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

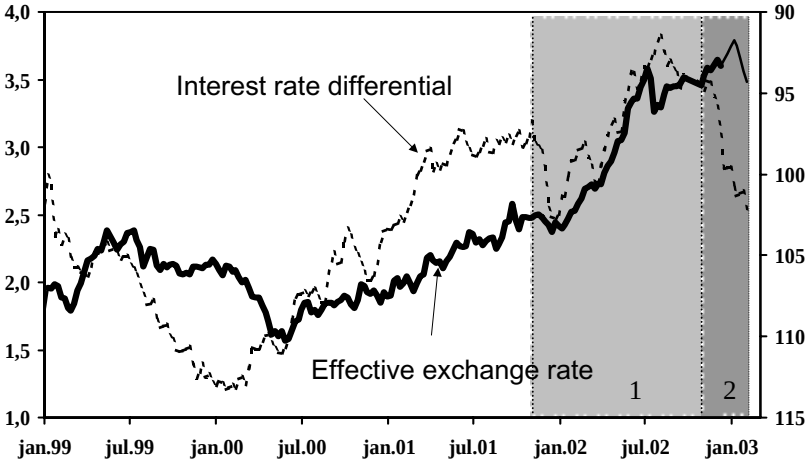
This article analyses, within the framework of uncovered interest parity, the extent to which movements in the krone exchange rate since November 2001 can be ascribed to the interest rate differential. We find that changes in the interest rate differential can explain some of the movements in the exchange 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

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

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":

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

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):

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

or alternatively

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

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

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

[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:

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

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 inter-

est 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

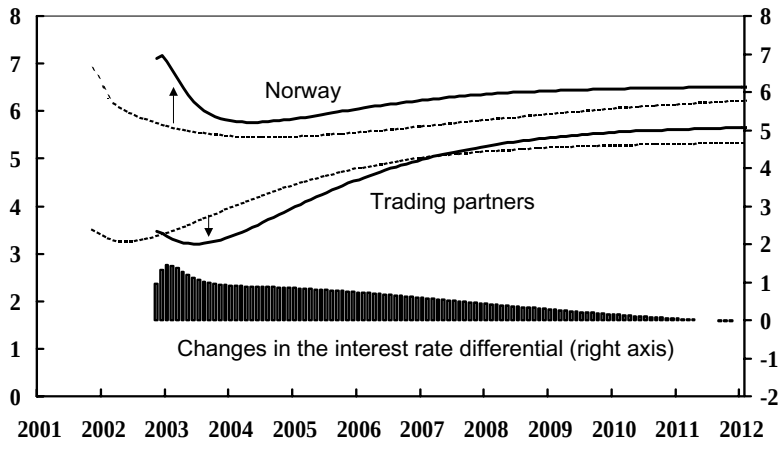


Table 1. Change in trade-weighted exchange rate index from 1 November 2001 to 4 November 2002

Per cent, percentage points in italics.

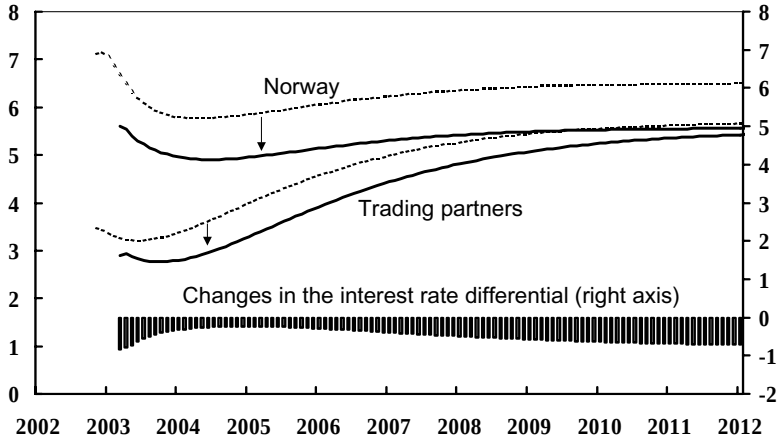
Actual exchange rate movements	(1)	8.6
Of which:		
Expected	(2)	- 2.9
"News"	(3)=(1)-(2)	11.5
Accumulated change in forward rate differentials	(4)	4.9
Of which:		
Real component	(5)	3.6 - 4.9
Inflation expectations	(6)=(4)-(5)	0 – 1.3
Contribution from interest rate differential	(7)=(2)+(5)	0.7 – 2.0
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.

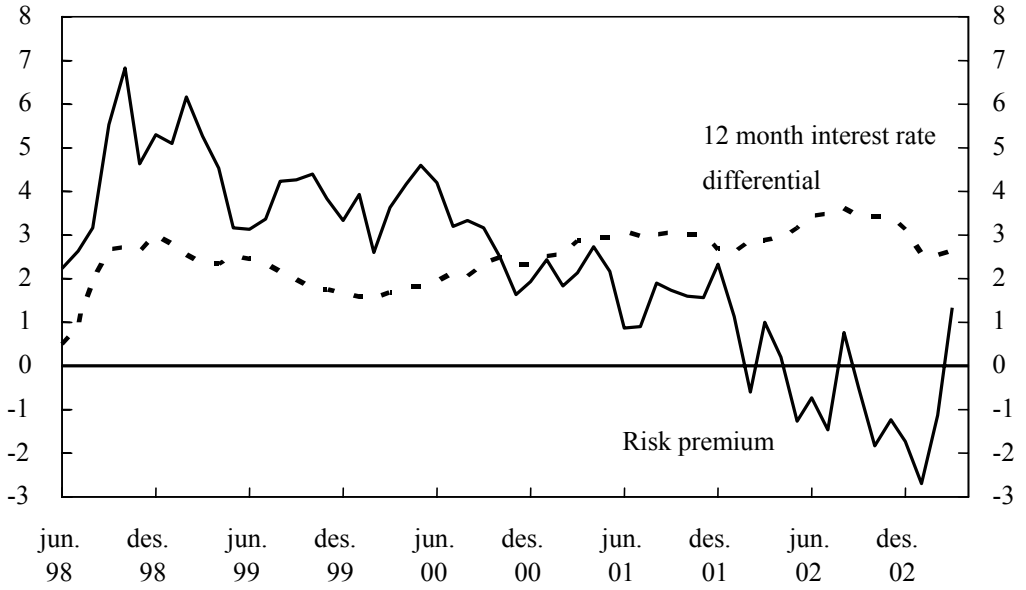
The risk premium has been reduced since the start of 2000 and has generally been negative since the start of 2002. A negative risk premium means that the expected depreciation more than offsets the positive interest rate differential. A smaller return is then expected on investments in NOK than in foreign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

[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.