STAFF MEMO

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MARIUS HAGEN AND
KJETIL STIANSEN

NORGES BANK

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Does structural liquidity have a greater impact on the Nibor premium than earlier?*

Marius Hagen and Kjetil Stiansen

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Abstract

In recent years, the liquidity premium between the Norwegian krone (NOK) and the US dollar (USD) in the FX swap market, the so-called OIS basis, has accounted for a larger share of the Nibor premium than earlier. This has been attributed by several to low structural liquidity and banks' adaptation to liquidity requirements (LCR). In this Staff Memo, we estimate the extent to which these factors have affected this liquidity premium, and whether this has changed over time. The results indicate that the relationship between structural liquidity and the OIS basis has become stronger, but that the increase in the OIS basis in recent years is also due to a low level of structural liquidity.

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1 Introduction

Three-month Nibor is the most important and widely used reference rate for contracts denominated in NOK. Virtually all NOK floating rate bonds are linked to Nibor. Nibor is also the reference rate for most NOK interest rate derivatives. Since banks' wholesale funding costs depend on Nibor, interest rates on bank loans are usually directly or indirectly linked to Nibor.

Nibor is intended to measure the interest rate charged by large banks for an unsecured loan to another bank for three months. However, banks lend little to one another in NOK at maturities longer than overnight. Large banks perform most of their NOK liquidity management in the foreign exchange (FX) swap market, mainly by swapping USD into NOK (see Stiansen (2022)).[1] Banks' Nibor quotations are therefore based on the interest rate at which they can obtain USD funding and the cost of swapping USD into NOK in the FX swap market.[2]

Nibor can be decomposed into the expected policy rate and a risk premium. The risk premium can also be divided into a premium in the USD money market rate, a liquidity premium on swapping USD into NOK in the FX swap market and a lending margin. The premium in the USD money market rate measures what large banks pay for unsecured three-month USD loans.[3] The liquidity premium on swapping USD into NOK in the FX swap market, also referred to as the OIS basis, depends on the supply and demand for swapping USD into NOK in the FX swap market. The lending margin reflects any risk-free investment options banks have, banks' required return on equity and a premium for credit risk (see Kloster and Syrstad (2019) for a more detailed description of this breakdown).

In recent years, the OIS basis between NOK and USD has contributed to pushing up the premium in Nibor (see Chart 1). Historically, the OIS basis between NOK and USD

[1] A foreign exchange swap is a transaction involving the actual exchange of two currencies on a specific date at a rate agreed at the time of the conclusion of the contract, and a reverse exchange of the same two currencies at a date further in the future.

[2] Banks can also take into account the rate they pay for financing in EUR when they quote their Nibor rates. As the bulk of transactions in the FX swap market in Norway involve NOK and USD, and banks' financing costs in EUR can be translated into USD, we focus on banks' financing costs in USD and the cost of exchanging USD into NOK in the FX swap market.

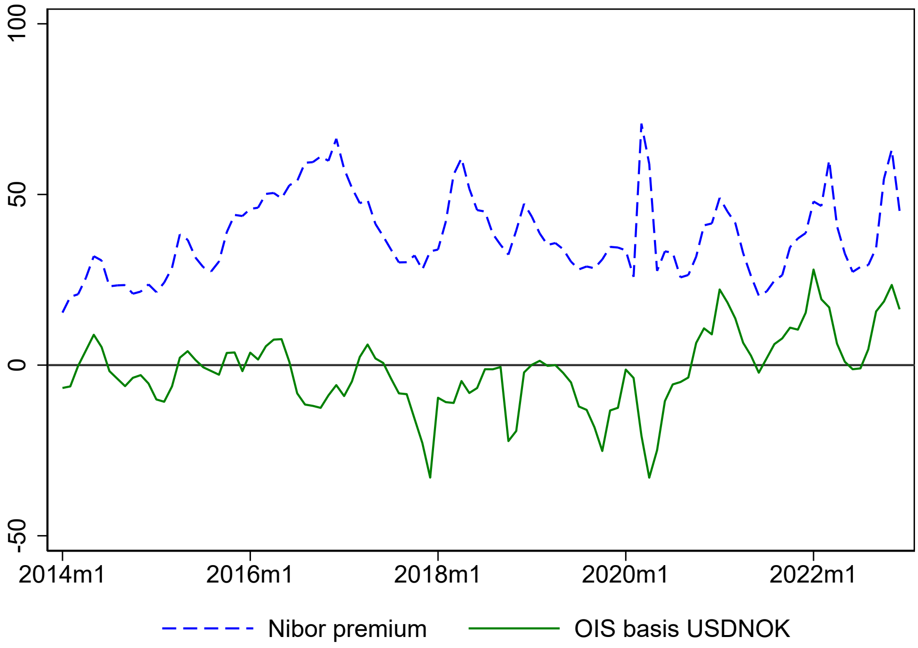
[3] Historically, the risk premium in three-month USD Libor has typically been used. However, USD Libor was phased out in June 2023.

has varied mostly around zero and has often been negative. A negative OIS basis pulls down the Nibor premium. The increase in the Nibor premium in the period between 2014 and 2020 was therefore due to higher premiums in USD and changes in the lending margin in Nibor. From autumn 2020 until today, however, the OIS basis between NOK and USD in the FX swap market has often been positive, periodically pushing up the Nibor premium substantially.

Long periods of low structural liquidity and the introduction of liquidity coverage ratio requirement (LCR) in NOK for a number of banks have been pointed to as important reasons for the rise in the OIS basis between NOK and USD in recent years (see Stiansen (2022))). When structural liquidity falls, banks often borrow NOK in the FX swap market at long maturities in order to maintain their LCR in NOK. This contributes to a higher OIS basis. A fall in structural liquidity may therefore be an important driver for the OIS basis, and in recent years structural liquidity has been at very low levels for extended periods. The LCR was introduced for Norwegian banks at the end of 2015, and since autumn 2017 banks have had to comply with the LCR separately in NOK. In recent years, several of the large Nordic branch banks have also been subject to LCR requirement in NOK by their national supervisory authorities. This may have contributed to reinforcing the relationship between the OIS basis and structural liquidity. The increase in the OIS basis in recent years may therefore be due both to the fact that structural liquidity has been very low and that the relationship between structural liquidity and the OIS basis has become stronger.

In this paper, we examine empirically whether the relationship between structural liquidity and the OIS basis has changed in recent years. We do this by estimating how Norges Bank's structural liquidity forecast affects the OIS basis over different time periods, while controlling for other factors that may affect the OIS basis. The results indicate that the relationship between structural liquidity and the OIS basis has become stronger, but that the increase in the OIS basis in recent years is also due to a very low level of structural liquidity. The paper is structured as follows: In Section 2 we present how the OIS basis is calculated and possible explanatory variables. In Section 3 we present the results from different regression models, while Section 4 concludes.

Figure 1: Nibor premium and OIS basis. Basis points.



Sources: Bloomberg and Norges Bank

2 OIS-basis and possible explanatory variables

2.1 Calculation of the OIS basis

The liquidity premium between two currencies in the FX swap market (OIS basis) is determined by the deviation between the difference in the expected policy rate between the two currencies and the interest rate differential that emerges in the FX swap market.

Policy rate expectations in different currencies can be measured using overnight indexed swap (OIS) rates. An OIS contract is an interest rate swap agreement, where one party to the agreement pays a fixed rate and the other pays a floating overnight rate for a given period, for example three months. The fixed rate in an OIS contract can therefore be interpreted as the expected overnight rate through the duration of the contract. There were no quoted rates for OIS rates in Norway prior to September 2020, and prior to this we therefore use Norges Bank's estimated OIS rates.

The interest rate differential in the FX swap market is given by the difference between spot and forward rates for a given maturity converted to a percentage annual return. The OIS basis between NOK and USD for a given maturity, can then be written:

$$OISB_{USDNOK} = OIS_{USD} + TP_{USDNOK} - OIS_{NOK} \tag{1}$$

where $OISB_{USDNOK}$ is the OIS basis between NOK and dollars, OIS_{USD} and OIS_{NOK} are the expected policy rates in USD and NOK measured by OIS rates in the two currencies, respectively. TP_{USDNOK} is the interest rate differential between NOK and USD in the FX swap market. The sum of OIS_{USD} and TP_{USDNOK} gives the USD OIS rate converted to NOK. The OIS basis is given by the difference between this implicit OIS rate and the actual NOK OIS rate.

The OIS basis depends on the supply of and demand for borrowing NOK against USD in the FX swap market. The theory of covered interest parity suggests that it should not be possible to achieve risk-free gains by borrowing in one currency and investing in another, having eliminated exchange rate risk by means of a FX swap contract. If all FX swap market participants could borrow and invest freely at the USD and NOK policy rates, the OIS basis would therefore be zero at all times. In practice, however, both banks and other participants' borrowing and investment options may deviate considerably from policy rates in the two currencies. Changes in the supply and demand for NOK against USD in the FX swap market among various participants may therefore result in a deviation from zero on the OIS basis.

2.2 Possible explanatory variables

Structural liquidity is probably an important driver of the OIS basis, and historically there has been a clear negative correlation between the two variables (Chart 2). Structural liquidity refers to the level of central bank reserves[4] in the banking system prior to Norges Bank's market operations and will primarily vary in connection with payments to and payments from the government's account in Norges Bank. For example, tax payments by private operators are settled by transferring central bank reserves from banks' accounts to the government's account in Norges Bank. The amount of reserves will then fall. Similarly, structural liquidity will increase in connection with government payments, such as pensions and wages. Through market operations, ie F-deposits and F-loans, Norges Bank ensures that total liquidity is kept at around NOK 35 billion every day (see Norges Bank (2021) for a description of the principles and formulation of Norges Bank's liquidity policy). In periods of low levels of structural liquidity, Norges Bank will supply liquidity via F-loans, which are loans against collateral in securities. F-loans are awarded through auctions, and banks do not know in advance the allotment they will receive. In order to increase liquidity predictability, banks therefore often borrow NOK at long maturities in the FX swap market prior to a fall in structural liquidity. Low structural liquidity therefore leads to increased demand for NOK in the FX swap market. This pulls up the OIS basis.

The introduction of the Liquidity Coverage Ratio (LCR) requirement may have made structural liquidity more important to the OIS basis than before. The LCR is a requirement under the Basel III framework, which requires banks to hold a portfolio of liquid assets sufficient to cover banks' net payouts during a 30-day stress period. Norwegian banks must satisfy LCR requirements for all currencies and individually for NOK and

[4] Central bank reserves are banks' (freely useable) deposits with the central bank. Banks need central bank reserves to settle transactions between themselves.

other so-called significant currencies.[5] A total LCR requirement of 100 percent was introduced for Norwegian banks at the end of 2015. In autumn 2017, the LCR requirement in NOK of 50 percent was introduced for large Norwegian banks with EUR or USD as a significant currency. In recent years, several of the Nordic branch banks have also been required to comply with specific LCR requirements in NOK by their home state supervisory authorities.

A fall in structural liquidity weakens banks' LCR coverage. When structural liquidity falls, banks lose deposits from the public on the liabilities side and central bank reserves on the asset side. In isolation, the loss of deposits leads to an increase of banks' LCR. This is because deposits have a so-called run-off factor in the LCR of between 5 and 100 percent, depending on the type of deposit. Different deposits are multiplied by their relevant run-off factor and are included in the calculation of net payouts in the denominator in the LCR. When banks lose deposits, the denominator in banks' LCR therefore also falls. The fall in denominators will be greater the higher the run-off factor is for deposits banks lose. At the same time, the numerator falls in the LCR of the bank, as banks lose reserves, which are included as a liquid asset in the LCR by 100 percent weight. Because the deposits the bank loses are multiplied by a withdrawal factor of between 5 and 100 percent, the numerator will usually fall more than the denominator in the banks' LCR when structural liquidity falls, weakening the LCR.[6]

F-loans will not normally assist banks in maintaining their LCR when structural liquidity falls. The reason for this is that the collateral required by Norges Bank for F-loans is mainly the same as those approved as a liquid asset in the LCR. Banks can replace reserves they lose in the event of a fall in structural liquidity with F-loans but must deduct collateral provided when calculating liquid assets in the LCR. If banks replace deposits they lose in the event of a fall in structural liquidity with F-loans, the numerator in the bank's LCR will therefore fall with the value of the collateral pledged.

Banks are often particularly concerned with protecting their LCR in NOK. Banks'

[5] A currency is considered significant if it accounts for more than 5 percent of banks' total liabilities.

[6] The effect of changes in numerators and denominators on LCRs may be different depending on what level the LCR is at initially. For example, if banks are close to the minimum requirement of 50 percent LCR in NOK, an equal fall in the numerator and denominator will also weaken the LCR, since the fraction is below 1. In other words, the dampening effect on the LCR of banks losing deposits when structural liquidity falls may be smaller for LCR in NOK if banks have less than 100 percent LCR in NOK.

LCR portfolios must be funded at a maturity of at least 30 days, and it is often cheaper to do this in currencies other than NOK. There are also relatively few high-quality liquid assets in Norway, which may make it more demanding for banks to maintain LCR in NOK than in other currencies. This is also the main reason for banks' LCR requirement in NOK of only 50 percent.

Banks can protect their NOK LCR by swapping foreign currency into NOK at long maturities in the FX swap market or using foreign securities as collateral for F-loans. If banks pledge foreign securities as collateral for F-loans, they can maintain the numerator in their NOK LCR when borrowing in the form of F-loans, at the expense of lower numerators in their foreign currency LCR. However, as discussed above, banks do not know the allotment of F-loans in advance, so they will take on substantial liquidity risk if they rely solely on using foreign securities as collateral for F-loans to protect their NOK LCR. By swapping into NOK at long maturities in the FX swap market, a bank can increase the predictability of its own liquidity position and reduce the need to use F-loans when structural liquidity falls. However, the banking system is a closed system, and when structural liquidity is negative, one or more banks will ultimately have to borrow NOK in the form of F-loans. By swapping into NOK at long maturities in the FX swap market and investing it in liquid NOK assets, banks can maintain their NOK LCR even if they borrow NOK in the form of F-loans or have to cover their position in the short-term when structural liquidity falls.

In recent years, structural liquidity has been at low levels for long periods (Chart 2). One reason for this was that over time, the government converted more foreign exchange into NOK from the Government Pension Fund Global (GPFG) than was necessary to cover the non-oil deficit.[7] The amount in the government's account in Norges Bank has thus increased and structural liquidity has fallen. Through 2022, unusually high oil tax payments as a result of high oil and gas prices have also contributed to periodically large falls in structural liquidity. Norges Bank exchanges the portion of the government's NOK petroleum revenues not spent over the central government budget into foreign currency. When oil tax payments increase, Norges Bank will therefore increase its NOK sales on

[7] In 2022, the government reversed transfers from the government's account in Norges Bank to the GPFG. For more on this, see Section 8.4 of the central government budget for 2022 and box on page 21 of Monetary Policy Report 4/21.

behalf of the government. This supplies liquidity to the banking system and counteracts the effect of oil tax payments on structural liquidity over time. However, Norges Bank smooths its NOK transactions on behalf of the government over the year, and transaction amounts are determined on the basis of the government's estimate of the need for transfers to and from the GPFG to cover the non-oil budget deficit. Very large oil tax payments may therefore have a considerable temporary impact on the level of structural liquidity.

Since we analyse the relationship between structural liquidity and a three-month OIS basis, which is a forward-looking variable, we look at market participants' expectations of structural liquidity in the same time period. To measure market participants' expectations of structural liquidity, Norges Bank's daily liquidity forecasts are used. We have daily forecasts from 2014 onwards.

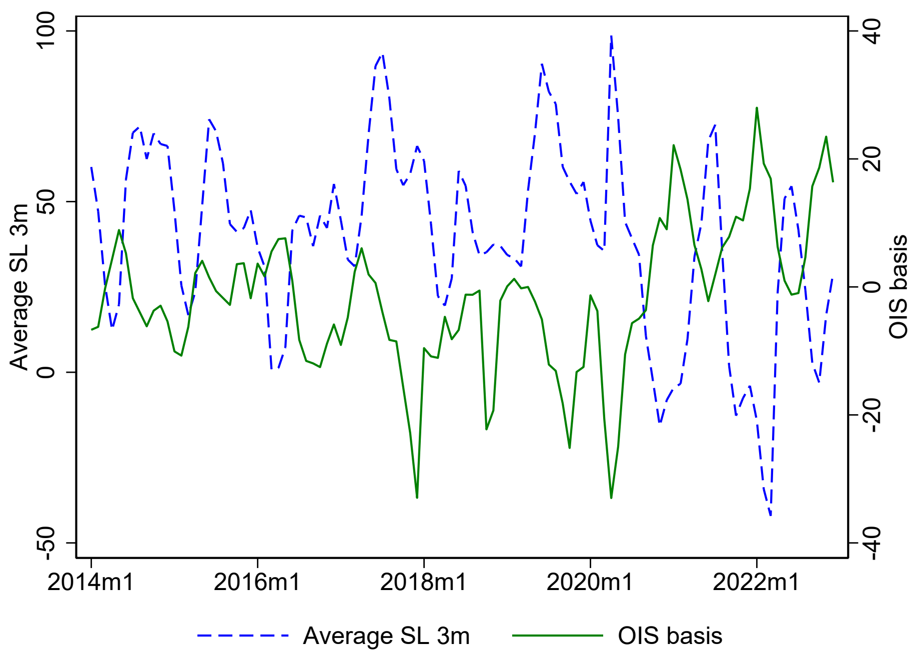
We want to include a variable in the regression that captures how expectations of structural liquidity affect the OIS basis. Chart 3 illustrates two ways of doing this: use expected average or minimum level of structural liquidity over the next three months. It is not necessarily clear which of these measures of structural liquidity is more important for the OIS basis. Banks must meet the LCR daily. If structural liquidity is expected to be very low on a single day, this may be enough for banks to adapt to this by swapping into NOK in the FX swap market at long maturities. In addition, there may be considerable volatility in prices for short maturities in the FX swap market when structural liquidity is at very low levels. This is important for participants who lend NOK at long maturities in the FX swap market and finance this by borrowing NOK at short maturities. Such participants are important marginal providers of NOK in periods of low structural liquidity (see Stiansen (2022)). At the same time, longer periods of low structural liquidity may entail a more persistent need for banks to swap into NOK at long maturities. As the chart shows, the expected average and minimum level of structural liquidity over the next three months are highly correlated.

In addition to structural liquidity, changes in banks' borrowing and investment options in USD may also affect the OIS basis. If banks can invest risk-free in USD at higher interest rates than that measured by OIS rates, they may be willing to swap NOK for USD in the FX swap market at lower forward points than implied by the differential between NOK and USD OIS rates. This was particularly the case between 2015 and 2020.

During this period, banks were able to generate substantial returns by swapping USD into EUR in the FX swap market and placing the EUR in the European Central Bank (ECB). This was partly due to ample EUR liquidity as a result of quantitative easing and increased segmentation in the US money market (see Rime and Syrstad (2022)). When we estimate the relationship between structural liquidity and the OIS basis between NOK and USD, we include the OIS basis between USD and EUR in the FX swap market as an explanatory variable. This provides an indication of the profitability of swapping USD into EUR and investing the EUR in the ECB. Chart 4 also shows that historically there has been a negative correlation between the OIS basis between NOK and USD and between USD and EUR, respectively.

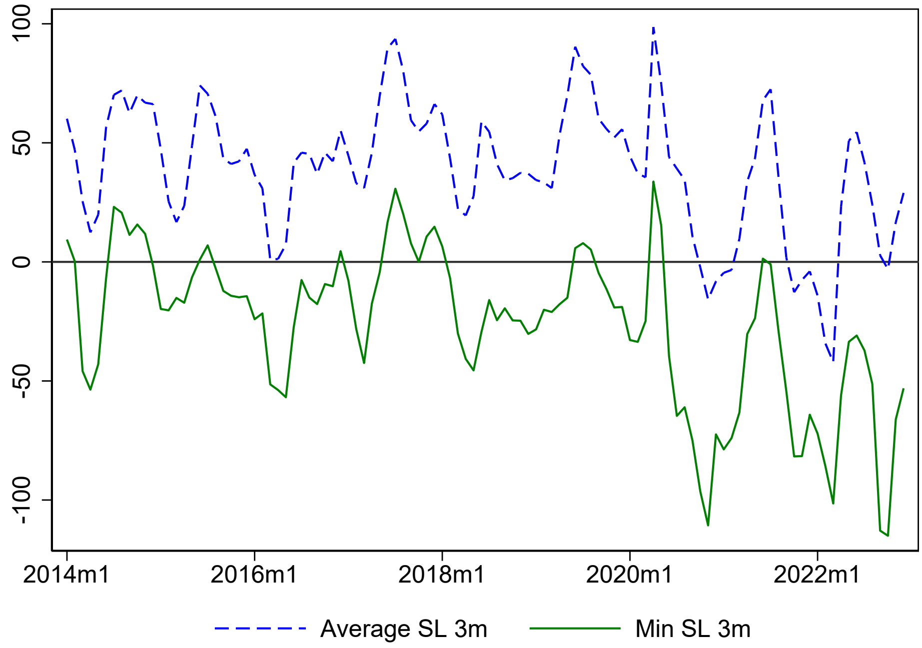
Business day data are available for all explanatory variables. Since we want to investigate what drives the OIS basis over time, and to a lesser extent what causes daily fluctuations, we use monthly data in our analysis. The data is transformed into monthly frequency by taking the average of the daily data.

Figure 2: OIS basis USDNOK and expected average structural liquidity over the next three months.



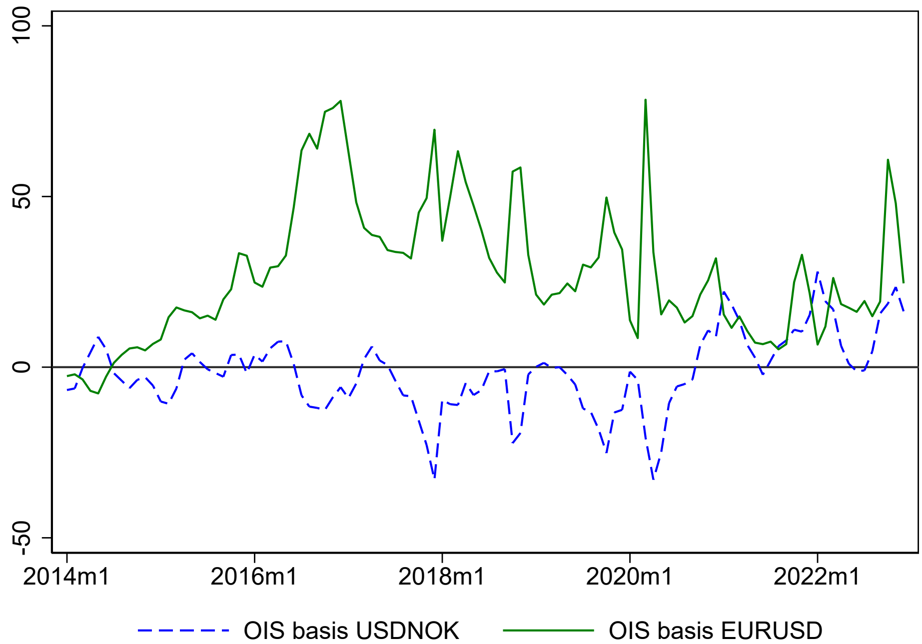
Comments on the chart: OIS basis is stated in basis points, while structural liquidity is stated in billions of NOK. *Sources:* Bloomberg and Norges Bank

Figure 3: Expected structural liquidity over the next three months, average and minimum.



Comments on the chart: Structural liquidity is stated in billions of NOK. *Source:* Norges Bank

Figure 4: OIS basis USDNOK and EURUSD



Comments on the chart: The OIS basis USDNOK and EURUSD are stated in basis points. *Sources:* Bloomberg and Norges Bank

3 Empirical analysis

To investigate the relationship between expected structural liquidity and the OIS basis, we start with the following equation:

$$OISB_{USDNOK,t} = \alpha + \beta_1 OISB_{EURUSD,t} + \boldsymbol{\delta_1} SL_{3m,t} + \boldsymbol{\delta_2} SL_{3m,t-1} + \theta D + \varepsilon_t \qquad (2)$$

where $OISB_{USDNOK,t}$ is the OIS basis between NOK and USD and $OISB_{EURUSD,t}$ is the OIS basis between USD and EUR. $SL_{3m,t}$ and $SL_{3m,t-1}$ are forecast for average or minimum structural liquidity over the next three months, respectively, in the same period and lagged by a period. The reason we lag these variables by one month is to investigate whether the OIS basis is also affected by structural liquidity expectations in the previous month. D are various dummies we include in the regressions.[8] Motivation for each of the dummies is described in more detail in the sections below. ε_t, is the error term. All variables are stationary, and the model can therefore be estimated at level form (see Table A.1 in the Appendix for stationary tests).

Both expected structural liquidity in this period and lagged by a period seem to have an impact on the OIS basis (see Table 1, which shows the results from various specifications based on equation (2)). In column (I) we use the expected average for structural liquidity over the next three months, while in column (II) the minimum level. The sum of the coefficients of expected structural liquidity included in the same period and lagged by a period is approximately equal to -0.25 in both specifications. This indicates that a reduction in the expected average or minimum level of structural liquidity of NOK 10 billion over the next three months will increase the OIS basis by 2.5 basis points.

However, there is positive autocorrelation of the error term (Chart A.1). In the case of autocorrelation, the standard deviation shown may be too small, which may lead us to erroneously conclude that the coefficient estimates are significant. To address this, we use Newey-West standard errors that are robust to heteroscedasticity and higher-order autocorrelation. In the case of autocorrelated error terms, there is also a risk that any relevant variables omitted are correlated with one of the explanatory variables. If this is the case, the coefficient estimates may be skewed. Since the residual appears to be

[8] A dummy variable is a binary variable, which is equal to either 0 or 1.

positive in some time periods and negative in others, in specification (III) and (IV) we have added time dummies on annual frequency to try to capture any omitted variables. We also add seasonal dummies on monthly frequency.[9] The coefficients are affected fairly little by whether we include time and seasonal dummies. There is also slightly less sign of autocorrelation of the error term than in the specifications where these dummies are not included. Further in the analysis, we test several different specifications to see to what extent the coefficient estimates vary.

To assess whether we should use the minimum level or average structural liquidity further, we examine the residual from the regressions in Table 1 (Chart A.2 in the Appendix). As mentioned in Section 2, both the average and the minimum level may be important for the OIS basis, but the series are highly correlated, and it is therefore not very informative to include them in the same regression. The residual of the regression, which includes the expected minimum level, has a somewhat smaller standard deviation and fewer extreme values than the regression where we include the expected average. We therefore choose to use the expected minimum level further in the analysis, but in the Appendix we also show the results where we use the expected average.

3.1 Introduction of LCR requirements and their effect on the OIS basis

We wish to analyse whether the introduction of LCR requirements in NOK has had an impact on the relationship between the OIS basis and structural liquidity. As previously mentioned, LCR requirements in NOK have been introduced over time, and requirements have been introduced for different banks at different times. This suggests that structural liquidity may have become gradually more important for the OIS basis. However, the coefficient estimates for structural liquidity in Table 1 will not capture whether the relationship has changed over time.

We use various methods to analyse whether structural liquidity has become more important for the OIS basis over time. In Section 3.1.1, we estimate the coefficient of the

[9] The annual dummies equal 1 in the current year, otherwise 0. For example, the annual dummy for 2015 is equal to 1 in all months in 2015, while it is equal to 0 in all other periods. The seasonal dummies equal 1 in the relevant month, otherwise 0. For example, the monthly dummy for February is equal to 1 in February in all years, otherwise 0.

Table 1: Dependent variable: OIS basis USDNOK.

	(I)	(II)	(III)	(IV)
OIS basis EURUSD	-0.22***	-0.21***	-0.29***	-0.26***
	(0.05)	(0.05)	(0.07)	(0.06)
Average SL 3m	-0.12*		-0.10**	
	(0.06)		(0.05)	
L.Average SL 3m	-0.16***		-0.16***	
	(0.05)		(0.04)	
Min SL 3m		-0.10*		-0.12***
		(0.05)		(0.04)
L.Min SL 3m		-0.14***		-0.14***
		(0.04)		(0.04)
Observations	107	107	107	107
Constant	✓	✓	✓	✓
Significant seasonal dummies (month)			✓	✓
Year dummies			✓	✓

Comments on the table: OLS regression with Newey-West standard errors (see Newey and West (1987)). Standard errors are robust to heteroscedasticity and up to a fourth-order autocorrelation and are shown in brackets under the point estimates. The asterisks show significance level. * = 10%, ** = 5% and *** = 1%. Monthly frequency. L means that the variable is lagged by one period.

minimum level of structural liquidity for three predefined periods to capture the phasing-in of LCR requirements in NOK. In Section 3.1.2, we estimate regressions where the estimation window moves gradually over time and study how the coefficient estimates change. In both sub-sections, we use variables at level form. This allows us to use the information from the level of the variables in the estimation of the coefficients. However, there is positive autocorrelation in the error term. To remove autocorrelation, we therefore finally estimate equations using differentiated data in Section 3.1.3.

3.1.1 Predefined time periods

Under the first method, we estimate the effect of structural liquidity separately over predefined time periods. We divide the sample into the following three time periods: 1) From 2014 to 2016, which will capture the period before LCR requirements in NOK were introduced, 2) From 2017 to 2019, which will capture the introduction of LCR requirements in NOK for Norwegian banks, 3) From 2020 to 2022, which will capture that several of the large Nordic branch banks have also been subject to LCR requirements in NOK. To allow for different constants in the predefined periods, we need to include time dummies for these periods. We also want to control for annual variations within the predefined periods in order to capture possible omitted variables, and therefore include time dummies at annual frequency.

Column (I) in Table 2 shows the results of the specification where we include the effect of the minimum level of structural liquidity both in the same period and lagged by a period. If we sum the coefficients, we see that the results support the hypothesis that structural liquidity has gradually become more important for the OIS basis after the introduction of LCR requirements in NOK. In the period from 2014 to 2016, the coefficients of the expected minimum level of structural liquidity combined are equal to -0.09 (0.03-0.12), for 2017-2019 equal to -0.24 (-0.04 -0.20) and for 2020-2022 equal to -0.32 (-0.21-0.11). This means, for example, that in the period 2017-2019, the OIS basis will rise by around 2.5 basis points from a NOK 10 billion fall in the expected minimum level of structural liquidity, while in 2020-2022, the OIS basis will rise by 3.2 basis points. In the specification in column (II), we have for each predefined time period either kept the variable contemporaneous or lagged based on which coefficient was most significant in specification (I), which means that the variables are lagged by a period in 2014-2016 and 2017-2019 but are included contemporaneous in the period 2020-2022. However, the coefficient estimates are little changed from specification (I). The coefficient estimate for 2017-2019 is significantly different from 2014-2016, while there is no significant difference between 2017-2019 and 2020-2022. The coefficient estimate for the OIS basis between USD and EUR is equal to around -0.25 in the various specifications.

One possible objection to the results in columns (I) and (II) is that they may have been affected by the coronavirus crisis in 2020 and the extraordinary crisis-related measures implemented by Norges Bank. For much of 2020, Norges Bank offered extraordinary F-loans with full allotment and maturities of three months or longer. Norges Bank also expanded eligible collateral for loans by allowing banks to leverage up to 100 percent of the value of each ISIN pledged. This allowed banks to issue covered bonds on their own balance sheets and use these fully as collateral for long-term F-loans. Since such own-issued covered bonds cannot count as liquid assets in LCRs, this gave banks greater scope for using F-loans from Norges Bank without this weakening their LCR coverage. This may have reduced banks' need to swap into NOK in the FX swap market in periods of low structural liquidity. If so, this could interfere with the estimates in columns (I) and (II).

To control for any effects of Norges Bank's measures in response to the coronavirus crisis, we include time dummies for all months in 2020. In practice, this means that we remove 2020 from the dataset. The results of this specification are presented in column (III) in Table 2. The coefficient estimates for the minimum level of structural liquidity are little affected by the exclusion of 2020 from the estimation. This may be because in specification (I) and (II) we partially take this into account by including an annual dummy for 2020. The results indicate that the relationship between the OIS basis and the expected minimum level of structural liquidity is robust to whether 2020 is included or not. The coefficient estimate of the OIS basis EURUSD is around -0.30.[10]

3.1.2 Rolling time periods

One drawback of estimating the relationship between structural liquidity and the OIS basis separately for predefined time periods is that the choice of time period can be decisive for the results. Although we know when both general and currency-specific LCR requirements were introduced, it is not a given that the periods we have defined are appropriate for investigating whether the relationship between structural liquidity and the OIS basis has changed. For example, if banks knew that LCR requirements would be imposed, they may have changed their behaviour well before the requirements became formally applicable.

[10] In the regressions, there are still clear signs of autocorrelation of the residual (Chart A.3 showing the residuals from Table 2). The coefficient estimates are relatively similar in the different specifications. This suggests that the estimates are robust. Furthermore, in the Appendix, we have included the OIS basis USDNOK lagged by one period as one of the explanatory variables to reduce the autocorrelation. As can be seen in Table A.2, these results also suggest that the minimum level of structural liquidity has gradually become more important. In Table A.3 in the Appendix, we have replaced the minimum level of structural liquidity with the average over the next three months; otherwise the specifications are equal to (I) and (III) from Table 2. The results also indicate that structural liquidity has become more important.

Another method for testing whether the relationship between the OIS basis and structural liquidity has changed is to use rolling time periods. We start with equation (2) and use 3 years rolling time periods. This means that we first estimate the equation on data from January 2014 to December 2016, then on data from February 2014 to January 2017 and so on. From each of these estimations, we store the coefficient of the minimum level of structural liquidity over the next three months, together with the 95 percent confidence interval. The results of the previous estimates indicate that the minimum level of structural liquidity in the previous period and in the same period affects the OIS basis. However, when we have rolling time windows with relatively few observations, it is not very informative to include them in the same regression since the variables are highly correlated and the coefficient estimates may therefore vary widely. We therefore estimate two different specifications, one where we include the minimum level of structural liquidity in the same period as the OIS basis and another where we instead lag this variable by a period.

The coefficient estimates also indicate that the minimum level of structural liquidity has gradually become more important for the OIS basis (Chart 5a. and b). In the specification where we include the minimum level of structural liquidity in the same period, the coefficient estimate changes from around -0.10 to -0.25, while in the specification where this variable is lagged with a period, the coefficient estimate changes from -0.15 to -0.25. These results are in line with the coefficient estimates presented in Table 2 where we had predefined periods.[11]

3.1.3 Differentiated variables

Under the third method, we differentiate all variables from equation (2), to try to remove autocorrelation in the residual:

$$\Delta OISB_{USDNOK,t} = \alpha + \beta_1 \Delta OISB_{EURUSD,t} + \boldsymbol{\delta_1} \Delta SL_{3m,t} + \boldsymbol{\delta_2} \Delta SL_{3m,t-1} + \theta D + \varepsilon_t \tag{3}$$

Here, too, the results indicate that expected structural liquidity has become more im-

[11] In the appendix we have performed a similar analysis for average of structural liquidity. The coefficient of structural liquidity seems to have become gradually more important (Chart A.4).

portant in recent years (see Table 3 which shows various specifications based on equation (3)). In column (I) we include the minimum level of structural liquidity in the different time periods, both in the same period and lagged by one month, while in specification (II) we have removed the minimum level of structural liquidity that does not have a statistically significant coefficient. If we start from the results from specification (II), we see that for the periods 2014-2016 and 2017-2019, the coefficient is equal to -0.10 and -0.11 respectively, while it rises to -0.27 for the period 2020-2022. The latter coefficient estimate is significantly different from the previous periods.[12]

It is possible that the relationship between expected structural liquidity and the OIS basis is stronger with large rather than small changes in structural liquidity, ie the relationship is non-linear in the event of a change in structural liquidity. In the period 2020-2022, fluctuations in structural liquidity have been greater than in previous years. If there is a non-linear relationship, it is possible that the higher coefficient estimate for this period is due to greater variations in the expected minimum level of structural liquidity rather than a stronger relationship between structural liquidity and the OIS basis.

One way to try to control for this is by including dummies in the months between 2020 and 2022 where there have been particularly large changes in the expected minimum level of structural liquidity. In practice, this means that we remove these periods from the estimation. The variation in the expected minimum level of structural liquidity in the period 2020-2022 will then be more similar to the previous periods. The coefficient estimate for the period 2020-2022 then changes from -0.27 to -0.17 (see specification (III) in Table 3). The coefficient estimate is still higher than in the previous periods, but we cannot conclude from this regression that there is a significant difference between the estimated coefficients.

Overall, the results suggest that expected structural liquidity has become more important for the OIS basis after the introduction of LCR requirements in NOK, thereby supporting the results from Sections 3.1.1 and 3.1.2. Furthermore, the results may indicate that there is a somewhat stronger relationship between expected structural liquidity

[12]Chart A.5 in the Appendix shows the residuals from the specifications presented in Table 3. The residuals in the various specifications generally follow each other closely. Formal tests indicate no first-order autocorrelation, but there are signs of higher order autocorrelation.

and the OIS basis in the event of particularly large changes in structural liquidity.

Table 2: Dependent variable: OIS basis USDNOK.

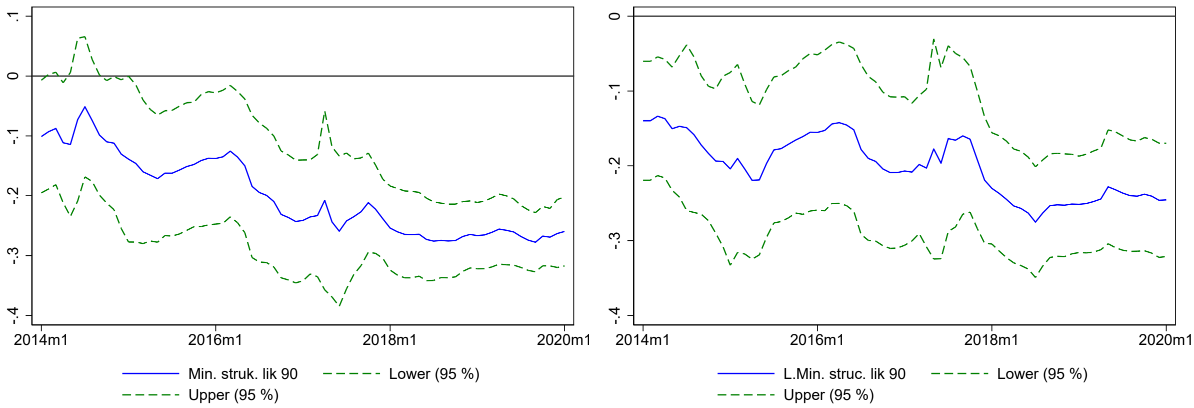
	(I)	(II)	(III)
OIS basis EURUSD	-0.28***	-0.24***	-0.28***
	(0.07)	(0.07)	(0.10)
Min SL 3m.* Dummy 2014-2016	0.03		
	(0.05)		
L.Min SL 3m.* Dummy 2014-2016	-0.12***	-0.11***	-0.10***
	(0.03)	(0.02)	(0.03)
Min SL 3m. * Dummy 2017-2019	-0.04		
	(0.11)		
L.Min SL 3m. * Dummy 2017-2019	-0.20**	-0.22***	-0.22***
	(0.10)	(0.05)	(0.05)
Min SL 3m. * Dummy 2020-2022	-0.21***	-0.29***	-0.29***
	(0.04)	(0.02)	(0.04)
L.Min SL 3m. * Dummy 2020-2022	-0.11*		
	(0.05)		
Observations	107	107	107
Constant	✓	✓	✓
Year dummies	✓	✓	✓
Significant seasonal dummies (month)	✓	✓	✓
Dummies for all periods in 2020			✓

Comments on the table: OLS regression with Newey-West standard errors (see Newey and West (1987)). Standard errors are robust to heteroscedasticity and up to a fourth-order autocorrelation and are shown in brackets under the point estimates. The asterisks show significance level. * = 10%, ** = 5% and *** = 1%. Monthly frequency. L means that the variable is lagged by one period.

i

Figure 5: Regressions with rolling time periods. Dependent variable: OIS basis USDNOK

a) Minimum structural liquidity included inb) b) Minimum structural liquidity lagged by the same period one period



Comments on the chart: We use three-year rolling time windows, where the x-axis shows the starting point of each regression. We estimate two specifications. In specification a) we have estimate equation $OISB_{USDNOK,t} = \alpha + \beta_1 OISB_{EURUSD,t} + \delta MINSL_{3m,t} + \theta D + \varepsilon_t$, where $MINSL$ is the expected level of minimum structural liquidity over the next three months and D are year dummies. In specification b). we replace minimum structural liquidity in the same period with lagged by a period. $OISB_{USDNOK,t} = \alpha + \beta_1 OISB_{EURUSD,t} + \delta MINSL_{3m,t-1} + \theta D + \varepsilon_t$.

Table 3: Dependent variable: Δ OIS basis USDNOK.

	(I)	(II)	(III)
D.OIS basis EURUSD	-0.30***	-0.28***	-0.31***
	(0.07)	(0.07)	(0.07)
D.(Min SL 3m * Dummy 2014-2016)	-0.05		
	(0.03)		
L.D.(Min SL 3m * Dummy 2014-2016)	-0.08***	-0.10***	-0.10***
	(0.03)	(0.03)	(0.03)
D.(Min SL 3m * Dummy 2017-2019)	-0.02		
	(0.06)		
L.D.(Min SL 3m * Dummy 2017-2019)	-0.11*	-0.11**	-0.11**
	(0.06)	(0.05)	(0.05)
D.(Min SL 3m * Dummy 2020-2022)	-0.21***	-0.22***	-0.17***
	(0.05)	(0.05)	(0.05)
L.D.(Min SL 3m * Dummy 2020-2022)	-0.06		
	(0.05)		
Observations	107	107	107
Constant	✓	✓	✓
Year dummies	✓	✓	✓
Dummies when abrupt changes in struc. liq. between 2020-2022			✓

Comments on the table: Standard errors are robust to heteroscedasticity and up to a fourth-order autocorrelation and are shown in brackets under the point estimates. The asterisks show significance level. * = 10%, ** = 5% and *** = 1%. Monthly frequency. L means that the variable is lagged by one period, while D means that the variable is differentiated.

4 Conclusion

In recent years, the OIS basis between NOK and USD has accounted for a larger portion of the premium in Nibor than earlier. One of the reasons for this is likely that structural liquidity has been appreciably lower in recent years than it had been in previous years. In this paper, we estimate a number of different models and find that the relationship between expected structural liquidity and the OIS basis between NOK and USD has become stronger since 2016. This is probably related to the introduction of LCR requirements in NOK both for Norwegian banks and gradually for a number of branch banks. Combined with the decline in structural liquidity in recent years, this may help to explain the rise in the OIS basis. Furthermore, the results may indicate that there is a somewhat stronger relationship between expected structural liquidity and the OIS basis in the event of particularly large changes in structural liquidity.

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Appendiks

Table A.1: Augmented Dickey-Fuller test for whether OIS basis USDNOK, OIS basis EURUSD, average and minimums level of structural liquidity next three months contain a unit root or not.

	OIS basis USDNOK	OIS basis EURUSD	Average SL 90	Min SL 90	Min SL 90 (II)
L.OIS basis	-0.22***				
	(-3.76)				
LD.OIS basis	0.26***				
	(2.68)				
L.OIS basis EURUSD		-0.19**			
		(-3.16)			
L2D.OIS basis EURUSD		-0.24**			
		(-2.59)			
L.Average SL 3m			-0.28***		
			(-5.27)		
LD.Average SL 3m			0.47***		
			(5.46)		
L.Min SL 3m				-0.23***	-0.18**
				(-4.48)	(-3.12)
LD.Min SL 3m				0.40***	0.41***
				(4.41)	(4.59)
L2D.Min SL 3m					-0.18*
					(-1.76)
Constant	-0.26	5.82***	11.12***	-6.44***	-4.80**
	(-0.42)	(2.82)	(4.36)	(-3.04)	(-2.22)
Observations	106	105	106	106	105
Adjusted R2	0.121	0.158	0.285	0.214	0.221

Comments on the table: T-values are shown in brackets under the point estimates.
The asterisks show significance level. * = 10 percent, ** = 5 percent and *** = 1 percent.
We test whether the coefficient of the lagged dependent variable is significantly different from 0. Critical values are based on Fuller (1996).
The null hypothesis is that the time series contains a unit root.

Figure A.1: Residuals from specification (I) and (II) in Table 1.

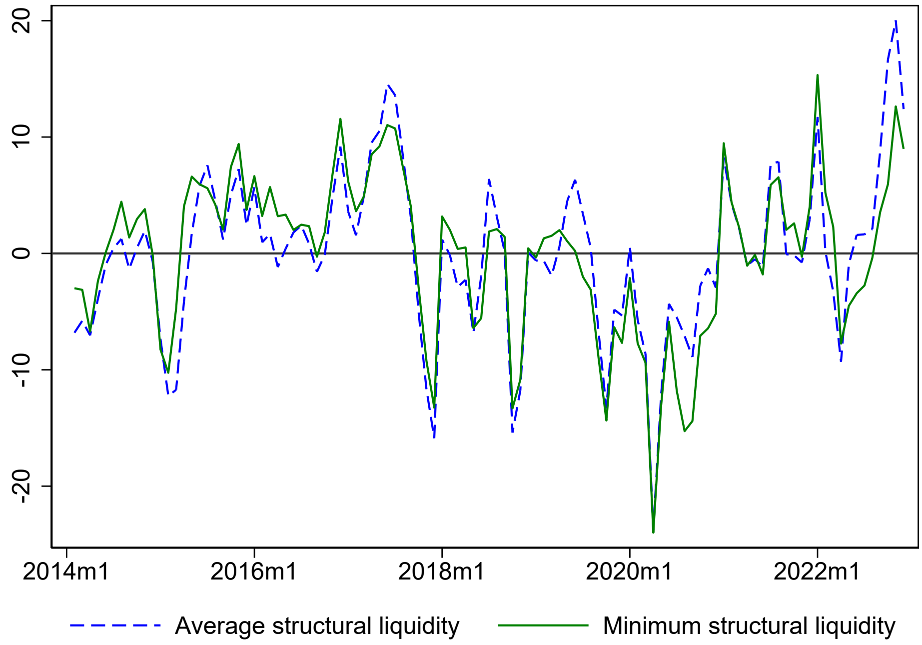


Figure A.2: Residuals from specification (III) and (IV) in Table 1.

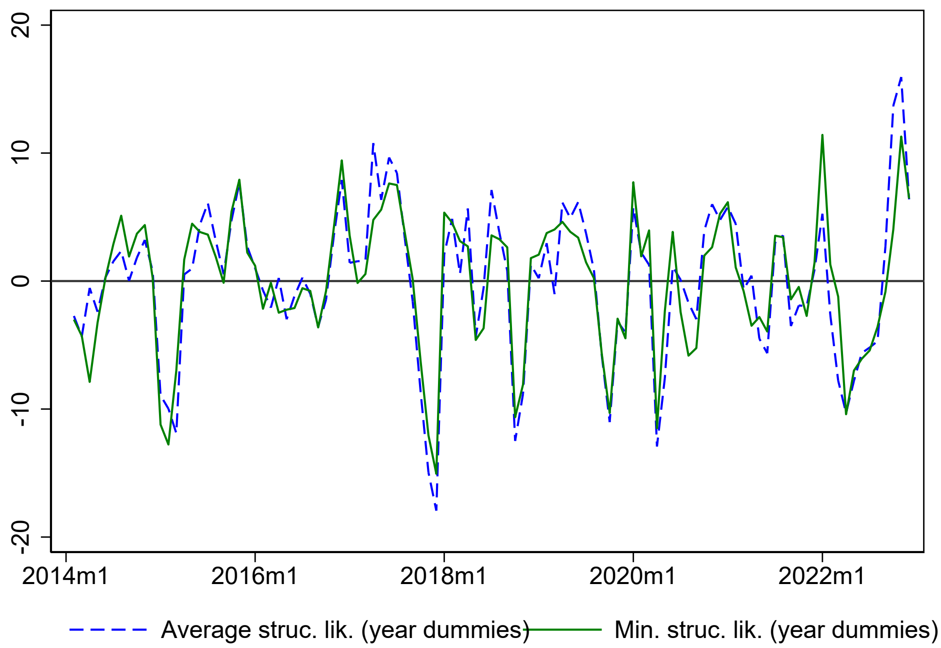


Figure A.3: Residuals from specification (I), (II) and (III) in Table 2.

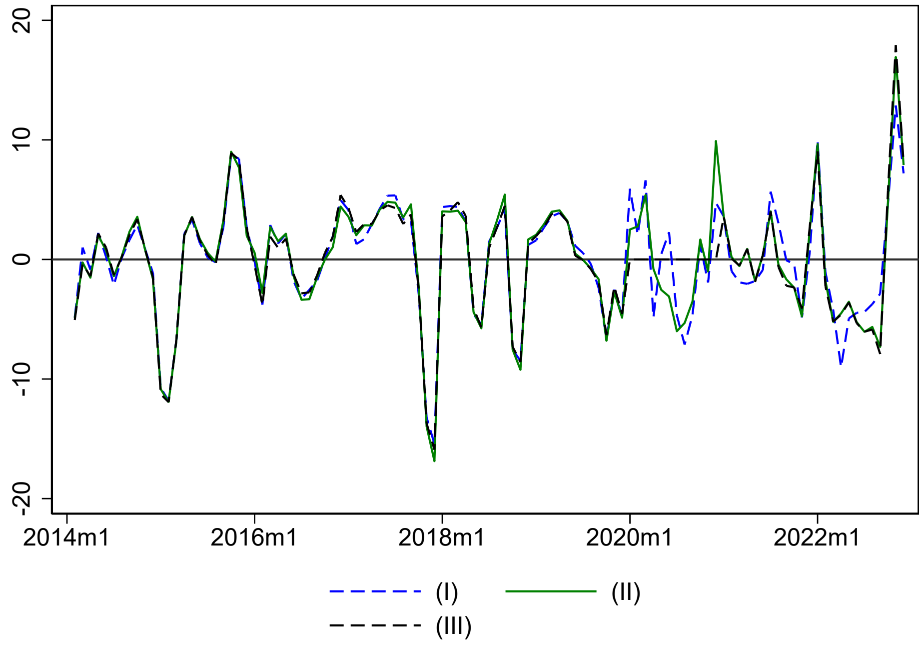
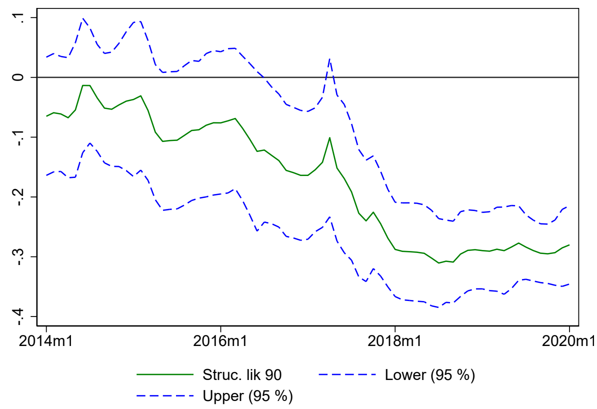
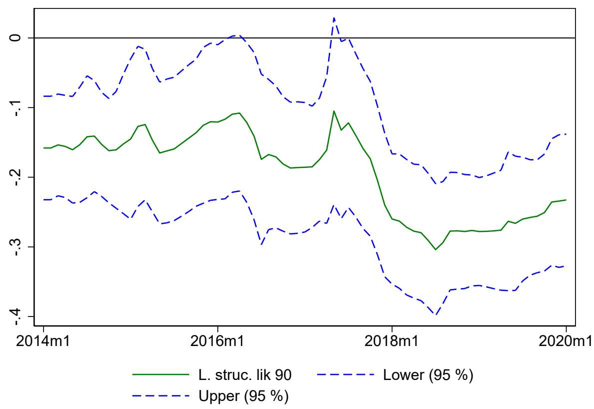


Figure A.4: Regressions with rolling time periods. Dependent variable: OIS basis USD-NOK

a) Average structural liquidity included in the same period



b) Average structural liquidity lagged by one period



Footnote: We use three-year rolling time windows, where the x-axis shows the starting point of each regression. We estimate two specifications. In specification a) we have estimated the following equation $OISB_{USDNOK,t} = \alpha + \beta_1 OISB_{EURUSD,t} + \delta SL_{3m,t} + D + \varepsilon_t$, where in specification b) we replace average structural liquidity in the same period with lagged by one period.
$OISB_{USDNOK,t} = \alpha + \beta_1 OISB_{EURUSD,t} + L.\delta SL_{3m,t} + D + \varepsilon_t$.

Table A.2: Specifications where we include lagged dependent variable as an explanatory variable. Dependent variable. OIS basis USDNOK.

	(I)	(II)
L.OIS basis	0.40***	0.40***
	(0.09)	(0.08)
OIS basis EURUSD	-0.24***	-0.23***
	(0.06)	(0.06)
Min SL 3m.* Dummy 2014-2016	-0.02	
	(0.05)	
L.Min SL 3m.* Dummy 2014-2016	-0.03	-0.05**
	(0.03)	(0.02)
Min SL 3m. * Dummy 2017-2019	-0.09	
	(0.07)	
L.Min SL 3m. * Dummy 2017-2019	-0.09	-0.15**
	(0.08)	(0.06)
Min SL 3m. * Dummy 2020-2022	-0.20***	-0.20***
	(0.04)	(0.02)
L.Min SL 3m. * Dummy 2020-2022	-0.01	
	(0.06)	
Observations	107	107
Constant	✓	✓
Year dummies	✓	✓
Significant seasonal dummies (month)	✓	✓

Comments on the table: OLS regression with Newey-West standard errors (see Newey and West (1987)). Standard errors are robust to heteroscedasticity and up to a fourth-order autocorrelation and are shown in brackets under the point estimates. The asterisks show significance level. * = 10%, ** = 5% and *** = 1%. Monthly frequency. L means that the variable is lagged by one period.

Table A.3: Dependent variable: OIS basis USDNOK.

	(I)	(II)
OIS basis EURUSD	-0.32***	-0.30***
	(0.08)	(0.08)
Average SL 3m. * Dummy 2014-2016	0.06	
	(0.06)	
L.Average SL 3m. * Dummy 2014-2016	-0.14***	-0.11***
	(0.05)	(0.04)
Average SL 3m. * Dummy 2017-2019	-0.04	
	(0.08)	
L.Average SL 3m. * Dummy 2017-2019	-0.12*	-0.11**
	(0.07)	(0.05)
Average SL 3m. * Dummy 2020-2022	-0.24***	-0.30***
	(0.05)	(0.04)
L.Average SL 3m. * Dummy 2020-2022	-0.09*	
	(0.05)	
Observations	107	107
Constant	✓	✓
Year dummies	✓	✓
Significant seasonal dummies (month)	✓	✓

Comments on the table: OLS regression with Newey-West standard errors (see Newey and West (1987)). Standard errors are robust to heteroscedasticity and up to a fourth-order autocorrelation and are shown in brackets under the point estimates. The asterisks show significance level. * = 10%, ** = 5% and *** = 1%. Monthly frequency. L means that the variable is lagged by one period.

Figure A.5: Residuals from specification (I), (II) and (III) in Table 3.