in paying as much. If the risk of holding foreign currency increases, the value falls. Thus we can write the exchange rate of a foreign currency as follows[2]

$$P_t = \frac{\overbrace{E_t}^{\text{Expectation}} [\overbrace{V_{t+1}}^{\text{“Value”}} \mid \overbrace{\mathcal{I}_t}^{\text{Info.set}}]}{1 + \underbrace{r_t}_{\text{interest rate}} + \underbrace{\rho_t}_{\text{risk premium}}} \qquad (1)$$

where P_t is the exchange rate in period t, $E_t[.]$ shows that there is an expectation, V_{t+1} is the correct value in the next period,[3] I_t is the relevant information on which the expectation is based, r_t is the risk-free interest rate and ρ_t is the compensation for taking risk.[4]

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[2] The foreign currency, for example euro, is seen as a 'product', and its value measured in, for example, Norwegian krone. If euro is expected to rise in value, or is assumed to be less risky, we have to pay more Norwegian krone for each euro.

[3] For the interested reader: You can think of V_{t+1} as the value of the currency, including the interest yield. You then get UIP, adjusted for the risk premium, by taking the logarithm of equation (1).

[4] Here the risk premium is formulated as the compensation demanded for investing in foreign currency. If the foreign currency is deemed to be very risky, the future value of the currency is discounted at a higher rate and the foreign currency is worth less. If foreign currency is very risky you need return in excess of the home return $(1+r_t)$ in order to make the foreign investment.

The problem with explaining exchange rate movements is that neither expectations, nor the information that forms the basis of these expectations, nor market participants' assessment of risk are things that we can observe directly. In addition, all three vary over time, making it even more difficult to establish stable relationships. There are more puzzles involved in international exchange rate research than there are satisfactory answers. The most important puzzle is linked to the fact that the variables that we believe to be important, such as interest rates, inflation and economic growth, are apparently not that important on horizons of less than one year. It is also a puzzle that the substantial *fluctuations* in the exchange rates do not seem to affect the macroeconomy. Paradoxically, it would seem that for horizons of less than one year,[5] macroeconomic conditions have no major effect on the exchange rate and that the exchange rate has no major effect on macroeconomic conditions. In addition, it is also possible that in the case of Norway, the restructuring of monetary policy to a floating exchange rate in spring 2001 was a new experience where market participants found that what they thought they knew about the exchange rate no longer applied. In other words, it created uncertainty about the structure of the market.

As with macroeconomic models for the exchange rate, traditional finance theory has not proved to be particularly well suited to explaining movements in the exchange rate. Below we will therefore try to cast light on more recent changes in the exchange rate on the basis of two new theoretical directions within financial economics: behavioural finance and the microstructure approach to the foreign exchange market.[6] The microstructure approach to foreign exchange is based more on information economics, but still within the context of rational participants, than standard macroeconomic approaches to foreign exchange. Behavioural finance, on the other hand, studies the implications of what happens when some participants do not behave "rationally" and how we can understand this. These two approaches have shown some promising results. We will start by looking at the microstructure approach.

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[5] This has been called the determination puzzle (see Frankel & Rose 1995) and the disconnect puzzle (see Obstfeld & Rogoff 2000) and is a relatively general phenomena for countries with floating exchange rates. The extent to which it will apply to Norway with a floating exchange rate regime, remains to be seen.

[6] See Lyons (2001) and Barberis & Thaler (2003) for good introductions to microstructure theory and behavioral finance. Shleifer (2000) includes reprints of Andrei Shleifer's work on behavioral finance, among others those quoted here. Thaler (1991) contains articles from the "Anomalies" column in *Journal of Economic Perspectives*, which discuss economics in the light of deviations from rationality.

2. Microstructure approach to foreign exchange

Macroeconomic exchange rate theories, be they “new open” economy variants or 1970s vintage, usually make three assumptions: *(i)* all relevant information is commonly known, *(ii)* all participants are the same and *(iii)* the structure of the foreign exchange market is of no significance to exchange rate formation. Naturally, no one believes this to be true, but the hope is that breaches of these assumptions only have negligible implications. The microstructure approach to foreign exchange focuses on deviations from these three assumptions and thus far has focused on the assumption that all information is commonly known, in particular.

The first indication that differences in information may be of importance to the foreign exchange market is the substantial volume of trade. According to BIS (2002), the volume of spot trading in the Norwegian foreign exchange market was nearly $57 billion in April 2001. In the same month, total import and export amounted to $7.4 billion. When all information is common knowledge and everyone agrees on the implications of this information for the exchange rate, new information will shift the supply and demand curves immediately so that a new (equilibrium) exchange rate is achieved without any trading taking place. Standard macroeconomic models for the exchange rate can therefore not explain why there is as much trade in the foreign exchange market as there in fact is.

All the same, the assumption that all relevant information is common knowledge appears, at the outset, to be reasonable. Given that exchange rates are determined by fundamental macroeconomic conditions, it seems reasonable to assume that all relevant information is commonly known. Hence, in order to understand what may constitute private information in the foreign exchange market, thereby breaching the common knowledge assumption, we need to be more specific about what participants could have private information about (see Figure 1). The columns in the matrix refer to the numerator (return) and the denominator (discount rate) in equation (1) and thereby to what the information includes. The rows can be seen to refer to the “quality” of the information.

Figure 1 Sources of private information

	Risk-neutral valuation	Discount rate
Concentrated information	Interest rate changes, interventions	
Dispersed information	Expectations, interpretations of public information	Risk premium (risk aversion, portfolio shift)

Normally, private information about returns on securities is regarded as concentrated return information, represented by the upper left-hand cell in the figure. This corresponds to (part of) the denominator in equation (1). Inside information in stock markets is an example of this. The insider has information that dominates that of all others. This sort of information is not the most relevant in the foreign exchange market. It is rare that anyone outside the central bank knows what changes are to be made to interest rates before they are announced. In the foreign exchange market, it is the small pieces of information that are dispersed amongst the participants (bottom line) that are most relevant. The reasoning here is that no one has superior information, as is the case with inside trading in equity markets, but rather that everyone has their bit of information.[7] The information may be how participants interpret announcements ($E_t[.]$ the expectations element), which variables they react to (I_t, the information element), or portfolio shifts that give rise to risk premiums (ρ_t). The task of a financial market is to aggregate information like this so that the exchange rate reflects as much relevant information as possible.

For every transaction there is of course both a buyer and a seller. The order flow comprises "signed" transactions. The action of the initiator of a transaction, buying or selling, determines the sign. If a participant takes the initiative for a transaction and sells euro (base currency) for krone, the order is given a negative sign; if the initiator buys euro and sells krone, it is given a positive sign.[8] So even though there is a buyer for each sale, the order flow does not necessar-

[7] The participants' information sets I_t are different, but not necessarily such that one person's information embraces everyone else's.

[8] The "product" is euro and is paid for with Norwegian krone. This is a useful perspective from which to understand why the krone weakens when the exchange rate *appreciates*: when the price of a product rises, the product (euro) is worth more, which means that the means of payment (krone) is worth less. Participants in the foreign exchange market talk about buying euro rather than selling krone, in the same way that we never sell krone when we buy a pizza.

ily add up to zero over a period. The aggregation of information occurs, among other things, when market participants observe the order flow in the market.[9] *If* the reason for the initiator to sell euro for krone is that he has reason to expect that the krone will increase in value (i.e. appreciate, but the exchange rate will fall), then observing this order flow will provide useful information and result in a strengthening of the krone (exchange rate declines; the sign for the order flow, negative, is therefore intuitive). In a microstructure model, therefore, a trader can learn what information other people have by observing the order flow. There may of course be other reasons behind the order flow, e.g. risk management or liquidity trading, but this does not diminish the value of the information, only adds noise to it.

Testing of this type of theory has been difficult due to the lack of data. The IT revolution in the foreign exchange market in recent years has, however, made it easier to record observations of order flows. Evans & Lyons (2002) have estimated a model for daily exchange rate movements that includes both order flows and changes in interest rates, which can explain over 60 per cent of exchange rate fluctuations. This is extremely high compared with most other empirical studies of exchange rate movements.[10] Furthermore, they find that most of the changes are due to the order flow and that changes in interest rates explain very little. The effect of the order flow has the same sign as the theory suggests - they find that a daily net order flow of $1 billion strengthens the dollar by 0.5 per cent in relation to the Deutsche Mark. This is also economically significant, as the average net order flow over the period was $3.9 billion.[11]

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[9] Market makers in banks are responsible for exchange rate determination, and therefore also the aggregation of information. Market makers can observe order flows, whereas normal customers cannot.

[10] Bjørn Naug's article in this collection is another example, however, not based on a particular theory model.

[11] Rime (2000) has corresponding results for the Norwegian market, but does not have the same degree of explanatory power.

However, most important is that the bulk of the effect is permanent.[12] The implication of this is that the information provided by the order flow is *relevant* and not just short-term noise. The theory of efficient financial markets can help us to understand that the effect of relevant information must be permanent. If a financial market is efficient the associated asset price can be expressed with the help of a random walk model. Efficient exchange rates aggregate all available relevant information; so given the available information, the best we can say about future exchange rates is that it is the same as today (corrected for interest rate differentials according to UIP). Or, to put it another way, movements in the exchange rate (in excess of UIP) cannot be predicted. Otherwise, not all available information would be reflected in the exchange rate. As soon as new information becomes available, e.g. from order flows, then the exchange rate will jump to its new level and be expected to stay there. Let us imagine that it is common knowledge that order flow is only of temporary importance, in other words, that market participants know that a given price change will be reversed after a time. This could not happen in an efficient market, as everyone would then know that the price would return to some level. Rather, when they then used the information to set prices for the day, they would set the price to the permanent level thereby removing any arbitrage opportunities. Hence, in an efficient market, the effect of useful information should therefore be permanent. Information that is not relevant should not have any role in determining exchange rates. There may of course be information that does have a temporary effect, e.g. price changes to induce position balancing, but it cannot be said that this is common knowledge. Furthermore, note that we do not claim that the foreign exchange market is efficient, but only point out that the impact of relevant information will be permanent. There may, however, be other pieces of information that are not fully reflected in the price.

Now, let us go back to what kind of information the foreign exchange market has to aggregate and therefore to what might be behind the order flow. This has yet to be studied satisfactorily, but recent research can give us an idea. *(i)* The balance of trade: underlying the aggregated figures in the trade balance there are a number of individual transactions in the foreign exchange market. Large banks can therefore get an idea of the trade balance long before the

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[12] Rime (2001) looks at a longer sample of weekly sales and purchases of currency in the USA and finds that a measure of cumulative order flows and the exchange rate cointegrate (Engle & Granger 1987), which implies that the effect on the exchange rate is permanent. Killeen, Lyons & Moore (2001) have also found support for cointegration.

official figures are presented, by observing the transactions of their import and export customers. *(ii)* Interpretation of announcements: all information is not aggregated through the order flow. Information about macroeconomic variables, such as changes in interest rates, may have a direct effect on prices as predicted by macroeconomic models, without there being any order flow. But if there is some uncertainty about the effect that a given change in interest rates might have on the exchange rate, market participants will be able to glean information about other people's interpretations by observing order flows. Such uncertainty does not seem unreasonable given the difficulties involved in explaining exchange rates with macroeconomic variables. *(iii*) Risk premiums: from time to time, investors may shift portfolios. Other participants in the market have to absorb this shift and therefore assume the risk. For them to assume this risk willingly, they have to receive compensation in the form of a risk premium. If someone buys Norwegian krone for euro (sells euro), then the recipient of euro will have to get a risk premium. From equation (1) we see that this would result in a fall in the exchange rate, which corresponds to an appreciation of the krone.

In what way can the microstructure approach help us to understand movements in the exchange rate? First of all, a significant permanent effect from the order flow implies that the assumptions underlying standard macroeconomic models are not correct. In particular, this shows that participants in the market have different information and expectations. This opens for the possibility that changes in macroeconomic variables may have effects other than those expected on the basis of standard macroeconomic theory. This only confirms what earlier research has shown: the foreign exchange market is difficult to understand. However, it does go a step further by pointing out possible sources as to why changes in the market are difficult to understand and that order flows can teach us something more about participants' expectations. In addition, if it is the case that market participants update their expectations based on observations of order flows, the result may be self-perpetuating waves of price and transaction patterns. In 2002, several banks reported that their order flow data showed a trend in Norwegian krone. This sort of herd behaviour is discussed in more detail below.

3. Behavioural finance

Traditional finance theories assume that participants always behave rationally.[13] Behavioural finance theory seeks instead to elucidate how participants *actually* gather, understand and process information and how they make their decisions. Results from psychology experiments are often used as a starting point. These results often show that participants do not behave in accordance with traditional theories of rational choice. Experiments show that participants often have an exaggerated belief in their own knowledge and abilities and make errors in expectations such as, for example, placing to much emphasis on observations from the recent past or events that have very little chance of occurring.[14] Or they do not sell loss positions when they should and simply follow “the fashion”. We will look in more detail at the part of behavioural finance that focuses on why the market does not adjust “incorrect pricing” when there are, or could be, irrational participants in the market.

In a well-functioning (efficient) market, the exchange rate is always “correct”.[15] Speculators, or traders, take care of this. If the exchange rate is too high, they sell and thereby push down the exchange rate, and if it is too low, they buy. In standard models, everyone will behave in this way because any deviation from the correct exchange rate represents a certain gain, an arbitrage opportunity. The exchange rate will therefore always be in equilibrium, because as soon as it deviates slightly, someone will try to make a gain. In 2002, the interest rate differential with other countries was substantial and positive, which according to the theory of uncovered interest parity (UIP) implies that the market expected the krone exchange rate to fall. If not, it would have been an opportunity for arbitrage as one could benefit from higher interest rates on Norwegian krone, without there being an expected loss on the exchange rate. The krone did not depreciate during the course of 2002. Why not?

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[13] Rational participants in financial economics maximize their expected utility and have rational expectations that are formed using Bayes' rule.

[14] It must be said that such experiments have been criticized for creating false environments. This means that the extent to which results are representative of actual economies is uncertain.

[15] Finance theory has two efficiency concepts: allocation efficiency, as in standard economics, and information efficiency. The latter is the most important concept in finance theory and says that exchange rates reflect all available information. The prices are therefore "correct."

De Long, Shleifer, Summers & Waldmann (1990) have a model for how security prices can deviate from the "correct" price when there are irrational participants in the market. It is based on the assumption that (correlated) trading by irrational participants can force prices away from the correct level. Imagine being an investor in 2002. You might have thought: "The interest rate differential is very high and has been for a while, but the exchange rate has not fallen. I am going to sell as much as I can now! I'm sure that's the best move!" The idea seems reasonable. However, the fact that the exchange rate still has not depreciated, when it seemed obvious to the trader that it should, may indicate that others perceived the situation differently. It may be that irrational participants are present in the market. In which case, the trader cannot rule out the possibility that the depreciation that he expects may not happen for some time. In the meantime, he will lose money and it is not even certain that incorrect prices will be adjusted in a market where some participants are irrational.[16] What at first appeared to be a certain gain proves to be less certain after all.

Professional traders rarely speculate with their own money, but manage other people's money. This in itself creates two problems in terms of achieving efficient prices (see Shleifer & Vishny, 1997). First, remuneration on the basis of actual gains may mean that some arbitrage opportunities are not exploited. Arbitrage opportunities that have a high expected return, but that may appear to be particularly risky, will not be exploited because there is a risk that a poor outcome may ultimately result in the manager losing his job. Another example is that if the delegating authorities reassess the manager regularly, thus encouraging the trader to be shortsighted in his positioning, the trader will often fail to take advantage of arbitrage opportunities that may not necessarily be realised before the next assessment.

Behavioural finance has also documented *patterns* in mis-pricing. In the short run, asset prices often underreact to new information, i.e. move less than implied by a fundamental model, and overreact in the long run (before returning to fundamental value). The fact that the Norwegian krone did not depreciate during 2002 may be understood in light of this. Instead of appreciating in one big jump and then starting to depreciate, the krone appreciated in small steps in each period. Hong and Stein (1999) explain short-run underreaction and long-run overreaction

[16] De Long, Shleifer, Summers and Waldmann (1990) show that it is not necessarily the case that irrational participants will be forced out of the market, as claimed by Friedman (1953).

in a model where some investors each have a private share of information about the true underlying fundamentals after an information event, hence only a share of the information can be incorporated into prices. Over time, however, they learn more and more about the information shares of others (who can keep a secret for ever?) and when all investors know all the information, i.e. the complete picture of the fundamentals, prices equal the fundamental value. As this takes time, there is underreaction in the short run. Overreaction is caused by trend-chasing investors who cannot observe whether there has been an information event or not. The gradual price process created by the informed investors gives the trend-chasers the impetus to join the trend and as they do not know the fundamental value, they may even push it past the fundamental value, thereby creating an overreaction. Barberis, Shleifer and Vishny (1998) explains the same phenomenon with a model where the investor makes mistakes about the underlying process governing fundamentals when observing prior developments. If there are several increases in a fundamental variable, they will believe that the underlying process is a trend process even if it is not. Could these kinds of mistakes or the failure to process all information help to explain the slow appreciation of the krone? The fact that so many banks reported that small investors were willing to move their savings to Norway may indicate that they believed the high interest rate differential would remain high for an unreasonably long period, i.e. governed by an unreasonable process.

And finally, "herd behaviour" must also be mentioned. This falls into the same category as "following fads", but is given equal attention in models with rational participants. Such behaviour may also help to explain the appreciation of the Norwegian krone last year. There are two arguments in particular for herd behaviour being rational.[17] Let us assume that participants are uncertain about what is the "correct" exchange rate. The fact that others are buying Norwegian krone will then be a "signal" that the exchange rate will at least not depreciate. If you are sufficiently uncertain to begin with, this signal could be given more importance than any information you already have and you simply follow the crowd. In such a scenario, the behaviour of others is an information externality. It is also possible that others' behaviour entails a return externality. If a trader believes in an arbitrage position, but can get no one else to take it, there will be no return. The strategies of different traders are complementary: the return for speculating in one direction is greater if other people do the same. And if you tie herd behaviour in

[17] See Brunnermeier (2001) for a relatively advanced presentation.

with behavioural finance, a trader seldom loses his job because he lost money in the same speculative trade in which all the other managers lost money.

So, to sum up, there are limits to how far we can rely on the market's ability to adjust “incorrect pricing” due to *(i)* the possible existence of irrational participants; *(ii)* the fact that traders act on behalf of others, and *(iii)* frequent assessment of traders. Deviations from the “correct” exchange rate may therefore be persistent. Furthermore, such deviations may be amplified by herd behaviour.

4. Conclusion

We have discussed how two relatively new theories in financial economics, behavioural finance and the microstructure approach, may help to explain movements in the krone exchange rate. There are two main conclusions. The first is that realistic assumptions regarding the behaviour of participants in the exchange market give little reason to expect that deviations from an equilibrium exchange rate will be swiftly corrected. Several studies of stock markets show that such deviations may be persistent. And secondly, we should also look to sources other than macroeconomic variables in order to understand the movements in the krone exchange rate. In a market where participants can have different information, the order flow will be an important factor in understanding these movements. What underlies order flows will be an important area of research in the period ahead. A critic could justifiably question the relevance of this to the macroeconomy. Is not the nature of the mechanism described here so short term that it is not worth worrying about? It is true that empirical studies of both microstructure and behavioural finance use high frequency data, often daily or intraday observations. *The implications* of these studies are, however, not limited to the short run. Information aggregation, which is studied in the microstructure approach, has *permanent* effects on exchange rates. Similarly, the existence of irrational participants implies that risk premiums will be *permanently* higher in those markets compared with what is expected in standard models.

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