STAFF MEMO

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Norwegian and international yields in the 10 year segment

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We investigate the relationship between the Norwegian 10 year Treasury yield and the corresponding yields in the major international markets, using both quarterly and monthly data. We find that the Norwegian yield is highly correlated with the EUR, USD and GBP yields. In recent years the correlation with the EUR yields has been stronger than correlations with the USD and GBP yields. We estimate error correction models for the difference between the Norwegian and the international yields. We establish that co-integrating relationships exist, but also that the convergence towards international yields is relatively slow. We test for the short term influence of macro variables on the yield difference and find some weak evidence that economic growth differences and unemployment differences are important, together with the price of oil.

1. Introduction and summary

In classical economic theory the long term natural or equilibrium real interest rate mainly depends on the growth capacity of an economy, i.e. on the growth in labour supply and productivity, as well as on consumers' time preferences. These factors are reasonably stable over time for all economies. For a small open economy the long term equilibrium yield will also depend on the equilibrium yields in the major international markets, which from a Norwegian perspective are the Eurozone, the UK and the US.

Yields in the major markets will be even more important for the yield on Norwegian krone debt in the short and medium term. In this note we are looking for a medium to long term equilibrium relationship between the Norwegian Treasury 10 year yield and the 10 year Treasury yields in the major economies. In particular we try to identify whether and how fast the yield differences between NOK and the major currencies converge towards a long term relationship. We also search for which other variables may be relevant to explain the yield differences during convergence.

The research literature includes a number of studies on the links between international bond yields, mostly covering only the major economies. Ilmanen (1995) and Barr and Priestley (2004) are examples of papers using asset pricing models to analyse excess returns on bond indices and testing for the importance of a common factor across economies. The present paper is more closely related to papers using time series models to test for co-integration, see for instance Hammersland and Vikøren (1997), Bruneau and Jondeau (1999) and Yang (2005).

We compare the yields on German and French (representing the Eurozone), US and UK 10 year Treasuries to the Norwegian Treasury 10 year yield. The analysis is performed both on quarterly and monthly data. The first and

obvious observation is that the 10 year yields in all major markets are highly correlated with each other and with the Norwegian yield. A very large portion of the variation in the Norwegian yield may thus be formally explained by the yield in any one of the major markets.

The quarterly analysis employs data from 1990 Q1 to 2015 Q4. Including all the four major markets in the analysis produces multicollinearity, and we are thus not able to identify which market is the most important for explaining the Norwegian yield. We choose to aggregate the yields in the four major markets by taking the simple unweighted average. Within that model we cannot reject a hypothesis that the Norwegian 10 year yield will in the long term be equal to the average yield in the major markets. But the convergence is slow; the yield difference tends to be reduced to half only after one to two years. We test for the importance of other factors and find that neither economic growth differences, inflation differences nor the oil price have any statistically significant effect on the Norwegian 10 year yield, and that unemployment rate differences have only a weak effect.

The monthly analysis employs data from January 2002 to December 2015. The GDP growth variable is not available at the monthly frequency, and it is replaced by the manufacturing growth rates. Based on the monthly data we find somewhat stronger evidence that the Norwegian yield is closely related to the German yield, with a constant mark-up over the German yield in the long term and with on average parallel monthly changes in the short term. If we aggregate the yields in the major markets by taking the simple unweighted average, we find a relationship very similar to the one in the quarterly analysis: We cannot reject a hypothesis that the Norwegian 10 year yield converges to the average yield in the major markets, with a zero mark-up. Again, the convergence is found to be relatively slow.

We test for the importance of manufacturing growth, inflation, unemployment and the oil price for short term yield differences. When restricting the analysis to the latest eleven years 2005-15, we find some evidence that relatively higher manufacturing growth rates in Norway contributes to a higher yield difference, whereas higher relative levels of unemployment in Norway and higher oil prices contribute to a lower yield difference in the short and medium term.

2. Analysis of quarterly data 1990-2015

2.1. The data

Figure 1 shows the quarterly averages of daily yields on 10 year benchmark Treasury bonds issued by Norway, France, Germany, UK and the US. The five time series trend downwards during the entire period and are clearly not stationary. We notice that the Norwegian yields are highly correlated with the yields in the major economies: The correlations computed for the Norwegian 10 year yield vs. the 10 year yields in the major markets range from 0.94 for the US yield to 0.98 for the French and German yields.

Figure 1: Yields on 10 year benchmark government bonds issued by Norway, Germany, France, UK and the US, in per cent per year. Quarterly averages 1990 Q1-2015 Q4. Source: Thomson-Reuters

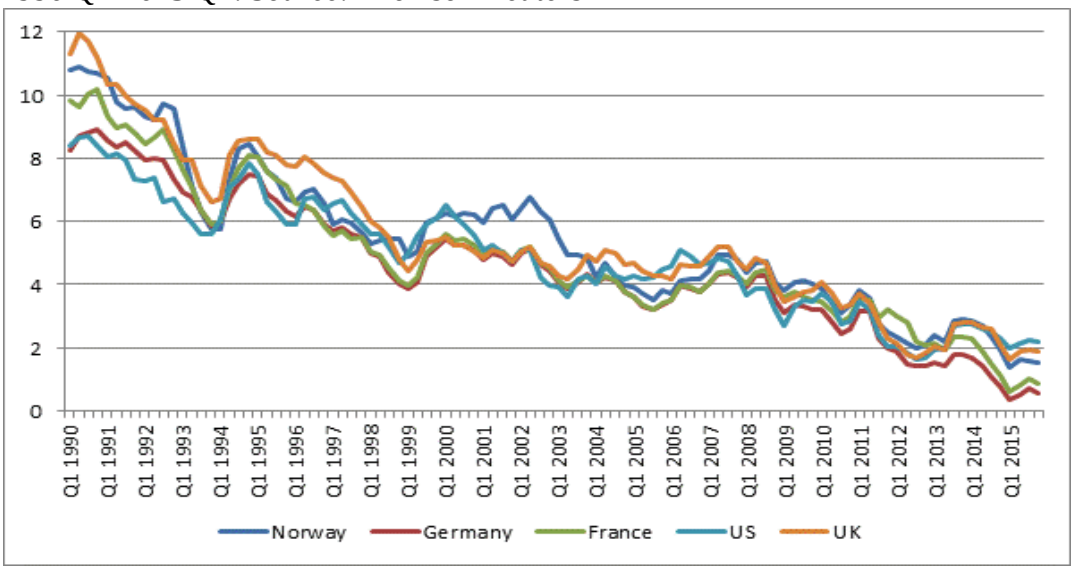
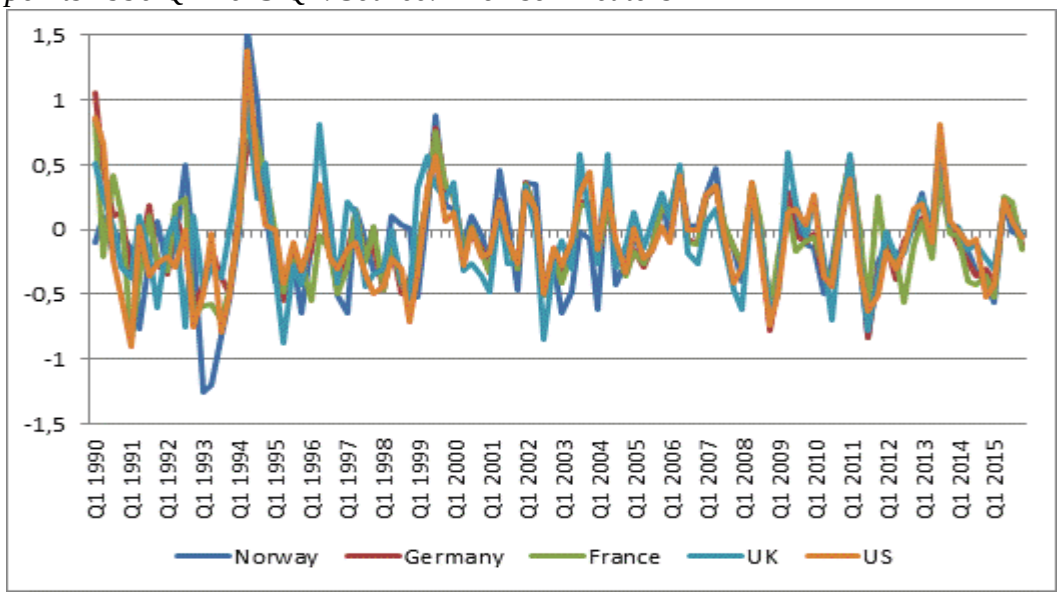


Figure 2 depicts the quarterly changes in the 10 year yields. Visual inspection strongly suggests that these series are all stationary, and standard Augmented Dickey-Fuller (ADF) tests confirm this. There is a high degree of correlation between the yield changes. The correlation of changes in the NOK yield from the previous quarter with the corresponding changes in the yield on French and German bonds is at 0.76 and 0.73 respectively, and at 0.60 and 0.70 with the UK and the US yield changes.

Figure 2: Quarterly changes in yields on ten year benchmark government bonds issued by Norway, Germany, France, UK and the US, in percentage points 1990 Q1-2015 Q4. Source: Thomson-Reuters



This suggests that the NOK yield is heavily influenced by the yields in the major markets; the relative size of the Norwegian market makes it unreasonable to assume an inverse causal relationship. Alternatively we could assume that there are common factors behind the yield changes in all these

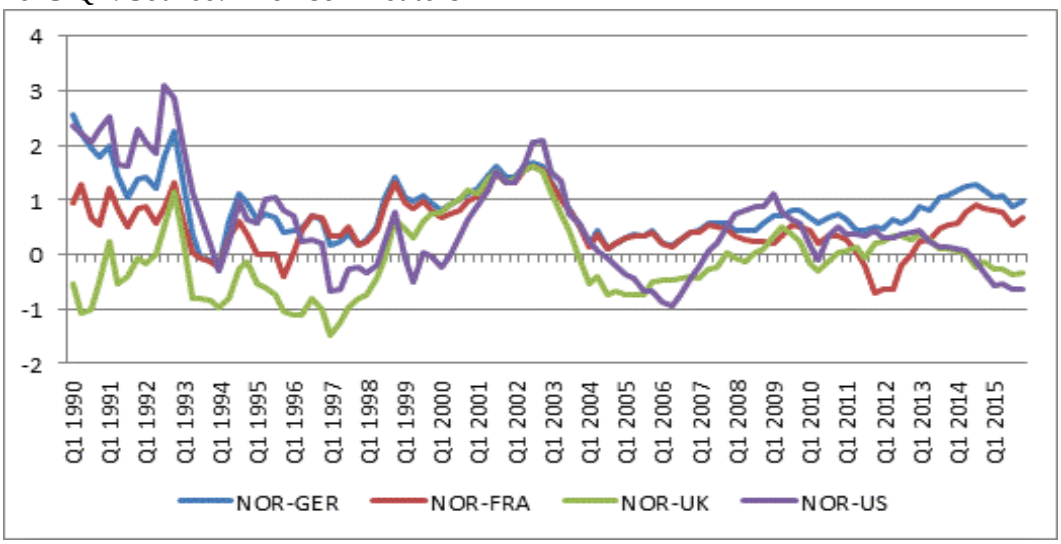
economies, but it seems likely that these factors mainly affects Norwegian yields through their effects in the major markets.

On average for these 26 years the French yield is the one most closely correlated with the Norwegian yield, but there are also high correlations with the three other major markets. This suggests that the Norwegian yield could formally be explained by the yield in any one of the major markets.

2.2. A long term relationship between yields

Figure 3 shows the differences between the Norwegian 10 year yield and the corresponding yields in the four major markets. There is some variation over time, but overall the differences look stationary, and standard ADF tests confirm this. It is thus reasonable to assume a long term relationship between the yield levels, with short term dynamics described by the quarterly yield changes.

Figure 3: The yield differences between Norwegian 10 year Treasuries and the German, French, UK and US 10 year Treasuries. Percentage points 1990 Q1 – 2015 Q4. Source: Thomson-Reuters



We specify an error correction model with a maximum of two quarters lagged changes in each of the four major markets, and with lagged yield differences between the Norwegian and each of the foreign yields. After eliminating insignificant variables using the PC-Give procedure[1], we obtain (with estimated standard errors in parentheses):

$$\begin{aligned}(1)\quad dNOR10 &= \underset{(0.112)}{0.561}*dFRA10 + \underset{(0.090)}{0.316}*dFRA10_{-1} + \underset{(0.106)}{0.453}*dUK10 \\ &\quad - \underset{(0.085)}{0.186}*dUS10 + \underset{(0.033)}{0.074}*(UK10_{-1} - NOK10_{-1})\end{aligned}$$

[1] See Doornik and Hendry (2007)

A standard ADF test confirms that the residuals of this equation are stationary. We thus find that the Norwegian yield has a co-integrating relationship with the UK yield, with the two yields equal in the long term. The short term dynamics depend on the changes in the UK yield, but also in the French and US yields. Notice that the sum of the short term coefficients for changes in foreign yields is not significantly different from one; i.e. the Norwegian yield tends to move in step with a weighted average of the yields in the major markets.

We should realize, however, that the yields and yield changes in the major markets are so highly correlated that the selection of relevant markets in the above equation may be arbitrary, in the sense that yields from the other major markets would have nearly the same explanatory power as the UK yield.

One way around the multicollinearity problem is introducing the simple unweighted average of the 10 year yields in the four major markets as a new variable. Starting from a general specification with a maximum of two quarters lagged yield changes in the major markets and a lagged yield difference; we obtain the following relationship after eliminating less relevant variables through the PC-Give procedures:

$$\begin{aligned}(2)\qquad dNOR10 &= \underset{(0.083)}{0.971}*dMajor10 + \underset{(0.082)}{0.179}*dMajor10_{-1} \\ &+ \underset{(0.046)}{0.106}*(Major10_{-1} - NOR10_{-1} + \underset{(0.299)}{0.464})\end{aligned}$$

A standard ADF test confirms that the residuals of this equation are stationary, and we have another co-integrating relationship. We find that the Norwegian yield is a 46 basis points mark up the average yield in the major markets. Notice, however, that this constant term retained by the elimination procedure is not statistically different from zero. The correction coefficient suggests that 11 per cent of the difference will be eliminated each quarter; thus half the initial difference will be eliminated within six quarters. The estimated relationship further implies that the Norwegian yield will tend to change approximately in step with the average yield in the major markets.

2.3. Yield differentials and macro variables

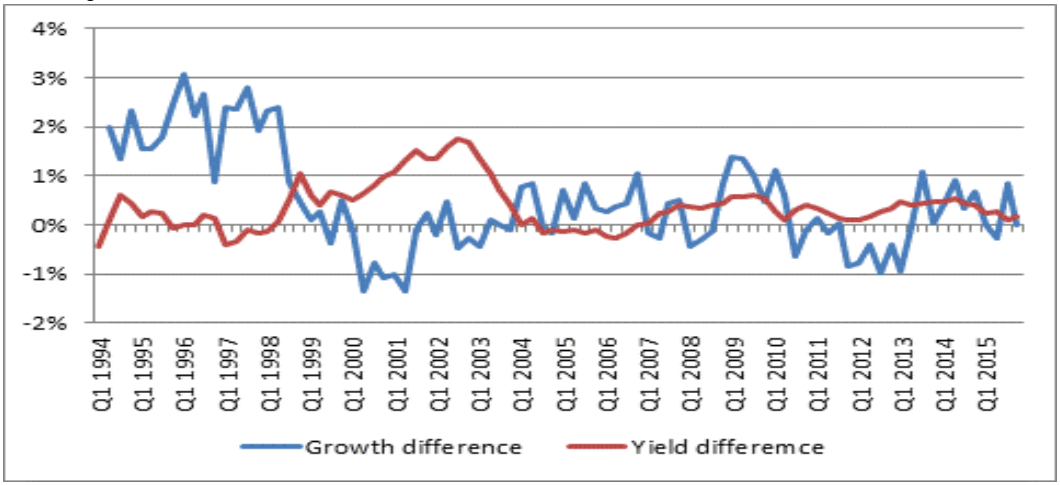
We shall now be asking whether macro economy variables contribute to the short term dynamics of the Norwegian 10 year yield. We shall be considering economic growth, inflation, unemployment and the price of oil.

We regularly observe that when growth prospects for a country are improving, its money and capital markets attract inflows and the market yields will increase. This is clearly an important short term mechanism in the markets. Whenever new information is published, markets are quick to decide what that information means for economic growth and behave accordingly. The simple rationale behind this behaviour is that higher economic growth will normally

allow the central bank to increase its policy rate to control inflation without hurting the economy, and investors can expect higher returns by moving their money there. Furthermore, the currency of that country is more likely to appreciate. For our purpose it means that differences in economic growth could be important for short term yield dynamics.

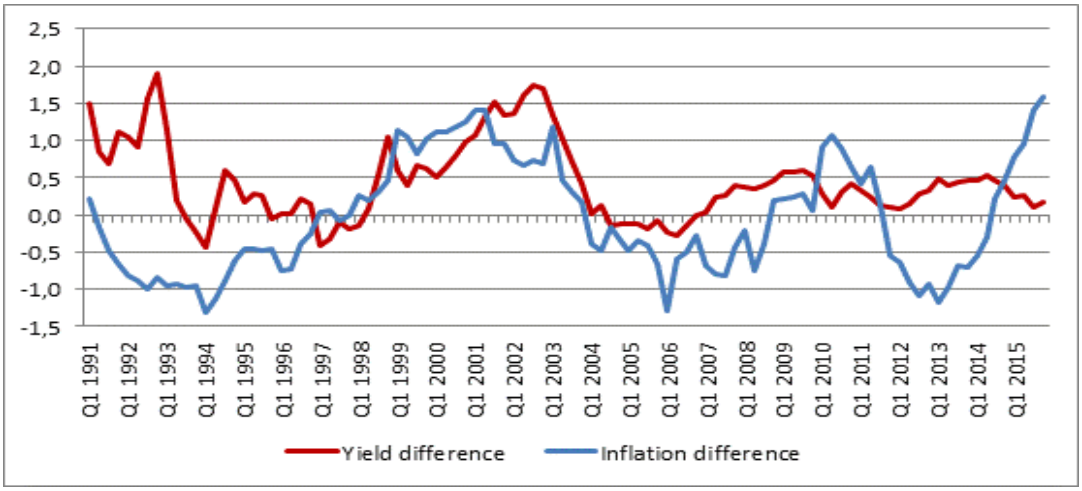
We shall look at rolling average three year growth rates for real (constant prices) GDP as an indicator of national output growth. Quarterly GDP data for Germany is available only from reunification in 1991, meaning that three year growth rates for all economies are only available from 1994. Figure 4 presents the difference between the three year growth rates for Norway and for the average of the four major economies. We notice that the Norwegian growth rate is particularly high in the late 1990s. The figure also includes the 10 year yield difference between Norway and the four major economies. It is hard to distinguish any systematic covariation between the growth and yield variables. Formal econometric analysis, where the variables from equation (2) are retained and the three year growth differences added as a new variable, confirms that growth differences do not help explain yield differences over this data set. Using one or five year average growth rates does not make much difference.

Figure 4: The difference between Norway and the average over the four major economies for three year real GDP growth rates and 10 year yields 1994 Q1 – 2015 Q4. Source: Thomson-Reuters



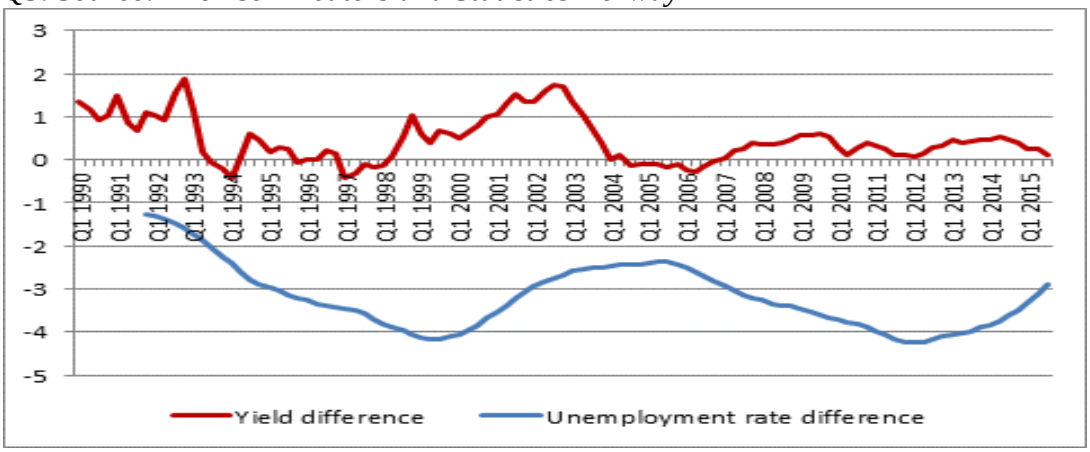
The yields we have been investigating are in nominal terms. Inflation differences may therefore be relevant to explain yield differences. In Figure 5 we plot the difference between the three year lagging average headline inflation rates in Norway and in the four major economies. While the inflation differences are positively correlated with the 10 year yield differences, the covariation is not very close, in particular not in the first and last years of the observation sample. This is presumably the reason why the inflation rate differences do not contribute to explaining the yield differences, either individually or as an average over the four major markets, when we introduce them into our error correction models. As was the case for the growth rates, trying one or five year averages does not make much difference.

Figure 5: The difference between Norway and the average of four major economies for three year inflation rates and 10 year yields 1991 Q1–2015 Q4. Source: Thomson-Reuters



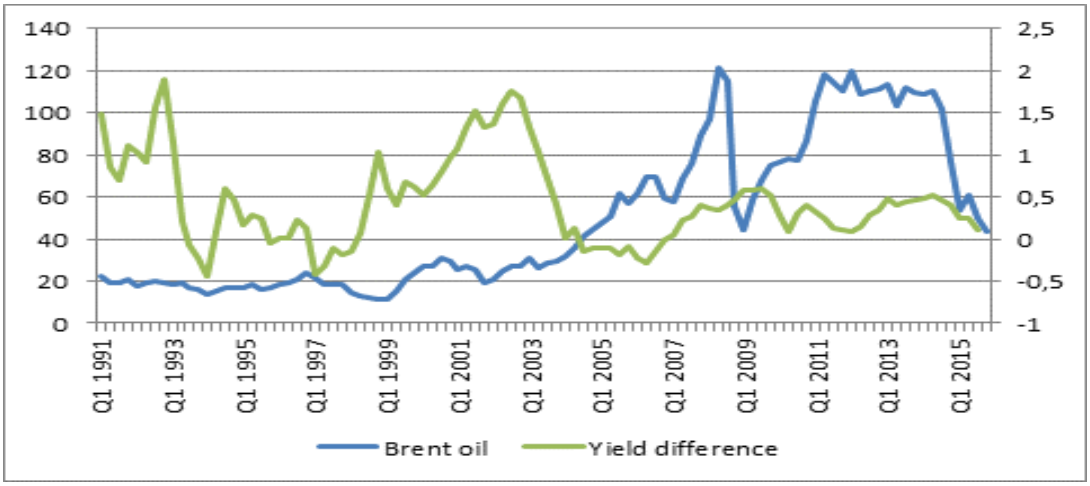
Unemployment rates could potentially be another factor behind yield differences, even for long maturities, since monetary policy will normally have some effect on the entire yield curve. Figure 6 shows that the difference between the three year average, seasonally adjusted, unemployment rates in Norway and the four major markets are much less volatile than the yield differences. Visually there seems to be some tendency that the yield difference is lower when the unemployment rate difference is lower.

Figure 6: The difference between average unemployment rates over the past three years between Norway and the four major economies (per cent of the labour force) and the corresponding 10 year yield differences 1990 Q1-2015 Q3. Source: Thomson-Reuters and Statistics Norway



We obtain the expected negative sign when introducing the unemployment rate differences into our error correction model. But the coefficient is statistically significant only at the 10 per cent test level. Similar results are obtained when averaging unemployment rates over only one year.

Figure 7: Brent oil price in USD (left hand axis) and yield difference between Norway and the major markets (right hand axis.) 1991 Q1 -2015 Q4. Source: Thomson-Reuters



The Brent oil price is shown in figure 7 together with the yield difference. It is hard to spot any systematic covariation. For instance, not much happens to the yield difference when oil price rose from 2004-5. Introducing the oil price into the error correction model we obtain the expected positive sign, but the coefficient is not statistically significant.

Thus, neither growth, inflation nor the oil price contribute significantly to explaining the yield difference to the major markets. There is some weak evidence that unemployment differences are important, but the coefficient is not statistically significant at conventional test levels. Our best model for explaining the quarterly changes in 10 year Norwegian yields over the period 1990-2015 remains equation (2).

2.4. Summing up on quarterly data

The analysis of the quarterly data indicates that the Norwegian 10 year yield is closely related to the average 10 year yield in the four major markets. The yield in any one of the major markets can be used to explain the Norwegian yield. We notice, however, that the Eurozone markets appear to have been more important to the Norwegian market than were the US or UK markets.

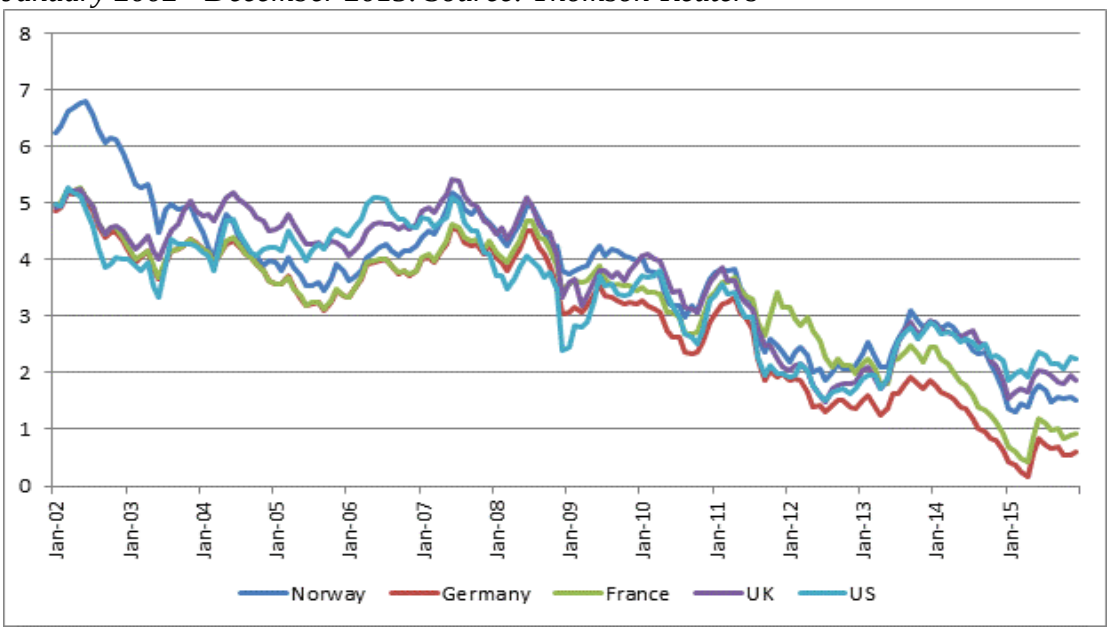
The macro economy variables that we tried did not contribute significantly to explaining quarterly changes in the Norwegian 10 year yield. Only the unemployment variable was weakly statistically significant. The internal dynamics of the Treasury markets appears to be much more important than macro variables. But one possible expanation is of course that macro variables we looked at influence the yields in the major markets, in which case their influence on the Norwegian yield will come through the yield variables.

3. Analysis of monthly data 2002-2015

3.1. The data

We now repeat the analysis on monthly data starting in January 2002. We can use the same data sources as for the quarterly data, with one important exception: There are only quarterly data available for GDP; we shall thus resort to using the monthly data for manufacturing production as an indicator for economic growth.

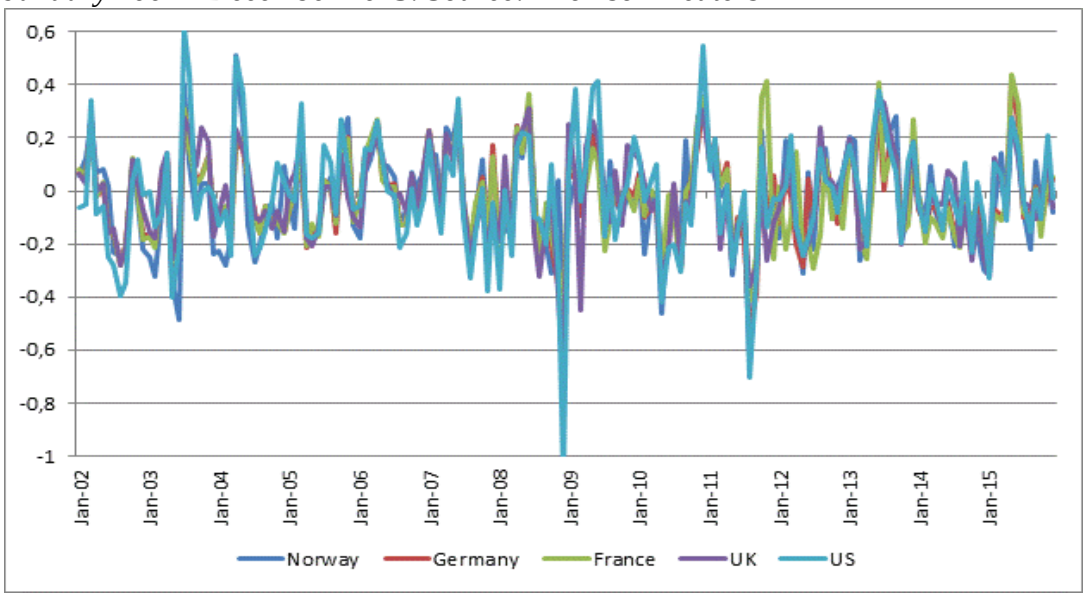
Figure 8: Yields on 10 year benchmark government bonds issued by Norway, Germany, France, UK and the US, in per cent per year. Monthly averages, January 2002 - December 2015. Source: Thomson-Reuters



The monthly data for 10 year yields are presented in figure 8. The non-stationarity and the high degree of correlation are obvious. The correlations between the Norwegian yield and the yields in the major markets range from 0.83 for the US to 0.95 for the German yield.

The differenced series with monthly changes in figure 9 are also closely related, with correlation coefficients for the Norwegian yield ranging from 0.74 against the UK to 0.84 against Germany. These correlations coefficients are close to the correlations we find for quarterly data during the same period: Correlations have been higher after 2002. Notice also that all the time series of yield changes appears to be stationary. Formal ADF tests confirm that they are.

Figure 9: Monthly changes in yields on ten year benchmark government bonds issued by Norway, Germany, France, UK and the US, in percentage points. January 2002 - December 2015. Source: Thomson-Reuters

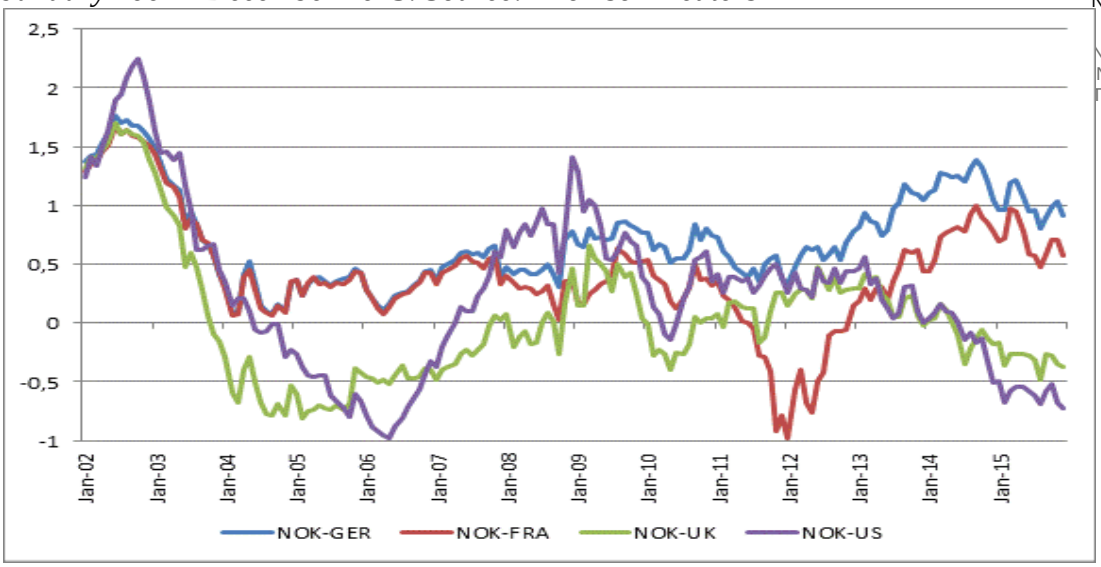


3.2. A long term relationship between yields

As in the quarterly analysis, we shall assume that the NOK yield is determined by the yields in one or more of the four major markets. The differences between the Norwegian yield and the yields in each of these four markets are shown in figure 10. We notice large yield differences at the start of the period up to 2004 and much smaller differences after 2004.

Formal ADF tests indicate that all these yield differences are stationary: There are likely to be long term equilibrium relationships between the Norwegian yield and the yields in the major markets. We explored the short term dynamics of the Norwegian 10 year yield within an error correction model where we initially allowed for the influence of French, German, UK and US yields with up to three months lag. We did not find a co-integrating relationship, but the estimated short term dynamics indicated that the change in the Norwegian rate is a weighted average of the changes in the major markets, with the dominant weight on the German yield.

Figure 10: The yield differences between Norwegian 10 year Treasuries and the German, French, UK and US 10 year Treasuries. Percentage points January 2002 - December 2015. Source: Thomson-Reuters



However, the strong positive correlation between yields in all markets indicates that any of the major markets may be used to explain the Norwegian yield. If we wish to focus on the relationship to one market only, the German market is an obvious candidate based on the correlation analysis. Estimating a relationship exclusively between Norwegian and German yields, and eliminating statistically insignificant variables, we obtain the following estimates for the remaining parameters (standard errors in parentheses):

$$(3) \quad dNOR10 = \underset{(0.049)}{0.953}*dGER10 + \underset{(0.020)}{0.045}*(GER10_{-1} - NOR10_{-1} + \underset{(0.366)}{0.613})$$

The Norwegian 10 year yield changes each month by approximately the same number of basis points as the change in the contemporaneous German yield, plus an error correction term that depends on whether the difference to the German yield is higher or lower than the equilibrium difference, which is estimated at 61 basis points. This compares to an average difference over the sample period of 72 basis points. The fit in equation (11) is reasonably good with a R^2 of 0.71, and the parameters have the expected signs with values that seem reasonable. The adjustment parameter for the lagged yields indicates that deviations from the long term relationship take about 15 months to be reduced to half of the original deviation.

The 2005-2015 subsample

As an alternative to looking at one market only we could choose to look at the unweighted average yield in the major markets. For the full 2002-2015 sample this does not lead us to a co-integrating relationship. We notice from figure 10, however, that the yield differences appear to behave differently during the first couple of years of the sample. Restricting the analysis to the last eleven years 2005-15 may thus provide a relationship that is more representative of what we can expect in the future.

Within this subsample we try to identify co-integrating relationships with the German yield and with the unweighted average yield in the major markets, respectively. Only in the latter case do we find a stable co-integrating relationship:

(4) $dNOR10 = 0.873*dMajor10 + 0.043*(NOR10_{-1} - Major10_{-1})$
(0.049) (0.024)

A standard ADF test confirms that the error term is stationary. Notice that the constant term has been eliminated by the PCGive procedure. The estimated relationship implies that the Norwegian yield will tend to become equal to the unweighted average yield in the major markets. Half the initial yield difference will tend to be eliminated within less than two years.

3.3. Yield differences and macro variables

Theory suggests that macro variables may be important for the yield differences, as motivated in section 2.3. As for the quarterly data we shall look at differences between Norway and the average level for the major economies with regard to economic growth, inflation, and unemployment. In addition we shall look at the oil price, which is more important for Norway than for most other countries. We shall concentrate on the 2005-2015 subsample, which we believe to be the more representative for the present situation.

Figure 11: The yield difference and three year industrial production growth differences between Norway and the four major markets. January 2005 to November 2015. Source: Thomson-Reuters

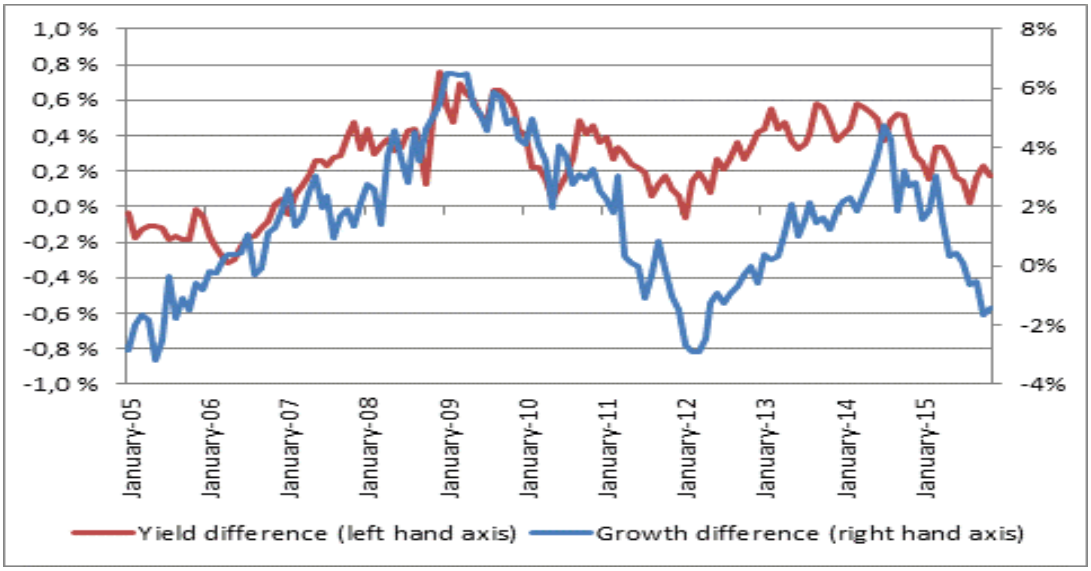


Figure 11 illustrates that the economic growth differences and the yield differences have been strongly positively correlated since 2005. Introducing the average growth difference over the past three years into equation (4), we obtain:

(5) $dNOR10 = 0.837*dMajor10 + 0.100*(Major10_{-1} - NOR10_{-1})$
(0.048) (0.036)
$+ 0.972*$growth difference
(0.456)

We find that the growth difference between Norway and the four major economies has given the Norwegian yield a significant push upwards since 2005, using the conventional 5 per cent test level.

Figure 12: The yield difference (NOR10-Major10) and the difference between three year headline inflation rates in Norway and the average of the major economies. January 2005 to November 2015. Source: Thomson-Reuters

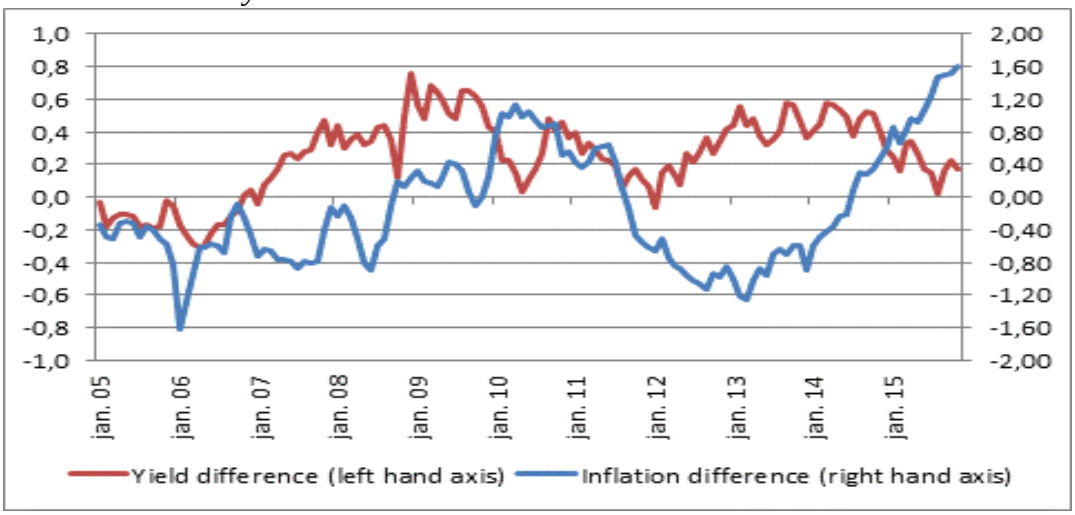


Figure 12 shows the inflation and yield differences between Norway and the four major economies. Here it seems hard to identify any pattern of systematic co-variation, in particular during the latest five years. The econometric exercise confirms this, by producing a statistically insignificant coefficient estimate with the wrong sign for the inflation difference:

(6) $dNOR10 = 0.877*dMajor10 + 0.041*(Major10_{-1} - NOR10_{-1})$
(0.049) (0.025)
$- 0.002*$inflation difference
(0.007)

Figure 13 shows the unemployment and yield differences. We notice that the periods with high yield differences in 2009 and in 2013-14 coincide with very different unemployment pictures. The first of these periods saw much lower unemployment rates in Norway than in the main economies, but this was less clear in the last of these periods. In the error correction specification we get the expected negative sign for the unemployment difference, but the coefficient is statistically significant only at the 10 per cent test level.

(7) $dNOR10 = 0.888*dMajor10 + 0.095*(Major10_{-1} - NOR10_{-1})$
(0.049) (0.037)
$- 0.006*$unemployment difference
(0.003)

Figure 13: The yield difference and the difference between average unemployment rates over the past year in per cent of the labour force for Norway and the average of the major economies. January 2005 to September 2015. Source: Thomson-Reuters

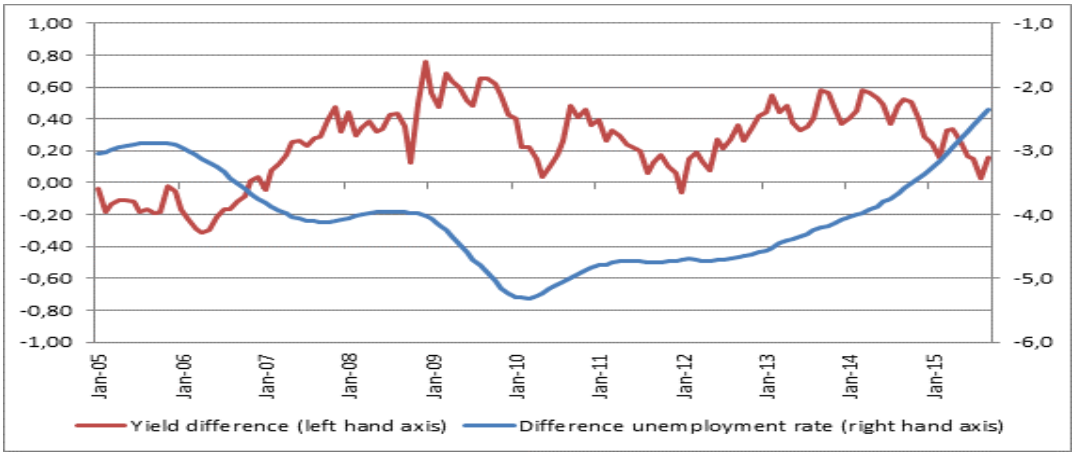


Figure 14: The yield difference between Norway and the major economies and the average Brent USD oil price over the past three years. January 2005 to December 2015. Source: Thomson-Reuters

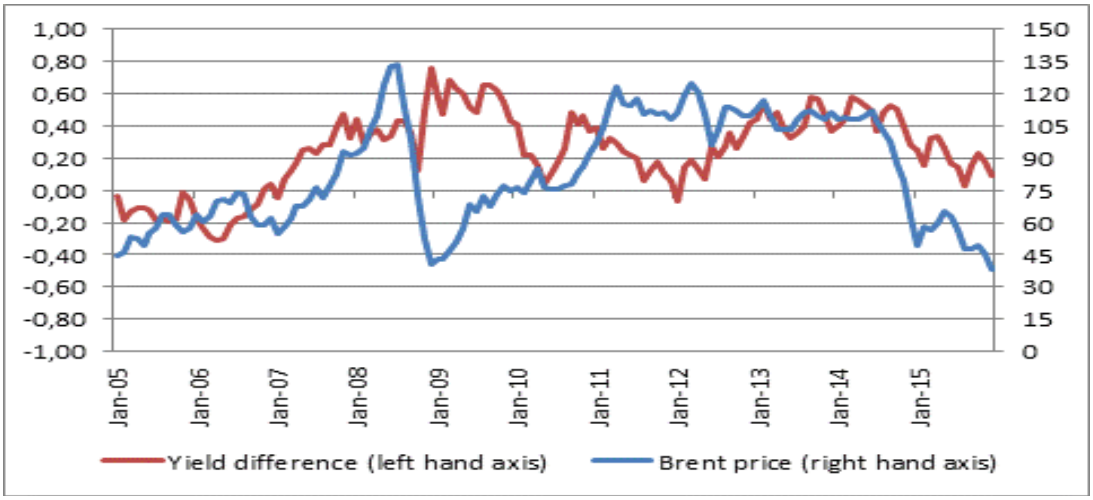


Figure 14 shows the yield difference together with the Brent oil price. As a large oil exporter the Norwegian economy should benefit from high oil prices. The Norwegian krone is likely to appreciate, and the interest rate will thus need to kept relatively low to protect the non-oil exporting industries. In the error correction model we obtain the expected negative sign, but the coefficient is statistically significant only at the 10 per cent test level.

$$(8) \quad dNOR10 = \underset{(0.049)}{0.885}*dMajor10 + \underset{(0.036)}{0.090}*(Major10_{-1} - NOR10_{-1}) - \underset{(0.00014)}{0.00025}*\text{Brent oil price}$$

Ideally we should estimate the error correction model with all macro variables included in one relationship. The macro variables are not eliminated by the PCGive procedure, meaning that they do contribute to explaining the yield change. The estimated signs do not change from equations (5-8), but none of the coefficients are statistically significant at any reasonable test level:

(9) $$dNOR10 = \underset{(0.051)}{0.879}*dMajor10 + \underset{(0.090)}{0.092}*(Major10_{-1} - NOR10_{-1}) + \underset{(0.564)}{0.505}*growth\ difference - \underset{(0.009)}{0.014}*inflation\ difference - \underset{(0.017)}{0.010}*unemployment\ difference - \underset{(0.00046)}{0.00013}*Brent\ oil\ price$$

From this we may perhaps learn that the impulses from the yields in the major markets are much more important than the impulses from the macro variables, at least in the way we have been able to measure them. Alternatively we may think that macro information is already included in the international yields, and that the macro variables do not contain much additional information.

3.4. Summing up on monthly data

The analysis of the monthly data indicates that the Norwegian 10 year yield is closely related to the unweighted average 10 year yield in the four major markets, but also to the yield in any one of these markets. We have identified is a co-integrating relationship with the German yield for the 2002-2015 sample and with the average major market yield for the 2005-2015 subsample.

For the macro variables we concentrated on the 2005-2015 subsample. We found relatively robust short term influences in the expected direction for both growth and unemployment differences and for the oil price, whereas the inflation difference was not found to contribute significantly to explaining monthly changes in the Norwegian 10 year yield. We conclude that the international Treasury markets are very important for explaining the Norwegian Treasury yield, but that economic growth, unemployment and the oil price also matter for the short term.

4. Conclusions

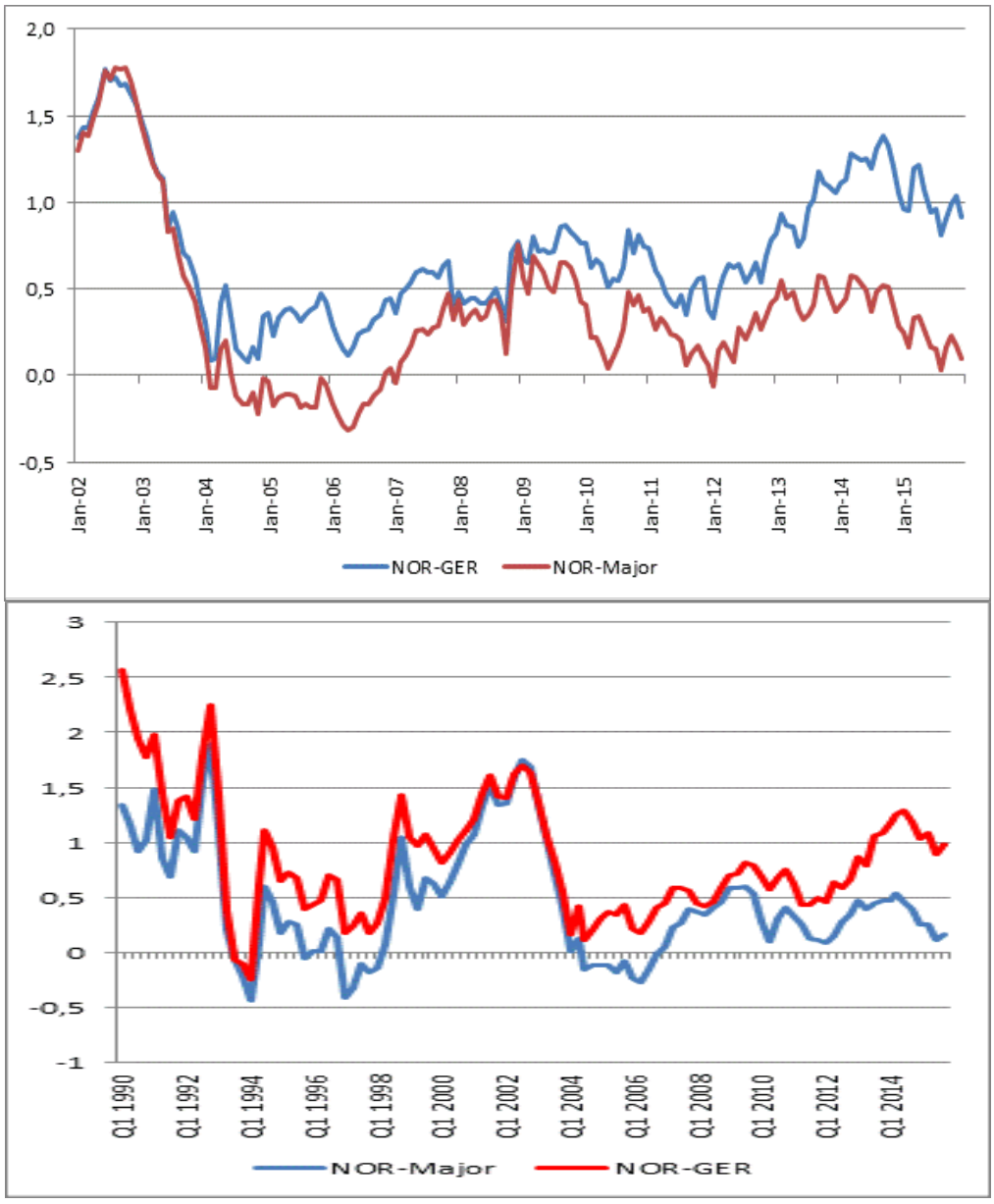
We do find strong evidence that the Norwegian 10 year yield has been closely related to the corresponding German yield and the unweighted average yield in the major markets at least since 2005. In the medium to long term the Norwegian yield appears to be a positive mark-up relative to the German rate, but with a closer to zero mark-up on average yield in the four major markets. The rate of convergence is similar both in the quarterly and the monthly data, with initial deviations reduced to half within approximately 18 months.

In the short term the Norwegian yield and yields in the major markets tend to move in step. Figure 15 shows the yield difference to Germany and to the unweighted average yield in the major markets, as computed over monthly

(upper panel) and quarterly averages (lower panel), respectively. There is no clear indication that the equilibrium level of yield difference has changed during the latest 25 years, but there seems to be some cyclical influence.

When trying to explain this cyclical influence, we have found some evidence that differences of macro variables for Norway and the major economies may matter in the short term. This is particularly true for the latest years 2005-15. For that period we identified a significant effect from differences in economic growth, and a somewhat weaker influence from unemployment and the oil price.

Figure 15: The average yield difference from the Norwegian to the German and average major markets' 10 year yields. Monthly data January 2002-December 2015 and quarterly data 1990 Q1-2015 Q4



References:

Barr, David G. and Richard Priestley (2004), *Expected Returns, Risk, and the Integration of International Bond Markets*. Journal of International Money and Finance 23, 71-97.

Bruneau, C. and E. Jondeau (1999), *Long-run Causality, with an Application to International Links Between Long-term Interest Rates*. Oxford Bulletin of Economics and Statistics 61(4), 545-568.

Doornik, , Jürgen A. and David F. Hendry (2007), PC-Give 12 (volumes I-III). Timberlake Consultants, London.

Hammersland, Roger and Birger Vikøren (1997), *Long-term Interest Rates in the US and Germany*. Working Paper 1997/10.

Ilmanen, Antti (1995), *Time-Varying Expected Returns in international Bond Markets*. Journal of Finance 50(2), 481-506.

Yang, Jian (2005), *International Bond Market Linkages: a Structural VAR Analysis*. International financial Markets, Institutions and Money 15, 39-54.