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# Economic commentaries

## Estimating forward Nibor premiums

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# Estimating forward Nibor premiums

Money market premiums show the difference between unsecured money market rates and expected key rates over the same time horizon. The premium expresses the additional return money market participants require for unsecured interbank loans in relation to the risk-free interest rate in a given period. The premium is compensation to the lender for credit risk and the benefit foregone from relinquishing liquidity. Prior to the financial crisis money market premiums were low and stable both in Norway and other countries. They soared in autumn 2008. Even though they have come down somewhat since then, in recent years premiums have been high for long periods and have fluctuated to a further extent than prior to the crisis. As a result, the uncertainty surrounding estimates of future premiums is greater than earlier.

Most economies have a market for expected overnight interest rates, or the overnight index swap (OIS)<sup>1</sup>. Expected overnight interest rates are closely linked to expected key policy rates. An OIS market makes it possible to extract both premium and key policy rate expectations directly from market prices. Norway does not have such an OIS market. Norges Bank still seeks to provide some indication of the market's key policy rate expectations and the market's pricing of expected money market premiums. The market's key policy rate expectations can be used to assess any deviations from Norges Bank's own key policy rate path. The market's premium expectations are of interest as the premium influences the level of market interest rates and hence the monetary policy transmission mechanism; the channel from the key policy rate to market rates with longer maturities, to real variables and to inflation. Moreover, money market premiums are an indicator of the degree of stress in financial markets.

Expected money market premiums are referred to as forward premiums. In this *Commentary*, we take a closer look at approaches to estimating forward premiums using market prices.

## The Norwegian money market rate, Nibor

The Norwegian interbank rate Nibor is defined in a regulation issued by the trade organisation for banks, Finance Norway (FNO). The regulation took effect on 1 August 2011. The regulation states the following:

*"Nibor is intended to reflect the interest rate level lenders require for unsecured money market lending in NOK. The rates shall reflect the interest rates the bank charges on lending in NOK to a leading bank that is active in the Norwegian money and foreign exchange markets"*

Nibor thus shows the interest rate that banks in the Nibor panel<sup>2</sup> on average indicate that they require for lending Norwegian kroner to other leading banks that are active in the Norwegian money and foreign exchange market in a given period.

## Nibor and covered interest parity

The Norwegian interbank market for unsecured loans with longer maturities than a few days is marked by little activity. Traditionally, price providers in the Norwegian money market have therefore quoted Nibor using the interbank rate in USD and forward points between USD and NOK in the foreign exchange market in line with covered interest parity. This is expressed by

$$(1) \quad (1 + i_N) = \frac{F}{S} (1 + i_{N,USD})$$

where  $i_{N,USD}$  is the USD rate Nibor banks apply,  $F$  is the forward exchange rate and  $S$  is the spot rate (number of NOK per USD, so that an increase denotes a weaker krone).<sup>3</sup> When covered interest parity holds, the forward points in the foreign exchange market (difference between forward exchange rates and spot rates,  $F-S$ ) are compensating for the difference between interest rates in different currencies. The theory states that deviation from such an equilibrium implies an opportunity for risk-free gains. Such arbitrage opportunities cannot persist over time in an efficient market.<sup>4</sup>

<sup>1</sup> Expected key rates can be measured by the Overnight Index Swap (OIS). They provide an expression of the market's estimates of expected overnight interest rates and are closely linked to expected key rates. The three-month OIS is used as a measure of the expected average key rate over the next three-months. There is no OIS for Norway, but Norges Bank estimates an interest rate corresponding to the OIS based on other interest rates in the market and judgement.

<sup>2</sup> The banks included in the Nibor panel are DNB, Nordea, Danske Bank, Handelsbanken, SEB and Swedbank.

<sup>3</sup> In equation (1), the maturity is assumed to be one year with annualised rates. If the interest period deviates from one year, either the interest rates or the fraction  $F/S$  must be adjusted so that all the factors in the equation represent the same number of days.

<sup>4</sup> Covered interest parity is further discussed in the appendix.

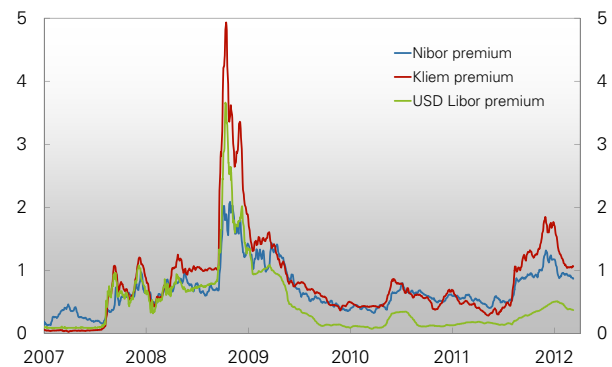
Prior to the financial crisis, the banks in the Nibor panel used Libor for USD as a basis for calculating Nibor.<sup>5</sup> Even though Libor increased sharply after the collapse of Lehman Brothers in September 2008, many participants argued that actual rate at which it was possible to borrow USD in the interbank market had increased even more. In September 2008, the banks in the Nibor panel decided to switch from applying Libor as a basis for Nibor to an interest rate they deemed to be closer to reality. The Nibor banks have reported since the Lehman bankruptcy that they have chosen to use the USD rate that is published by interbank broker Carl Kliem in Frankfurt as a basis for Nibor.

## The premium in Kliem and Nibor rates have moved in tandem over time<sup>6</sup>

Chart 1 shows the premiums in three-month Libor, Kliem and Nibor rates.<sup>7</sup> Up to the Lehman bankruptcy, the premiums in Kliem and Libor rates showed a fairly similar movement over time. The premium in Nibor was somewhat higher. After the Lehman bankruptcy, the premiums rose in all three money markets. The increase in the Kliem premium was, however, clearly more pronounced than the increase in the Libor premium, possibly reflecting Libor's underestimation of the actual rate on unsecured USD loans, at least for European banks. The premium in Nibor also increased in autumn 2008, but not to the same extent as for Libor and Kliem. This was primarily because the forward points between USD and NOK fell markedly owing to increased demand for USD (further discussed below).

Given the assumption that the banks in the Nibor panel use the Kliem rate as a basis for Nibor quotes, the Kliem rate provides an starting point for the discussion of Nibor premiums ahead.

Chart 1: Premiums in Kliem and Nibor have moved in tandem over time. Three-month money market premiums. Percentage points. Daily data. 5 day moving average. 1 January 2007 – 8 March 2012



Sources: Bloomberg, Thomson Reuters and Norges Bank

## What does the Kliem rate express?

Price providers in the Norwegian interbank market argue that the Kliem rate is the interest rate that best expresses the USD cost for European banks. The premium in the Kliem rate can be shown to be approximately equal to the sum of two variables; the premium in the interbank rate in the euro area (Euribor) and a shortage premium on USD, expressed by the OIS basis (this relationship is derived mathematically in the appendix). The OIS basis shows the difference between the OIS rate in USD that is priced in the market and the implied USD rate that is obtained by exchanging USD against EUR in the foreign exchange market. The OIS basis is expressed by

$$(2) \quad OISB_{EURUSD} = i_{OIS,USD,actual} - i_{OIS,USD,viaEUR}$$

where  $i_{OIS,USD,actual}$  is the actual OIS rate in USD and  $i_{OIS,USD,viaEUR}$  is the USD rate swapped from euro. If covered interest parity holds, the OIS basis is zero. The OIS basis moves away from zero if the forward exchange rate does not compensate for the difference between the OIS rate in EUR and USD. If there is a dollar shortage in the market, the implied USD cost for banks that seek to use EUR to procure USD will increase. The implied USD rate (swap rate via EUR) is then higher than the OIS rate in USD and the OIS basis is quoted with a negative sign in the market.

Chart 2 shows how the Kliem rate is approximately equal to the Euribor premium and the OIS basis between EUR and USD. In the chart, the OIS basis between EUR and USD is inverted.<sup>8</sup>

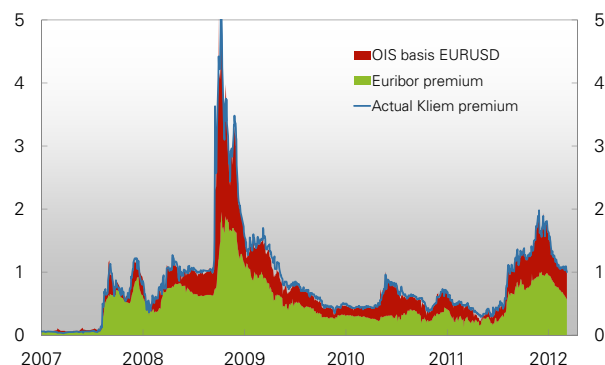
<sup>8</sup> If the OIS basis is for example -2 percentage points, it is presented in the chart as +2 percentage points.

<sup>5</sup> This means that  $i_{N,USD}$  was equal to Libor in equation (1).

<sup>6</sup> A more precise mathematical presentation of the connection between NOK, USD and EUR premiums is presented in the appendix.

<sup>7</sup> As there is no OIS market in Norway, the Nibor premium is derived from Norges Bank's estimation of market participants' key rate expectations. The expected key rate in Norway is estimated on the basis of market interest rates, interviews of market participants and judgement. Judgement includes comparing the OIS estimate with other market prices, including OIS rates in other countries, money market premiums in other countries and forward exchange rates between NOK and other currencies. The accuracy of the OIS estimates can be evaluated by looking at the reactions in Nibor and FRA rates immediately after Norges Bank's monetary policy meeting. The results of such comparisons imply that the errors in our OIS estimates are relatively small and the error is not systematically in the same direction each time.

Chart 2: The Kliem premium consists of the premium in the Euribor rate and the OIS basis between EUR and USD (inverted). Percentage points. Daily data. 1 January 2007 – 29 February 2012



Sources: Bloomberg, Thomson Reuters and Norges Bank

## The premium profile for the Kliem rate

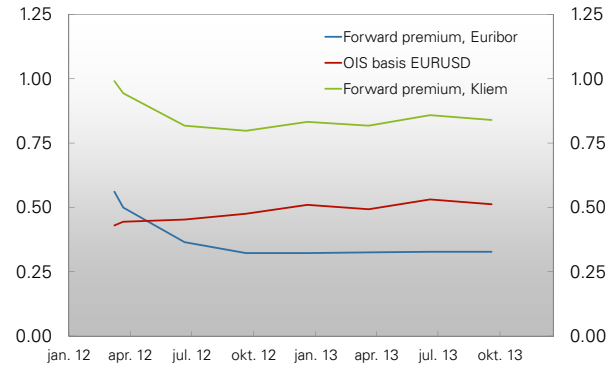
As shown above, the Kliem premium consists of the premium in the Euribor rate and the shortage premium on USD expressed by the OIS basis between EUR and USD. The market quotes prices for future Euribor premiums and OIS bases at various maturities. The forward OIS bases between EUR and USD can be calculated from the market quotes.<sup>9</sup> The forward Kliem premium for a given point in the future is the sum of the forward Euribor premium and the forward OIS basis.

Chart 3 shows today's premium in the Euribor rate and the market's pricing of the Euribor premiums on IMM dates<sup>10</sup> two years ahead (blue line). The chart also shows the estimated forward OIS bases between EUR and USD (inverted, red line). The sum of these two variables is the forward premiums for Kliem at different dates (green line).

<sup>9</sup> The forward (implied) OIS bases are estimated in the same way as implied interest rates are estimated from the yield curve

<sup>10</sup> IMM (International Monetary Market) dates are used as settlement dates for a large number of money market instruments. IMM dates are defined as the third Wednesday in March, June, September and December.

Chart 3: Forward premium in 3-month Euribor rate (blue), forward values for OIS basis between EUR and USD (red, inverted) and forward premium for Kliem rate (green). Basis points. 8 March 2012



Sources: Bloomberg and Norges Bank

## The premium profile for Nibor

Even though the Nibor premium may deviate from the Kliem premium, particularly when the Kliem premium is high, they have generally moved in fairly close tandem over time. Kliem's premium profile therefore provides a natural starting point for assessing developments in the Nibor premium ahead.

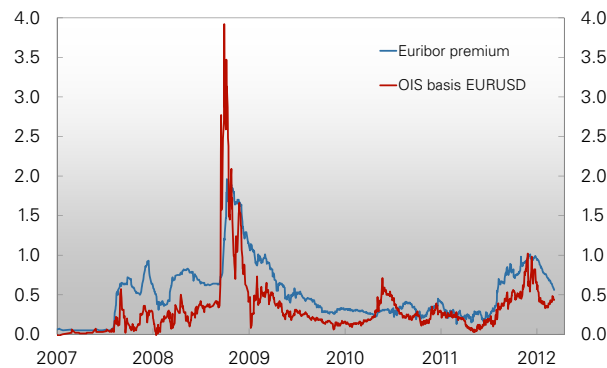
There is still reason to make adjustments based on judgment so that the Nibor premium ahead will deviate from the estimated forward premium in the Kliem rate: (i) developments in the OIS basis between EUR and USD, (ii) developments in the USD rate applied by Norwegian banks in Nibor relative to Kliem and (iii) developments in the forward points between USD and NOK.

### (i) Developments in the OIS basis between EUR and USD

As shown in Chart 3, market pricing indicates that the Euribor premium is expected to edge down in the years ahead. This may reflect expectations that the euro area crisis will ease and European unsecured bank funding markets gradually improve. At the same time, the OIS basis suggests growing pressures on demand for USD via the forward foreign exchange market (see rising inverted red line in Chart 3). Such a development might seem inconsistent with the expected movement in the Euribor premium. If the crisis is expected to recede gradually in the coming years, it might also be natural to assume that the access to USD will improve gradually so that the OIS basis between EUR and USD will move towards zero again. This has also been the tendency in recent years: the Euribor premium and the OIS basis between EUR and USD have generally moved in the same direction (see Chart 4). A fall in the Euribor premium has occurred when the OIS basis between EUR and USD has

approached zero. An expected improvement in the conditions for unsecured EUR funding is consistent with a comparable development in USD. This indicates a future decline in the OIS basis between EUR and USD and warrants a downward adjustment in excess of the rate provided by the estimated forward OIS bases<sup>11</sup>.

Chart 4: Euribor premium and OIS basis between EUR and USD (inverted). January 2007 – February 2012. Percentage points. Daily data. 1 January 2007 – 2 February 2012



Sources: Bloomberg, Thomson Reuters and Norges Bank

### (ii) Developments in Nibor-banks' USD interest rate

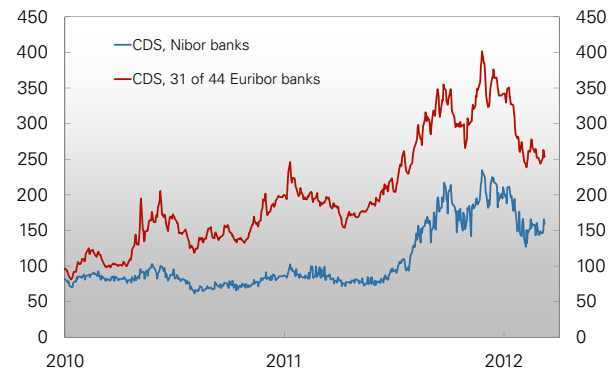
Although the Nibor premium has followed the Kliem premium through longer periods, it does not necessarily mean that Kliem should be used for quoting NIBOR in future. Fundamental conditions may in fact warrant the use of a lower interest rate. One factor that should be reflected in a money market rate is the credit risk that can be linked to the banks that participate in the relevant market. The market price of credit risk in the longer term for the banks that participate in the Euribor panel is very different from the price of credit risk for Nibor banks. Chart 5 shows the average five-year credit default swap (CDS) premium for banks in the Nibor panel and the average of the same type of premium for 31 of the 44 Euribor banks.<sup>12</sup> The chart shows that the difference in credit risk in the past few years has been considerable and, all else being equal, it should be expected that Nibor banks are facing a lower

11 The OIS bases can contain term premiums. When there's a shortage of USD, market participants will likely be willing to pay more to secure USD funding over a longer period of time than risking renewing financing during the period. This may move the forward exchange rates on longer maturities more than forward exchange rates on shorter maturities. This might cause the implicitly calculated forward OIS bases to overestimate the market's expectations of future OIS bases. If this is the case, it's fair to conclude that the market's expectations is lower than the implicit short OIS bases. This is analogous to the term structure of the yield curve, where term premiums might lead implicit forward rates to overestimate the market's expectations of future short interest rates.

12 CDS (Credit Default Swap) provides an expression of the cost of insuring against default on an underlying security and is thus an expression of the credit premium for the issuer of this. For a bank, the CDS price expresses the premium linked to an unsecured bond issued by a bank. Norges Bank has access only to historical CDS prices for 31 of the 44 banks in the Euribor panel.

USD rate than the Kliem rate.

Chart 5: Estimated average five-year CDS premium for Euribor banks and average five-year CDS premium in EUR for Nibor banks. Daily data. 1 January 2010 – 8 March 2012. Basis points



Sources: Bloomberg and Norges Bank

Data for banks' borrowing from US money market funds also indicate that Nordic banks face a lower dollar cost than European banks. Since mid-2011, these funds have reduced their lending to European banks fairly markedly, while lending to Nordic banks has increased somewhat. US money market funds are among the most important lenders in the US money market. If short-term funding from these funds becomes scarcer, a bank will have to bid up the price of funding from other sources, all else being equal. While European banks probably have had to bid up the price of short-term funding, this was a situation Nordic banks have presumably been able to avoid in equal measure<sup>13</sup>.

### (iii) Developments in the OIS basis between USD and NOK

If we assume Norges Bank's estimated OIS rate, we can calculate the OIS basis between USD and NOK. This has the same interpretation as the one between EUR and USD, it reflects relative supply and demand pressure for the various currencies. When the price of borrowing USD rises in the unsecured interbank market, some participants will try to borrow USD through the foreign exchange market. They buy USD and sell NOK spot, while selling USD and buying NOK forward. This pushes up the forward price of NOK against USD, with the result that forward points and thus the OIS basis fall ( $\Delta F < 0$  in equation 1). The fall in forward points dampens the effect of a higher USD premium on the premium in Nibor<sup>14</sup>.

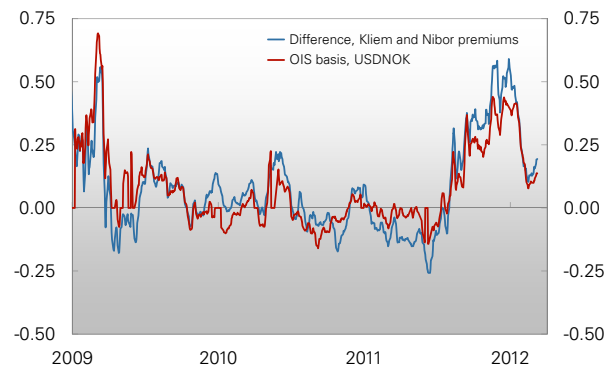
13 Another possible interpretation is that Nordic banks have been willing to pay more for funding from US money market funds, while Nordic banks were able to manage without bidding up the price. However, available market prices suggest the first explanation.

14 If the premium in USD increases, and forward points remain unchanged, the USD premium will spread to the Nibor rate at a one-to-one ratio. If forward points fall, there will be less contagion (see appendix for the mathematical derivation).



Chart 7 shows the OIS basis between EUR and USD, according to our estimates, and difference between the premiums in three-month Kliem and Nibor rates. It is primarily the OIS basis that explains the difference between premiums. The reason for differences in premiums not due to the OIS basis between USD and NOK is that banks assume a USD interest rate in the three-month Nibor quotations that differs from the three-month Kliem rate.

Chart 6: Estimated OIS basis between USD and NOK and difference between premiums in three-month Kliem and Nibor rates. Daily data. 1 January 2009 – 8 March 2012. Percentage points



Source: Norges Bank

## Premium profile for three-month Nibor rate in MPR 1/12

The premium profile for the three-month Nibor is derived on the basis of observed market prices (plus the estimated OIS for Norway) as well as judgement adjustments as discussed in (i)-(iii) above. The premiums in MPR 1/12 are based on the following criteria:

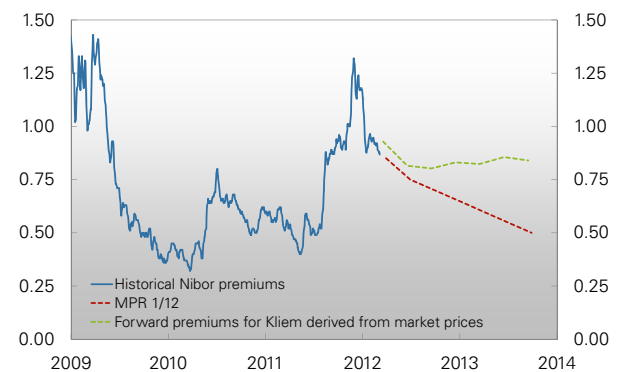
- It is assumed that the OIS basis between EUR and USD will approach zero (see discussion relating to Chart 4 above). It is also assumed that the OIS basis between USD and NOK will approach zero, but not as quickly as between EUR and USD<sup>15</sup>. The fall in the OIS basis between EUR and USD is the most important single factor in Norges Bank's adjustments. The assumed fall in the OIS basis between EUR and USD is one reason that the premium in the Nibor is estimated approximately in line with market participants' expectations for the premium in the Euribor rate at end-2013. As at 8 March, the term premiums for Euribor is approximately 35 basis points in December 2013.
- Second, the assumption is that price providers in the

<sup>15</sup> It makes sense to assume that the OIS bases will approach zero simultaneously. They express the demand for USD relative to other currencies. If the pressure abates, it is natural to assume that this will apply to more currency crosses.

Norwegian money market will continue to quote Norwegian banks a USD interest rate that is somewhat lower than the three-month Kliem rate. This makes sense, since the three-month Kliem rate reflects premiums that seem to be too high for Nordic banks.

Chart 7 shows historical data for premium in the three-month Nibor rate (solid blue line), the premium profile derived from market prices without any form of adjustment (green line), and Norges Bank's projection for the premium in the three-month Nibor rate in MPR 1/12 (red line). The red line (MPR 1/12) has been adjusted to reflect the assumption that the OIS basis between EUR and USD will approach zero somewhat quicker than currently priced in the market and the assumption that Nibor banks apply a USD interest rate somewhat lower than the three-month Kliem rate in their Nibor quotation<sup>16</sup>.

Chart 7: Historical premium in the three-month Nibor rate (solid blue line), market prices for forward Kliem premiums (broken green line) and Norges Bank's projection for the premium in the three-month Nibor-rate in MPR 1/12 (broken red line). Percentage points



Sources: Bloomberg, Thomson Reuters and Norges Bank

<sup>16</sup> Norges Banks assesses the projections of premiums for reasonability. A cross-check of premiums in forward rates can be obtained by subtracting the alternative premium paths from observed FRA rates. FRA rates are market estimates of future Nibor rates. If the implied path for market expectations regarding the key policy rate does not seem reasonable, the projections for forward premiums are reassessed.

## Appendix: Relationship between interest rate premiums in NOK, USD and EUR

In this appendix we derive relationships between the interest rate premiums in NOK, USD and EUR.

### (i) Relationship between the NOK premium and the USD premium

The NOK rate must be consistent the USD rate and the forward premium, the difference between the forward and the spot price. This means that the NOK interest rate can be written as

$$(1) \quad i_N = i_{N,\$} + (f_{USDNOK} - s_{USDNOK})$$

where  $i_{N,\$}$  is the USD interest rate Nibor banks are changed in the unsecured USD market and that they assume for their Nibor quotation,  $f_{USDNOK}$  is the forward exchange rate,  $s_{USDNOK}$  is the spot exchange rate, and  $i_N$  is the implied NOK interest rate. Exchange rates are in logarithmic form and are defined as NOK per USD. Thus, an increase implies a weaker krone<sup>17</sup>.

In recent years the USD interest rate on which the Nibor quotation has been based has been close to the Kliem rate, but we allow for these rates to diverge, i.e. that

$$(2) \quad i_{N,\$} = i_{K,\$} + i_{DK,\$}$$

where  $i_{K,\$}$  is the Kliem rate and  $i_{DK,\$}$  the deviation between Kliem and the USD rate assumed in the Nibor quotation. Thus

$$(3) \quad i_N = i_{K,\$} + i_{DK,\$} + (f_{USDNOK} - s_{USDNOK})$$

Furthermore, the interest rate premium in NOK and USD is provided by the equations

$$(4) \quad rp_N = i_N - i_{OIS,N}$$

<sup>17</sup> Equation (1) is covered interest parity (CIP). CIP holds when the interest rates and the exchange rates can be traded in efficient markets. The implied interest rate differential reflected in the forward exchange rate shall be equal to the interest rate differential between the two currencies. The derivation is as follows: An investor can invest a krone domestically and obtain return  $(1+i_N)$  with safety in three-months. Or, he can first exchange the krone for a dollar today at the current spot price, and get USD  $1/S$ , where  $S$  is the NOK spot price (number of NOK per USD). Then he can invest the amount he exchanged for USD interest, and receive USD  $1/S (1+i_{N,\$})$  with safety in three-months. He sells this USD amount already today in the forward market at the current forward price,  $F$ . He knows, then, that he will receive with safety NOK  $F/S (1+i_{N,\$})$  in three-months. Since these two investment alternatives yield a safe return, they must be equal, that is  $(1+i_N) = F/S(1+i_{N,\$})$ . Taking the logarithm of both sides results in the equation  $i_N = i_{N,\$} + (f-s)$ , where  $f = \ln(F)$ ,  $s = \ln(S)$ ,  $i_N \approx \ln(1+i_N)$  and  $i_{N,\$} \approx \ln(1+i_{N,\$})$ .

$$(5) \quad rp_{K,\$} = i_{K,\$} - i_{OIS,\$}$$

where  $i_{OIS,\$}$  and  $i_{OIS,N}$  are the OIS-rates for USD and NOK, respectively. Inserting (3) and (5) into equation (4) results in

$$(6) \quad rp_N = rp_{K,\$} + i_{DK,\$} + (f_{USDNOK} - s_{USDNOK}) - (i_{OIS,N} - i_{OIS,\$})$$

The NOK interest rate premium (the premium in the three-month Nibor rate) is equal to the premium in the three-month Kliem rate plus the deviation between the Kliem rate and the USD interest rate on which the Nibor is based, in addition to the difference between the forward premium and the difference between OIS interest rates. The last segment is referred to as the OIS basis and is given by

$$(7) \quad OISB_{USDNOK} = i_{OIS,N} - [i_{OIS,\$} + (f_{USDNOK} - s_{USDNOK})]$$

If the covered interest parity holds,  $i_{OIS,N} = i_{OIS,\$} + (f_{USDNOK} - s_{USDNOK})$ , and the OIS basis is zero. If there is a shortage of USD, market participants will try to obtain USD via the forward exchange market. They buy USD and sell NOK spot, and sell USD and buy NOK forward. Forward purchases of NOK boost the NOK forward price ( $\Delta f < 0$ ), so that the forward premium falls and the OIS basis increases. In other words, when there is a shortage of USD, there will be a tendency for the OIS basis between USD and NOK to increase.

Thus, we see that (equations 6 and 7 combined)

$$(8) \quad rp_N = rp_{K,\$} + i_{DK,\$} - OISB_{USDNOK}$$

Chart 1 in the body of the article shows that the premium in the three-month Nibor rate has been considerably lower than the premium in the three-month Kliem since the second half of 2011. Equations (6) and (8) show that this may be due to two circumstances: (i) the Nibor quotation is based on a USD interest rate lower than Kliem ( $i_{DK,\$} < 0$ ), and/or the (ii) OIS basis between USD and NOK is positive owing to a shortage of USD.

### (ii) Relationship between the premium in USD and the premium in EUR

The relationship between the premium in USD and the premium in EUR is analogous to the relationship between the premium in NOK and the premium in USD: The USD interest rate must be consistent with the EUR rate and the

forward premium or discount. Covered interest parity is given by

$$(9) \quad i_{\$} = i_{Euribor} + (f_{EURUSD} - s_{EURUSD})$$

where  $i_{\$}$  is the USD interest rate,  $i_{EUR}$  is the three-month Euribor,  $f_{USDEUR}$  is the forward exchange rate and  $s_{US-DEUR}$  is the spot rate. Both exchange rates are defined as number of USD per EUR, so that an increase implies a weaker dollar (logarithmic form). The USD interest rate ( $i_{\$}$ ) in equation (9) is the USD interest rate resulting in covered interest parity between this rate, the Euribor rate and the forward premium or discount traded in the market. It is appropriate to divide this USD interest rate in two, the three-month Kliem rate and the deviation from the Kliem rate, i.e.

$$(10) \quad i_{\$} = i_{K,\$} + i_{DEK,\$}$$

where  $i_{DEK,\$}$  is the deviation from the Kliem rate (“Deviation Euro Kliem”). If covered interest parity holds for the three-month Euribor and Kliem rates,  $i_{DEK,\$} = 0$ . Inserting equation (10) into (9) results in

$$(11) \quad i_{K,\$} = i_{Euribor} - i_{DEK,\$} + (f_{EURUSD} - s_{EURUSD})$$

Furthermore, the interest rate premiums are given by

$$(12) \quad rp_{K,\$} = i_{K,\$} - i_{OIS,\$}$$

$$(13) \quad rp_{Euribor} = i_{Euribor} - i_{OIS,EUR}$$

Inserting equations (12) and (13) into (11) results in

$$(14) \quad rp_{K,\$} = rp_{Euribor} - i_{DEK,\$} + (f_{EURUSD} - s_{EURUSD}) - (i_{OIS,\$} - i_{OIS,EUR})$$

The OIS basis between EUR and USD is given by

$$(15) \quad OISB_{EURUSD} = i_{OIS,\$} - [i_{OIS,EUR} + (f_{EURUSD} - s_{EURUSD})]$$

When covered interest parity holds between OIS interest rates, the OIS basis is zero. Thus

$$(16) \quad i_{OIS,\$} = i_{OIS,EUR} + (f_{EURUSD} - s_{EURUSD})$$

If there is a shortage of USD, the OIS basis between EUR and USD will tend to be negative. Market participants will buy USD and sell EUR spot and buy EUR and sell USD forward. Forward sales of USD will weaken the USD forward rate ( $\Delta f_{EURUSD} > 0$ ), causing the forward

premium/discount and the swap rate to rise. Thus, the OIS basis will fall<sup>18</sup>. Thus, we see that

$$(17) \quad rp_{K,\$} = rp_{Euribor} - i_{DEK,\$} - OISB_{EURUSD}$$

If for the sake of simplicity we assume that  $i_{DEK,\$} \approx 0$ , as shown in Chart 2, the result is

$$(18) \quad rp_{K,\$} = rp_{Euribor} - OISB_{EURUSD}$$

### (iii) Relationship between the premium in NOK and the premium in EUR

We can now express the premium in the three-month Nibor rate as a function of the premium in the three-month Euribor, the OIS basis between USD and NOK and the OIS basis between EUR and USD. Inserting equation (18) into equation (8) results in

$$(19) \quad rp_N = rp_{Euribor} + i_{DK,\$} - OISB_{EURUSD} - OISB_{USDNOK}$$

Which fully written out is:

$$(20) \quad rp_N = rp_{Euribor} + i_{DK,\$} + (f_{EURUSD} - s_{EURUSD}) - (i_{OIS,\$} - i_{OIS,EUR}) + (f_{USDNOK} - s_{USDNOK}) - (i_{OISNOK} - i_{OIS,\$})$$

On the basis of equation (19) the premium in the forward three-month Nibor can now be calculated. The market provides prices for future premiums on the three-month Euribor and the OIS basis between EUR and USD at many maturities. From the quoted OIS basis, future OIS bases for EUR and USD can be calculated. Likewise, future OIS bases between USD and NOK can be calculated on the basis of Norges Bank’s estimated OIS for Norway. These calculations follow standard techniques for calculating implied interest rates.

<sup>18</sup> If there is a shortage of USD, the OIS basis between EUR and USD will fall. This follows from market convention, i.e. the way the exchange rate and the OIS basis between EUR and USD is defined. No OIS interest rate is quoted for NOK, which is why there is no market convention for quoting a hypothetical OIS basis between USD and NOK. We have chosen to define the hypothetical OIS basis between USD and NOK as given in equation (7), so that a shortage of NOK results in a positive OIS basis. This is the converse of the case for EUR, where a shortage of USD results in a negative OIS basis between EUR and USD. This reason for this difference is that for USD and EUR the exchange rate is defined by number of USD per EUR, whereas for NOK the rate is defined a number of NOK per USD.