Factors that influence the krone exchange rate

Tom Bernhardsen and Øistein Røisland, senior economists in the Economics Department, Norges Bank[1)]

This article examines how the krone exchange rate is influenced by factors such as the oil price and turbulence in international financial markets. The article contains an analysis of the krone exchange rate against the German mark (the euro from 1 January 1999) and against an average of our trading partners' currencies. In the long term, the krone exchange rate is found to be dependent on the oil price and the price differential between Norway and other countries. In the short term, the krone exchange rate is also influenced by international financial turbulence and by the interest rate differential against other countries. International financial turbulence has had a particular effect on the krone exchange rate since January 1997, when there was a sharp increase in the daily volatility of the krone exchange rate. In this period, effects stemming from international foreign exchange markets appear to have had at least as great an impact as the oil price on monthly movements in the krone exchange rate.

The estimation results indicate that the krone exchange rate against trading partners is at present considerably weaker than its long-term equilibrium rate. This being the case, it would be natural to expect a strengthening of the effective krone exchange rate over time. However, the model predicts that, measured against the euro, the krone will depreciate somewhat in the longer term. If both effects are to occur at the same time, the euro will have to appreciate considerably in relation to its present level.

1. Introduction

Exchange rates affect a country's economy in many ways. For instance, the krone exchange rate affects demand for Norwegian goods and services, the return on financial investments in Norway compared with investments in other countries, and domestic inflation through prices for imports. Since the Norwegian economy is small and very open, the krone exchange rate is of relatively great importance to economic development. This is why Norway has traditionally had the objective of a fixed or stable exchange rate. Today, monetary policy is geared towards maintaining exchange rate stability against European currencies, which Norges Bank has defined as the euro.

Since the krone exchange rate has an influence on economic developments in general and since monetary policy is aimed at achieving exchange rate stability, it is important to determine which factors affect the krone exchange rate. There is, of course, no single definitive krone exchange rate, since the exchange rate depends on the currency or basket of currencies against which the krone is measured. For instance, the krone may appreciate against the euro and depreciate against the dollar at the same time. Consequently, when the international value of the krone is measured, it should be measured against a basket of currencies. There are several indices which measure the *effective* krone exchange rate in various ways. One such exchange rate index is the *trade-weighted exchange rate index*, which measures the value of the krone against a weighted average of the currencies of Norway's trading partners.[2)]

In the long term there is a tendency for a country's exchange rate to move in line with domestic price and cost inflation relative to that of other countries. This is in accordance with the hypothesis of purchasing power parity (PPP) between countries. Although PPP does not apply in the short term, a number of international studies indicate that there is a certain degree of convergence towards PPP in the long term (see Froot and Rogoff, 1995). If the price level in one country rises more swiftly than that in other countries, there is a tendency for that country's currency to depreciate correspondingly over time. Akram (2000a) finds evidence for PPP between Norway and its trading partners in the long term.

Experience shows that it is difficult to construct robust models of short-term developments in the exchange rate (see Frankel and Rose, 1995). Random walk models, in which the exchange rate is expected to remain at the current level in the future, are often just as useful for forecasts as sophisticated models. It is hardly surprising that it is difficult to construct good models for forecasting developments in exchange rates in the short and medium term. Were it simple, it would also be easy to make money on currency speculation. However, in well functioning markets such profit opportunities would soon be exhausted. Of course, this does not prevent some market participants from making a large profit on currency speculation, but it does mean that one cannot expect to make large profits without taking considerable risks.

In this article, we take a closer look at the factors which determine exchange rate movements, focusing, unlike previous articles on the subject, on how turbulence in international financial markets affects the krone exchange rate. The article includes analyses of movements in the exchange rate between the krone and the German mark (from 1 January 1999 the euro) and developments in the trade-weighted exchange rate index. Short- and long-term exchange rate movements are modelled.

There appears to be a perception among market participants that the oil price influences the krone exchange rate. According to economic theory, a sustained rise in oil prices will result in more favourable terms of

1) Valuable comments by Farooq Akram, Steinar Holden, Bent Vale, Pål Winje and other colleagues at Norges Bank are gratefully acknowledged.

2) For an explanation of how the trade-weighted exchange rate index is calculated, see the Norges Bank website at http://www.norges-bank.no.

trade for an oil-exporting country such as Norway. This, in isolation, implies a strengthening of the exchange rate. There is also a tendency for terms of trade to have an effect on the exchange rate in other commodity-exporting countries, such as Canada, Australia and New Zealand. Akram (2000b) has studied the relationship between the oil price and the krone exchange rate. His findings show that a fall in the oil price leads to a weakening of the krone exchange rate, but that the relationship is non-linear. For instance, when the oil price is in the range USD 14 to USD 20 per barrel, the relationship is weak or non-existent.

The relationship between the krone exchange rate and the oil price probably depends on the degree of dependence of the domestic economy on the petroleum sector. If the level of domestic activity is largely independent of petroleum revenues, there is likely to be a weaker relationship between the krone exchange rate and the oil price. The Government Petroleum Fund may therefore contribute to making the krone exchange rate less dependent on the oil price.

In addition to oil prices, experience indicates that turbulence in international financial markets also affects the krone exchange rate. In the international foreign exchange market, the Norwegian krone is regarded as a "peripheral" currency. In periods of high volatility in international financial markets, there is a tendency for international agents to seek to reduce the krone holdings in their portfolios. This leads to a depreciation of the krone.

Our model of the krone exchange rate includes the price differential and the interest rate differential against other countries, as well as the oil price and an indicator of international financial turbulence. The main findings are that in the long term the krone exchange rate, measured against both the mark and the currencies of Norway's trading partners, is dependent only on the oil price and the price differential against other countries. In the short term, it is also affected by international financial turbulence and the interest rate differential. From a short-term perspective, turbulence in international financial markets appears to have been an important factor contributing to the fluctuations in the krone exchange rate since January 1997. The exchange rate between the krone and the mark is also dependent in the short term on the exchange rate between the mark and the US dollar.

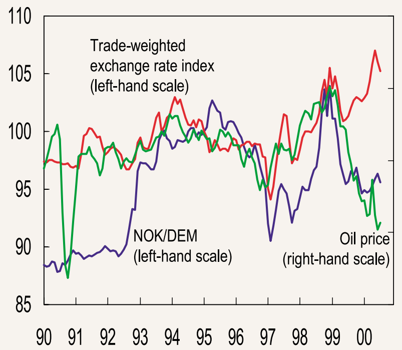
The article is structured as follows: section 2 contains an introductory discussion of krone exchange rate movements using charts; section 3 presents the model of the krone exchange rate; the estimation results are presented and analysed in section 4, and conclusions are presented in section 5. There is also an annex which describes the indicator used for turbulence in international foreign exchange markets.

2. Analysis of the charts

Before the estimated model of the krone exchange rate is presented, it may be useful to look at some charts showing movements in the krone exchange rate, measured against the mark (since 1 January 1999 the euro) and against the currencies of Norway's trading partners (trade-weighted exchange rate index), as well as some of the explanatory variables in the model. However, it is important to be aware that relationships which appear clear-cut in charts can often be misleading, particularly if there are several variables affecting the krone exchange rate at the same time. For instance, a particular variable may appear to influence the krone exchange rate, while in reality it is another variable, which is correlated with the first variable, that is causing the effect.

As mentioned, there may be a relationship between the krone exchange rate and the oil price. Chart 1 shows movements in the krone exchange rate and the oil price. It would appear that the oil price affects the krone exchange rate, measured against both the mark and the currencies of Norway's trading partners. A rise in the oil price tends to translate into a stronger krone exchange rate. However, over the past year there has been a tendency for the krone exchange rate to depreciate against an average of trading partners' currencies, despite the rise in the oil price. Moreover, the increase in the oil price has not led to a pronounced strengthening of the krone exchange rate against the euro, which has been relatively stable in the same period. The weakening of the effective krone exchange rate, even while the krone has remained relatively stable against the euro, reflects a general depreciation of the euro.

Chart 1 Trade-weighted exchange rate index, NOK/DEM exchange rate and oil price in USD. Exchange rates are in index form, with base year 1995. A rising curve denotes a falling oil price.

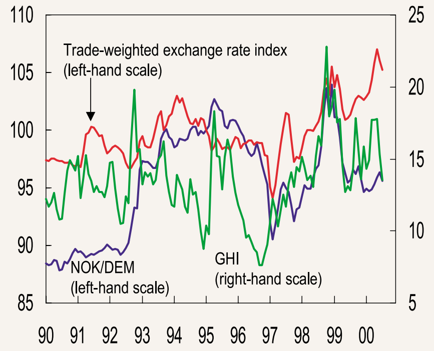


Source: Norges Bank

Before the relationship between the krone exchange rate and turbulence in international financial markets can be investigated, some means of measuring turbulence is needed. We have chosen an indicator of international financial turbulence which measures expected volatility between three major currencies: the US dollar, the mark (euro) and the Japanese yen. This indicator – the GHI (Global Hazard Indicator) – is based on prices for currency options. A more detailed account of the indicator is given in the annex. An increase in the GHI is a sign of increased uncertainty in foreign exchange markets.

Chart 2 shows movements in the krone exchange rate and the GHI. A look at the relationship between the NOK/DEM exchange rate and the GHI shows that an increase in the GHI would appear to lead to a weakening of the krone exchange rate. The relationship is particularly strong from January 1997 onwards. At that time there was a sharp rise in the short-term volatility of the krone exchange rate (see the Gjedrem, 2000). The relationship between the GHI and the effective krone exchange rate has also been relatively strong since 1997. However, the weakening of the effective krone exchange rate over the past year cannot be explained by increased turbulence in financial markets.

Chart 2 Trade-weighted exchange rate index, NOK/DEM exchange rate and Global Hazard Indicator. Exchange rates are in index form, with base year 1995



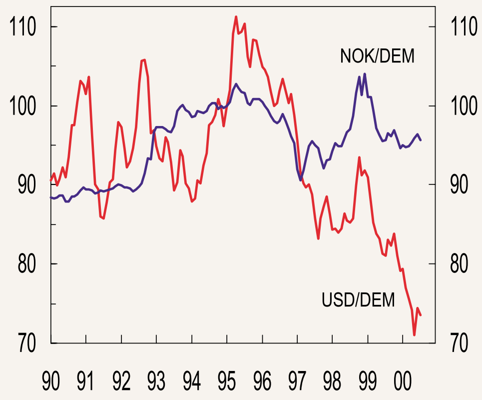
Sources: Norges Bank (trade-weighted exchange rate index and NOK/DEM) and Citibank and Chase Manhattan (GHI)

As mentioned, both the effective krone exchange rate, measured using the trade-weighted exchange rate index, and the exchange rate between the krone and the mark (NOK/DEM) will be modelled. When modelling a bilateral exchange rate such as NOK/DEM, it is important to take into account the effect of the fluctuation of the mark against other currencies, which will affect the NOK/DEM exchange rate for no reason directly related to the krone. In order to take this into account, the relationship between NOK/DEM and USD/DEM has been studied. Chart 3 shows that there has been a tendency for the krone to appreciate against the mark when the mark depreciates against the US dollar, at least in the latter half of the 1990s.

3. Modelling the krone exchange rate

As mentioned, relationships that appear clear-cut in graphical illustrations may give a misleading impression of the true relationships. To quantify the relationships and reveal the importance of the various explanatory factors, the krone exchange rate must be estimated econometrically.

Chart 3 NOK/DEM exchange rate and USD/DEM exchange rate. Exchange rates are in index form, with base year 1995



Source: Norges Bank

First, the exchange rate between the krone and the mark is modelled. As discussed in section 2, it would appear that the oil price, international financial turbulence and the USD/DEM exchange rate all influence the NOK/DEM exchange rate. In addition, the price differential between Norway and Germany has been included, to take into account any convergence towards PPP in the long term.

According to economic theory, such as the theory of uncovered interest parity, the interest rate differential also affects the exchange rate. If there is confidence in monetary policy, an increase in the interest rate differential will in isolation lead to a strengthening of the exchange rate. For this reason the interest rate differential between Norway and Germany has also been included in the model. However, it is important to note that the interest rate differential is an endogenous variable, which means that there is not necessarily any direct causal link between the interest rate and the estimated exchange rate. Historically, for instance, it has often been the case that the central bank has raised its key rate when the currency has been exposed to depreciation pressure. As such, it may appear that an increase in the interest rate differential leads to a weaker exchange rate, whereas in fact the interest rate rise prevents further depreciation. The coefficient of the interest rate differential should therefore be interpreted with caution. The other variables in the model may, however, be regarded as exogenous for Norway, which simplifies economic interpretation of these relationships.[3)]

[3)] The inclusion of an endogenous variable such as the interest rate differential in the set of explanatory variables may lead to a bias in the estimates. However, the final estimated models only include lagged values for the interest rate differential as an explanatory variable. This may reduce the problem somewhat.

Our model has the following general specification:

$$\Delta nokdem_t = a + \sum_{i=1}^{q} b_i \Delta nokdem_{t-i} - \sum_{i=0}^{q} c_i \Delta oil_{t-i} + \sum_{i=0}^{q} d_i \Delta ghi_{t-i}$$

$$+ \sum_{i=0}^{q} e_i \Delta usddem_{t-i} - \sum_{i=0}^{q} f_i \Delta rdiff_{t-i} - \theta_1 (nokdem_{t-1} + p_{t-1}^{DEM} - p_{t-1}^{NOK})$$

$$- \theta_2 oil_{t-1} + \theta_3 ghi_{t-1} + \theta_4 usddem_{t-1} - \theta_5 rdiff_{t-1} + \varepsilon_t \qquad (1)$$

where *nokdem* is the logarithm of the exchange rate between the krone and the mark (an increase indicates depreciation of the krone), *usddem* is the logarithm of the exchange rate between the US dollar and the mark (an increase indicates depreciation of the dollar), *ghi* is the indicator for international financial turbulence (an increase indicates greater turbulence), *oil* is the logarithm of the oil price measured in dollars, and ε is an unsystematic residual. Δ indicates the first differential of the variable, ie $\Delta nokdem_t = nokdem_t - nokdem_{t-1}$. Since the variables are in logarithmic form, the first differentials represent the percentage change in the variables, while the parameters may be interpreted as elasticities.[4] *rdiff* = r_{nok}-r_{dem}, where r_{nok} and r_{dem} are the one-month rates in Norway and Germany, respectively. p^{NOK} and p^{DEM} are the logarithms of the price levels in Norway and Germany, respectively.[5]

In the model, the difference terms represent relationships of a short-term nature, while the level terms represent long-term relationships.

The first level term, $\theta_1 (nokdem_{t-1} + p_{t-1}^{DEM} - p_{t-1}^{NOK})$, represents the effect on the exchange rate of a deviation from PPP between Norway and Germany. This deviation is also defined as the real exchange rate between Norway and Germany. If $\theta_1 > 0$, the exchange rate will adjust in line with PPP over time. In this case, we would expect higher domestic inflation to lead to a depreciation of the krone.

The long-term solution can be found by setting all the change terms equal to zero and solving the model with respect to the level terms:

$$nokdem = p^{NOK} - p^{DEM} - \frac{\theta_2}{\theta_1} oil + \frac{\theta_3}{\theta_1} ghi$$

$$+ \frac{\theta_4}{\theta_1} usddem - \frac{\theta_5}{\theta_1} rdiff + \frac{a}{\theta_1} \qquad (2)$$

To discuss the long-term solution, we start by assuming that $\theta_2 = \theta_3 = \theta_4 = \theta_5 = 0$. PPP will therefore be maintained in the long term, and thus the exchange rate will be independent of the oil price, international financial turbulence, etc. Long-term changes in the exchange rate will thus only reflect differences in inflation between the two countries. If θ_2 is not equal to zero, the oil price will affect the real exchange rate in the long term. The coefficient $-\theta_2/\theta_1$ expresses how an increase in the oil price affects the long-term real exchange rate.

Under certain conditions, the long-term solution may be interpreted as an "equilibrium exchange rate". A common definition of an equilibrium exchange rate is the exchange rate level which is consistent with internal and external balance in the economy. Since the present model does not represent the entire economy, it is not possible to estimate an equilibrium exchange rate in this sense. However, it is reasonable to assume that the exchange rate and the economy as a whole will move towards equilibrium in the long term, so that in a sense the long-term solution may be interpreted as an equilibrium exchange rate. However, such a definition implies that the equilibrium rate is constantly changing, partly as a result of oil price fluctuations. Thus, at any given time an equilibrium rate exists which indicates the level towards which the exchange rate is moving in the long term, provided that the values of the explanatory variables at this time do not change. Estimates for the long-term equilibrium rate therefore also involve estimates of the values of the explanatory variables in the long term. It should be noted that the equilibrium exchange rate as defined by the long-term solution is not necessarily the exchange rate level which ensures internal and external balance today.

The above model is often referred to as an equilibrium correction model since discrepancies from the long-term solution are partially adjusted in each period. The equilibrium correction term is an expression of the degree to which the exchange rate deviates from the equilibrium rate, and is given by:

$$-\theta_1 [nokdem_{t-1} + p_{t-1}^{DEM} - p_{t-1}^{NOK} + \frac{\theta_2}{\theta_1} oil_{t-1} - \frac{\theta_3}{\theta_1} ghi_{t-1}$$

$$- \frac{\theta_4}{\theta_1} usddem_{t-1} + \frac{\theta_5}{\theta_1} rdiff_{t-1} - \frac{a}{\theta_1}]$$

The coefficient of the equilibrium correction term, θ_1, expresses how swiftly the krone exchange rate moves towards equilibrium when the krone exchange rate deviates from this. In addition to equilibrium correction, the short-term dynamics of the exchange rate can be explained by the difference terms.

The model of the effective krone exchange rate, measured by the trade-weighted exchange rate index, corresponds to model (1) in which the interest rate and price differentials are measured against an average of Norway's trading partners, rather than against Germany.

In econometric analysis, model (1) is reduced in accordance with standard model specification tests. In simple terms this means that variables which do not deviate significantly from zero are excluded. The long-term solution is then calculated.

4. Results

We have estimated the relationship between the exchange rate between the krone and the mark and the explanatory variables described above for the period

4) Assume the model y = a+bx, where x = ln(X) and y = ln(Y). Then dln(X)/dX = 1/X. Assume the same for the variable y, so that b = dln(Y)/dln(X) = (dY/dX)(X/Y) = the elasticity of Y with respect to X.

5) Options data used to construct the variable *ghi* are from Citibank London and Chase Manhattan. All other data are from Norges Bank's Troll database.

1993-2000 and the sub-period 1997-2000. The fixed exchange rate system was abandoned in December 1992, so the period 1993-2000 represents a period with a floating exchange rate (managed float). Although the fixed exchange rate system was formally abandoned in December 1992, the krone remained relatively stable up to 1997. However, as pointed out by Gjedrem (2000), there was a marked shift in early 1997, with a sharp rise in the daily volatility of the krone exchange rate. In simplified terms, it may be said that the period 1993-2000 is the *formal* floating exchange rate period, while 1997-2000 constitutes the *real* floating exchange rate period.

For the period 1993-2000 as a whole we have estimated the following model for the exchange rate between the krone and the mark (written as in (1), as explained in section 3 with values of t in parentheses):

$$\Delta nokdem_t = \underset{(3.32)}{0.46} + \underset{(4.93)}{0.21}\,\Delta usddem_t + \underset{(1.76)}{0.001}\,\Delta ghi_t$$

$$+ \underset{(2.14)}{0.001}\,\Delta ghi_{t-2} + \underset{(1.76)}{0.45}\,\Delta rdiff_{t-1} - \underset{(-1.78)}{0.02}\,\Delta oil_t$$

$$- \underset{(-1.71)}{0.008}\,oil_{t-1} - \underset{(-3.28)}{0.09}\,[nokdem_{t-1} - (p^{NOK} - p^{DEM})_{t-1}]$$

$$R^2 = 0.45,\ \sigma = 0.008,\ DW = 1.73$$

The long-term solution is:

$$nokdem = 5.0 + (p^{NOK} - p^{DEM}) - 0.09\ oil$$

For the period January 1997-July 2000 we have estimated the model:

$$\Delta nokdem_t = \underset{(3.68)}{1.44} + \underset{(3.31)}{0.21}\,\Delta usddem_t + \underset{(2.29)}{0.002}\,\Delta ghi_t$$

$$+ \underset{(3.56)}{0.003}\,\Delta ghi_{t-2} + \underset{(1.84)}{0.82}\,rdiff_{t-1} - \underset{(-2.53)}{0.03}\,\Delta oil_t - \underset{(-2.24)}{0.018}\,oil_{t-1}$$

$$- \underset{(-3.72)}{0.29}\,[nokdem_{t-1} - (p^{NOK} - p^{DEM})_{t-1}]$$

$$R^2 = 0.68,\ \sigma = 0.008,\ DW = 1.73$$

The long-term solution is:

$$nokdem = 4.9 + (p^{NOK} - p^{DEM}) - 0.06\ oil$$

In the models, σ is the estimated standard deviation of the residual, R^2 is the determination coefficient, and *DW* is the Durbin-Watson test observer for residual autocorrelation. The models pass a number of standard tests for model specifications, including tests for parameter stability and residual autocorrelation. Measured by the determination coefficient (R^2), the model explains 45 per cent of the monthly movements in the krone exchange rate in the period 1993-2000, and 68 per cent of those in the period 1997-2000. Experience shows that these results are relatively high for this type of model of financial variables.

What do the estimation results tell us? Consider first the long-term relationships. The oil price is found to be the only explanatory variable in the long-term solution for the exchange rate apart from the price differential against Germany. This implies that in the long term the exchange rate between the krone and the mark will be determined by the price differential between Norway and Germany and by the oil price. The long-term solution for the whole period of 1993-2000 implies that a sustained increase of 1 per cent in the oil price will lead to a real appreciation of 0.09 per cent. The figure for the sub-period 1997-2000 is somewhat lower, at 0.06 per cent. Although there is a relatively high degree of uncertainty associated with the exact relationship between the krone exchange rate and the oil price, the estimated coefficient has the right sign in view of what one would expect from economic theory. However, in a study of a more long-term nature, Akram (2000b) does not find any systematic relationship between the krone exchange rate and the oil price in the long term. The difference between our results and Akram's may be due to our having focused on a shorter period (the floating exchange rate period) and using a slightly different model, in which we have included the GHI as an explanatory variable.

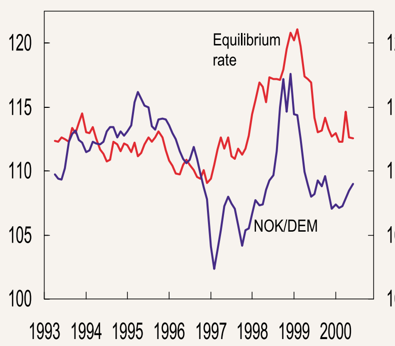
The equilibrium correction term shows that the difference between the exchange rate and the equilibrium rate was reduced by 0.09 per cent per month in the model for 1993-2000. As long as the krone is weaker than the equilibrium rate, it appreciates towards the new level, thereby reducing the gap. It is possible to calculate the half life of this adjustment. After 6.5 months, half of the appreciation towards the new equilibrium has taken place.[6] In the model for 1997-2000, the equilibrium correction term shows that the difference between the krone exchange rate and the equilibrium rate was reduced by 0.29 per cent per month. This implies a half life of a good two months for the deviation from the equilibrium rate. This is substantially faster than for the period 1993-2000 viewed as a whole. These results thus indicate that the krone exchange rate was moving more rapidly towards the long-term equilibrium level in the late 1990s than in the mid-1990s.

Chart 4 shows movements in the actual krone exchange rate and in the equilibrium rate, defined through their long-term relationship. It can be seen that there was no major difference between the actual exchange rate and the equilibrium rate until 1996-1997. At this time the krone appreciated sharply, and throughout the rest of the period it remained stronger than the model's estimated equilibrium rate. Following the appreciation pressure in 1996-1997, the actual krone

6) The formula for half life is $(1-\theta_1)^t = 0.5 \Rightarrow t = \ln(0.5)/\ln(1-q1)$, where θ_1 is the coefficient of the equilibrium correction term (see equation (1) in section 3).

exchange rate largely mirrored movements in the equilibrium rate, but at a stronger level. The fact that the equilibrium rate was not stronger towards the end of the calculation period, despite a historically high oil price, is due to the considerably higher inflation in Norway than in Germany over the past few years, so that, in isolation, the price differential would indicate a weaker nominal equilibrium rate. The model thus predicts that the krone will weaken somewhat against the euro over time if the current price differential is maintained.

Chart 4 NOK/DEM exchange rate and estimated equilibrium NOK/DEM exchange rate.Exchange rates are in index form, with base year 1995.



Source: Norges Bank

Neither financial turbulence, the interest rate differential nor the DEM/USD exchange rate appear to have any significant effect on the krone exchange rate in the long term. However, the estimation results show that the USD/DEM exchange rate, the GHI and the interest rate differential all influence the krone exchange rate in the short term, since they are of significance in the form of difference terms. For both periods, if the euro appreciates by 1 per cent against the US dollar, the krone depreciates 0.21 per cent against the euro. This means that the krone appreciates 0.79 per cent against the dollar.

An increase in international exchange rate instability, measured in terms of the GHI, will lead to a temporary weakening of the krone exchange rate. A comparison of the periods 1993-2000 and 1997-2000 reveals that financial turbulence has a greater effect on movements in the krone exchange rate after 1997, as reflected in both the size and the t-values of the coefficients. In addition, the GHI is found to explain just as much of the variation in the krone exchange rate as the oil price does after 1997.[7] This result is not unexpected in view of the visual impression given by Chart 2. One reason for the increased significance of international financial turbulence for the krone exchange rate may be that the increase in the volatility of the krone following the appreciation pressure in 1996-1997 led to a number of major international market participants "discovering" the krone as an interesting object for speculation. As a result, developments in international financial markets became of greater significance for the krone exchange rate.

So far, the factors that influence the exchange rate between the krone and the mark have been discussed. However, it is the effective exchange rate that is of greatest importance for developments in price and cost inflation, and hence competitiveness. The following model for the effective krone exchange rate has been estimated for the period 1993-2000 (where kki is the trade-weighted exchange rate index):[8]

$$\Delta kki_t = 0.98 + 0.29\ \Delta kki_{t-1} + 0.001\ \Delta ghi_{t-2}$$

(3.47) (2.92) (2.10)

$$-\ 0.02\ \Delta oil_t - 0.03\ \Delta oil_{t-2}\ -\ 0.01\ oil_{t-1}$$

(-1.73) (-2.02) (-2.13)

$$-\ 0.20\ [kki_{t-1} - (p^{NOK} - p^{KKI})_{t-1}] + 0.01\ D99$$

(-3.45) (3.57)

$$R^2 = 0.33,\ \sigma = 0.008,\ DW = 2.15$$

The long-term solution is:

$$kki = 4.8 + (p^{NOK} - p^{DEM}) - 0.06\ oil$$

The following model has been estimated for the period 1997–2000:

$$\Delta kki_t = 1.7 + 0.25\ \Delta kki_{t-1} + 0.35\ \Delta kki_{t-2} + 0.003\ \Delta ghi_t$$

(4.40) (2.09) (2.64) (3.67)

$$+\ 0.02\ \Delta ghi_{t-2} - 0.03\ \Delta oil_t\ -\ 0.018\ oil_{t-1}$$

(2.82) (-2.15) (-2.59)

$$-\ 0.35\ [kki_{t-1} - (p^{NOK} - p^{KKI})_{t-1}] + 0.014\ D99$$

(-4.38) (3.24)

$$R^2 = 0.64,\ \sigma = 0.007,\ DW = 1.92$$

The long-term solution is:

$$kki = 4.8 + (p^{NOK} - p^{KKI}) - 0.05\ oil$$

The regression coefficient (R^2) in the model explains 33 per cent of the monthly movements in the trade-weighted exchange rate index in the period 1993-2000, and 64 per cent of those in the period 1997-2000.

For both periods, only the oil price and the price differential are included in the long-term relationship. The effect on the exchange rate of a sustained rise in the oil price is approximately the same for both periods. If the oil price increases by 1 per cent, the exchange rate rises by 0.05-0.06 per cent.

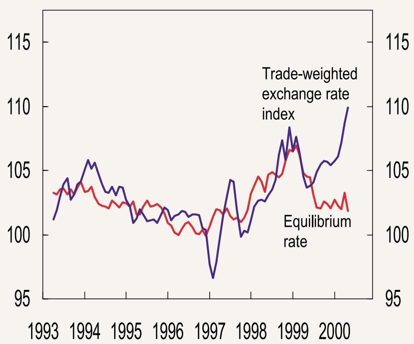
Chart 5 shows movements in the actual krone exchange rate and the equilibrium exchange rate. We see that the krone exchange rate to a large extent mirrors

7) This is shown by, among other things, the partial determination coefficients (part R^2), which are not reported here.

8) In the model of the trade-weighted exchange rate index there is a dummy variable (D99) with a value of zero up to and including April 1999 and a value of 1 from May 1999. As Chart 1 shows, there is a distinct change around the middle of 1999. After this, the oil price rises, while the effective krone exchange rate weakens. The cause of this weakening lies outside the model, and cannot be explained by developments in the oil price or any of the other explanatory variables.

movements in the equilibrium exchange rate. During the period of speculation against the krone in 1996-1997, the krone exchange rate deviated somewhat from the equilibrium rate. However, developments over the past year are the most striking. During this period the effective krone exchange rate weakened considerably, while the equilibrium rate strengthened as a result of the rise in the oil price. The weakening of the effective krone exchange rate, despite the relative stability of the krone against the euro, reflects the substantial depreciation of the euro against several currencies, including the US dollar. Thus the calculations indicate that the krone is substantially undervalued at present. If the statistical relationships that have been estimated have not changed significantly during the past year, the model predicts that the krone will appreciate in the period ahead.

Chart 5 Trade-weighted exchange rate index and estimated equilibrum trade-weighted exchange rate index. Exchange rates are in index form, with base year 1995



Source: Norges Bank

However, as seen from the analysis of Chart 4, according to the calculations the krone is somewhat overvalued in relation to the euro. The euro will have to appreciate substantially from its current level if both the exchange rate between the krone and the euro and the effective krone exchange rate are to attain their respective equilibrium levels.

Nevertheless, changes may well have occurred in the equilibrium exchange rate over the past few years. For example, the strong productivity growth in the US in recent years may have resulted in a strengthening of the equilibrium exchange rate of the US dollar, which implies a weakening of all other currencies. One important question is then whether the "productivity shock" in the US is a sustained one, and whether the rest of the world will experience the same type of productivity growth. If the shock to the US economy is subsequently reversed, or the rest of the world catches up, there is reason to believe that the US dollar will depreciate again. In such case, the effective krone exchange rate may strengthen. If the shock is sustained and restricted to the US economy, however, the weakening of the trade-weighted exchange rate index may represent a fundamental weakening of the krone, together with the rest of the world's currencies.

When it comes to short-term changes in the effective krone exchange rate, calculations of the trade-weighted exchange rate index also indicate that international currency turbulence has become increasingly important since 1997. The model for the period 1997-2000 shows that if the GHI increases by 1 percentage point, the trade-weighted exchange rate index will drop by 0.4 per cent in the first two months. The corresponding figure for the whole period 1993-1997 is 0.1 per cent. The partial determination coefficients (not reported) associated with the GHI are also substantially larger for the sub-period 1997-2000 than for the period as a whole. This confirms the results from the models of the NOK/DEM exchange rate.

5. Conclusions

We have developed a model of the exchange rate between the krone and the mark, and the effective krone exchange rate. Although experience shows that exchange rates are relatively difficult to model, we find a systematic tendency for the krone exchange rate to depend in the long term on the price differential between Norway and other countries, and on the oil price. In isolation, an increase in the price level in Norway leads to a weaker krone in the long run. A sustained rise in the oil price leads to an appreciation of the krone.

In the short term, we find that the krone exchange rate is influenced by international financial turbulence, the interest rate differential and the oil price. However, since the interest rate differential is an endogenous variable for Norway, the relationship between the krone exchange rate and the interest rate differential cannot be interpreted as a causal relationship.

There appears to have been a clear tendency for the krone exchange rate to be more strongly influenced by developments in international financial markets since 1997. The results indicate that volatility in international foreign exchange markets provides just as much of the explanation for movements in the krone exchange rate from month to month as the oil price. Part of the reason for this may be that a number of international operators have become aware of the krone as an object for speculation.

Our estimates for the long-term relationships between the krone exchange rate, the oil price and the price differential against other countries indicate that the current krone exchange rate against trading partners' currencies is substantially weaker than the equilibrium rate. If there has been no change in the equilibrium rate over the past few years, we can expect the krone to appreciate against trading partners' currencies in the period ahead. However, the NOK/EUR exchange rate is somewhat stronger than the long-term relationship would suggest. This reflects the fact that price inflation has been substantially higher in Norway than in the euro area in recent years.

It is likely that changes in the oil price and turbulence in international financial markets will continue to influence the krone exchange rate. Such disturbances lie outside the control of the central bank. Short-term movements in the krone exchange rate are therefore a permanent phenomenon.

Annex: Global Hazard Indicator, GHI

The currencies of small countries appear to have a tendency to depreciate in times of considerable uncertainty in the global economy and turbulence in international financial markets. To study the relationship between the krone exchange rate and uncertainty in global financial markets, an indicator of this type of uncertainty is needed. Prices for currency options are one such indicator, referred to as implied volatility. As described in Eitrheim, Frøyland and Røisland (1999), prices for currency options are quoted directly in terms of implied volatility, which is an expression of expected exchange rate fluctuations (measured as standard annual deviation).

Options are available for a number of currencies. The largest, most liquid markets are for the US dollar (USD), the euro (EUR) and the Japanese yen (JPY). One way of constructing an indicator based on prices for these options is to use the average implied volatility for these currency pairs.[9] However, this may produce misleading results. Brousseau and Scacciavillani (1999), two economists at the European Central Bank, have developed a formula for comparing implied volatility for USD, EUR and JPY. Using this formula it is possible to construct an indicator of global exchange rate risk – the Global Hazard Indicator.

Let σ_{DE}, σ_{DY} and σ_{EY} symbolise implied volatility for USD/EUR, USD/JPY and EUR/JPY, respectively. The Global Hazard Indicator (GHI) is given by the following formula:

$$GHI = \frac{2\sigma_{DE}\sigma_{DY}\sigma_{EY}}{\sqrt{(\sigma_{DE}+\sigma_{DY}+\sigma_{EY})(-\sigma_{DE}+\sigma_{DY}+\sigma_{EY})(\sigma_{DE}-\sigma_{DY}+\sigma_{EY})(\sigma_{DE}+\sigma_{DY}-\sigma_{EY})}}$$

The formula can be explained geometrically using Charts 1 and 2.

The bold lines represent volatility (the longer the line, the greater the volatility between the currencies labelled at the endpoints of the lines). The figure is drawn in such a way that the volatility of all three currency pairs is the same. With three variables, the GHI will be equal to the circle's *diameter*. The average volatility is represented by a third of the *circumference of the circumcircle* of the triangle. The diameter, and thus the GHI, is larger than the average volatility. To prove that this is a natural property of an indicator of global exchange rate risk, let us assume that there are no more than three currencies in the world: USD, EUR and the Danish krone (DKK).

This is represented in Chart 2, where the volatility of EUR/DKK is very low. The diameter of the circle, and thus the GHI, is approximately the same as the volatility of EUR/USD, while the average volatility is considerably lower, since the volatility of EUR/DKK pushes the average down considerably. Almost all exchange rate risk internationally will be represented here by the volatility of EUR/USD, and it is therefore natural for this to have the highest weight in the GHI.

Chart A1

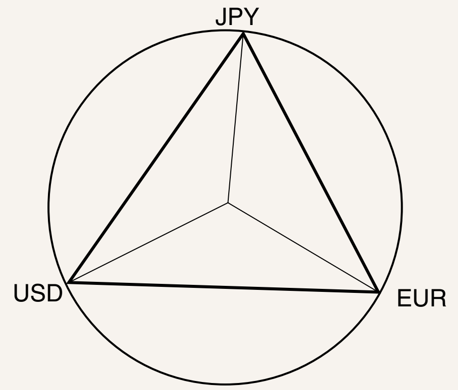
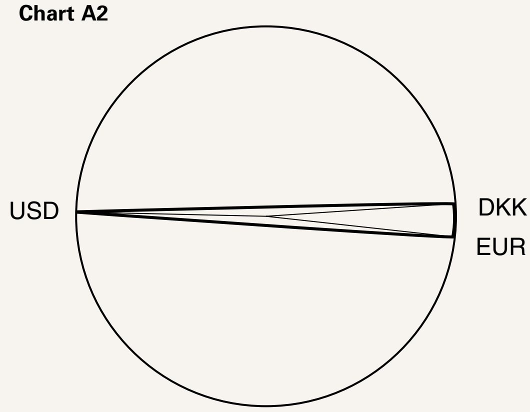


Chart A2



If Denmark had introduced the euro, reducing the volatility of EUR/DKK from low to zero, global exchange rate risk would naturally have been reduced (even if only marginally). This is the case since, while average volatility would have increased, the GHI would now be equal to the volatility of EUR/USD.

Although the GHI is a superior indicator to, for instance, average volatility, it has certain weaknesses. The main weakness is that it treats all three currencies – USD, EUR and JPY – symmetrically, despite the fact that they are not equally "heavy". It could therefore be argued that JPY has too great a weight in the formula.

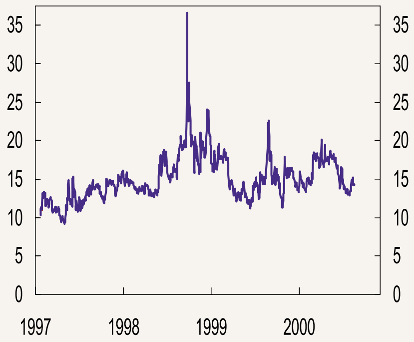
Moreover, the formula cannot be said to be immediately intuitive, even though it is in a sense theoretically consistent. However, the indicator is being adopted internationally, and we know of no alternative indicator with

[9] Before 1999, implied volatility for the mark is used

better overall properties. In any event, there is reason to believe that alternative indicators show more or less the same path as the GHI, although the level may differ.

Chart 3 shows movements in the GHI since January 1997. We see that international currency risk has fluctuated widely, and that major fluctuations are often associated with events in international financial markets. The GHI peaked noticeably in the days around 10 October 1998, the date of a sharp fall in the exchange rate between the US dollar and the Japanese yen.

Chart A3 Global Hazard Indicator. Daily observations



Sources: Citibank and Chase Manhattan

References:

Akram, Qaisar Farooq (2000a): "PPP despite real shocks: An empirical analysis of the Norwegian real exchange rate". *Working Paper* 2000/7, Norges Bank.

Akram, Qaisar Farooq (2000b): "When does the oil price affect the Norwegian exchange rate?". *Working Paper* 2000/8, Norges Bank.

Brousseau, Vincent and Fabio Scacciavillani (1999): "A Global Hazard Index for the World Foreign Exchange Markets", European Central Bank *Working Paper Series* No. 1.

Eitrheim, Øyvind, Espen Frøyland and Øistein Røisland (1999): "Can the price of currency options provide an indication of market perceptions of the uncertainty attached to the krone exchange rate?" *Economic Bulletin* Vol. LXX No. 2.

Gjedrem, Svein (2000): "Economic Perspectives". Annual address of the Governor of Norges Bank, published in *Economic Bulletin* Vol. LXXI No. 1.

Frankel, Jeffrey A. and Andrew K. Rose (1995): "Empirical Research on Nominal Exchange Rates". In Grossman, Gene M. and Kenneth Rogoff (ed.) *Handbook of International Economics Vol. 3*, North-Holland.

Froot, Kenneth A. and Kenneth Rogoff (1995): "Perspectives on PPP and Long-Run Real Exchange Rates". In Grossman, Gene M. and Kenneth Rogoff (ed.) *Handbook of International Economics Vol. 3*, North-Holland.