N^O 2008/3

Staff Memo

Norges Bank Monetary Policy

The relationship between the key policy rate and macroeconomic variables: A simple cross-check for Norway

by

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1. Introduction

In this paper we discuss simple relationships between the key policy rate and macroeconomic variables in Norway. Such models may be useful tools in monetary policy analysis as they provide a cross-check for the interest rate.[2] This study is an update of Bernhardsen and Bårdsen (2004), who estimate similar models for the period 1999-2004.[3]

An estimated relationship between the policy rate and macroeconomic variables can be interpreted as reflecting the central bank's <u>average reaction pattern in monetary policy given the development of macroeconomic variables in the past</u>. However, an estimated equation of this kind can not be interpreted as "the reaction function of the central bank". The actual interest rate setting is based on a vast amount of information about economic developments, macroeconomic equilibrium models and – not least – *experience and judgment.* No central bank follows simple cross-checks when setting the interest rate. Still, simple cross-checks may give guidance in the process of interest rate setting and if the actual interest rate deviates considerably from simple cross-checks, one should be able to explain why. Moreover, we should recall that econometrics is not an exact science. In the estimation process emphasis is put on economic theory, experience about the Norwegian economy, judgement and econometric evidence.

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[1] The author is senior adviser at the Monetary Policy Department at Norges Bank. The views and conclusions in this paper are the responsibility of the author alone and should not be interpreted as reflecting the views of Norges Bank.

[2] Simple cross-checks for the krone exchange rate are discussed in Bernhardsen (2008) and in a box in Norges Bank's Monetary Policy Report 1/2008.

[3] The estimation period in this study is from first quarter 1999 to first quarter 2008.

2. The preferred model

The preferred model takes the form

$$(1) \quad i_t = c + \rho\, i_{t-1} + \beta_\pi (\pi - \pi^*)_t + \beta_{itp} (i_{tp} - i_{tp}^*)_t + \beta_w (w - w^*)_t + \beta_g (g - g^*)_t$$

where

- i is the key policy rate ("foliorenten")
- π is core inflation (inflation adjusted for energy and taxes, CPI-ATE) and π^* is the inflation target equal to 2.5 per cent from first quarter 2001 and assumed to be 2 per cent in the two previous years[4]
- i_{tp} is the three-month nominal interest rate among Norway's trading partners and i^*_{tp} is the corresponding equilibrium rate. The concept of a nominal equilibrium interest rate hinges on a real equilibrium rate and an inflation target (explicitly or implicitly defined)
- w is the nominal wage growth in Norway and w^* is the nominal equilibrium rate (the latter is determined by the real equilibrium rate and the inflation target)
- g is Norges Bank's own mainland GDP growth forecast, as published in the Monetary Policy Report, and g^* is the bank's forecast of potential growth (as determined by the Bank's macro model NEMO[5])

The model is formulated in "gap-form", that is, when all explanatory variables are equal to their equilibrium values the constant term can be interpreted as the neutral level of the nominal policy rate. According to the model, inflation above target brings (in isolation) the interest rate above the neutral level. Note that it is the <u>current rate</u> of (core) inflation that

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[4] In the couple of years prior to the introduction of the inflation target in March 2001, monetary policy was oriented towards stabilising the krone exchange rate against the euro. This was pointed out in Inflation Report 2/1999, as *"…The objective of monetary policy, as stipulated by the authorities, is stability in the krone exchange rate against European currencies. Since the beginning of the year Norges Bank has interpreted the concept "European currencies" as the euro. However, the Bank does not have instruments to fine-tune the exchange rate. In the orientation of instruments, the Bank emphasises the fundamental conditions for exchange rate stability. <u>Price and cost inflation must, therefore, be brought down to the corresponding aim in the euro area</u>…"* (my underscore). Though the euro area has no explicit inflation target, an implicit target is considered to be around 2 per cent.

[5] The general equilibrium model NEMO (Norwegian Economy MOdel) is discussed in a box in Monetary Policy Report 2007/3 and in Brubakk et. al. (2006). The model "1a" is discussed in Husebø et. al. (2004).

enters the model. Hence with respect to the inflation variable the model is not forward looking. However, both the wage gap (w-w*) and the growth gap (g-g*) may have an effect on expected inflation. According to equation (1), wage growth and GDP growth above their respective equilibrium values bring (in isolation) the interest rate above the neutral level.

The foreign interest rate is supposed to capture the effect via the exchange rate. Including the exchange rate directly into the equation introduces a serious simultaneity problem. The correlation between the exchange rate and the interest rate in the sample reflects that the two variables are related to each other in two ways: In an exchange rate equation, given higher interest rate, the exchange rate normally appreciates.[6] In contrast, in a reaction function, given an appreciation and hence tighter monetary policy, the interest rate must fall to stabilise inflation and production. Including the exchange rate directly in the one-equation reaction function (1) results in the wrong sign: What dominates in the sample is the effect from the interest rate to the exchange rate. Obviously, the econometric correct strategy would be to model two equations simultaneously and hope for one reaction function where the interest rate depends positively on the exchange rate and one exchange rate equation where the exchange rate depends negatively on the interest rate (assuming an increase in the exchange rate denotes a depreciation). However, as this framework did not result in convincing results a simpler econometric strategy was chosen: Replace the exchange rate with the *exogenous* foreign interest rate. Then, in an econometric sense the foreign interest rate acts as a kind of instrument for the exchange rate, the idea being that higher foreign interest rate leads to a weaker currency and a looser monetary policy, which in turn requires higher domestic interest rate to stabilise inflation and production. Hence the expected sign of the foreign interest rate gap is positive.[7]

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[6] At least if the rise in the interest rate is unexpected.

[7] In a more advanced econometric study, Bjørnland (2008) estimates a VAR model and study the interactions between monetary policy and the exchange rate in Norway for the two periods 1993-2004 and 1999-2004. She shows that in a larger econometric framework, the two effects stemming from the reaction function and the exchange rate function can be identified.

The estimated equation turned out to be (t-values in parenthesis):

$$(2) \quad i_t = 1.55 + 0.75\, i_{t-1} + 0.38\,(\pi - 2.5)_t + 0.19\,(i_{tp} - 3.58)_t + 0.20\,(w - 4.78)_t + 0.16\,(g - g^*)_t$$

$$\quad\quad (3.74) \quad (9.99) \quad\quad (3.11) \quad\quad\quad\quad (1.93) \quad\quad\quad\quad (1.61) \quad\quad\quad\quad (3.63)$$

R^2=0.98, s=0.24, DW=1.70, t=1999Q1-2008Q1.

where all parameters are estimated with the expected sign and significantly different from zero.[8] In the estimated model the equilibrium rate of inflation is set equal to the inflation target, while the equilibrium values of the foreign three-month interest rate and the wage growth are set equal to their respective sample means. Potential growth, g*, varies over time and is determined by the macro model NEMO.[9]

Note that equation (1) can be written as

$$(3) \quad i_t = 0.75\, i_{t-1} + 0.25\,[\,6.0 + 1.5\,(\pi - 2.5)_t + 0.73\,(i_{tp} - 3.58)_t + 0.8\,(w - 4.78)_t + 0.6\,(g - g^*)_t\,]$$

where the term in brackets is the long-term solution of the model. According to equation (3) the interest rate depends on the lagged interest rate and the interest rate's deviation from the long-term solution. The latter can be written as

$$(4) \quad i_t = 6.0 + 1.5\,(\pi - 2.5)_t + 0.73\,(i_{tp} - 3.58)_t + 0.8\,(w - 4.78)_t + 0.6\,(g - g^*)_t$$

We will now interpret the parameters. The so-called "smoothing coefficient" is large, 0.75, indicating a high degree of autocorrelation[10] in the interest rate. This means that the interest rate to a considerably extent depends on the interest rate in the previous quarter. Normally central banks want to change the interest rate in small steps. That is, even though the central

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[8] For the wage gap the t-value is slightly less than the conventional critical value, implying a p-value of the null hypothesis of having no effect on the interest rate equal to 0.12.

[9] Data sources: *Policy rate*: Norges Bank (to be found on EcoWin); *CPI-ATE*: Statistics Norway (to be found on EcoWin); *Interest rate for trading partners, average of euro-area, US, UK and Sweden*: Ecowin; *Wage growth*: Norges Bank and Technical Reporting Committee on Income settlements; *Growth*: Norges Bank and Statistics Norway; *Potential growth*: Norges Bank.

[10] Autocorrelation means that a variable is correlated with its own lag.

bank foresees a large change in the interest rate, it is normally changed gradually.[11] This results in autocorrelation in the interest rate data. In addition, cross-check models are too simple to reflect the complete reaction function of the central bank. In particular, we know with certainty that the central bank takes considerably more information into account in the interest rate setting process. Hence in an econometric sense relevant explanatory variables may be left out of the model. To the extent that these omitted variables are autocorrelated – a feature quite common in macroeconomic variables – the interest rate will appear to depend on its lagged values (see Rudebusch (2002) for more details). [12] Note, however, that the estimated smoothing coefficient of 0.75 is in line with other studies.[13]

The parameters in the long-term solution have the following interpretation:

- An increase in inflation by one percentage point increases the interest rate by 1.5 percentage point. Hence following higher inflation the real interest rate rises, in line with the Taylor-principle (which says that following higher inflation an increase in the real interest rate is necessary to stabilise inflation over time). Also note that the coefficient of 1.5 is equal to the one proposed by Taylor (1993).

- Higher foreign interest rate leads to higher domestic interest rate. An increase in the foreign interest rate of one percentage point, leads to an increase in the domestic rate of 0.73 percentage point.

- A one percentage point increase in wage growth leads to a 0.8 percentage point increase in the interest rate.

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[11] See Woodford (2003) for a discussion.

[12] In a regression where relevant autocorrelated explanatory variables have been omitted from the equation, the error term will turn out to be autocorrelated. By including the lagged dependent variable in the model, the autocorrelation in the error term "disappears". "Best practice econometrics" implies a strategy where autocorrelation in the error term is removed by searching for the relevant explanatory variables. In fact, this is the main criteria for how to search for the true model. However, in practice most macro econometrics needs to rely on lagged dependent variables to obtain errors free for autocorrelation. Moreover, note that in some situations the correct model should contain the lagged dependent variable because we have a priori information that the dependent variable will depend on past values. In fact, this is the case in our model as we know that the central bank reacts smoothly in the interest rate setting.

[13] Riksbanken (2004) reports a smoothing coefficient equal to 0.73. Kuttner (2004) estimates the smoothing coefficient for Sweden to be in the range of 0.77-0.9 and in the range of 0.75-0.95 for USA, UK and New Zealand. Gerdesmeier and Roffia (2003) estimate the coefficient to be 0.8-0.9 for countries in the euro area. Clarida et. al (1998) find it to be around 0.9 for Japan, Germany and USA.

- An increase in GDP growth of one percentage point, leads to 0.6 percentage point higher interest rate (close to the coefficient of 0.5 attached to the output gap in the original Taylor-rule).

- The constant term can be interpreted as the nominal equilibrium – or neutral – policy rate, <u>given that it has remained constant over the estimation period</u>. The neutral three-month real interest rate is assumed normally to be in the range of 2½ - 3½ per cent. Adding the inflation target to that, the neutral nominal three-month rate would be in the range of 5-6 per cent. In the recent years and as of the first half of 2008, Norges Bank perceives the neutral rate to be in the lower part of this range. Furthermore, the nominal policy rate (the dependent variable in the model) is normally say 20-25 basis points lower than the three-month rate. Hence the constant term of 6 per cent probably overestimates the current value of the neutral nominal policy rate somewhat. However, the neutral real rate (and hence the nominal rate) has probably fallen from a higher level over the estimation period, see Bernhardsen and Gerdrup (2007) and Chart 1.6 in Monetary Policy Report 1/2008, reported as Chart 1 below. Since the neutral interest rate has probably declined over the estimation period, we would expect the constant term to be somewhat higher than what is perceived to be the current neutral level.

Overall, the estimation results seem reasonable. The effects of the inflation gap, the foreign interest rate gap, the growth gap and the wage gap are roughly in line with theory. Chart 2 shows the key policy rate, the interest rate that follows from the model and a 90 per cent uncertainty interval around the estimated model rate.

Finally, note that output gap (production minus potential production) is not included in the model. In a standard Taylor-rule, the output gap is the variable reflecting the degree of capacity utilisation in the economy. The reason for excluding the output gap in the model above is an econometrical one. It turned out that the model fitted data better and gave more reasonable results with the output gap excluded. In fact, the output gap turned out to have a significant effect on the interest rate with the wrong sign. Excluding the output gap resulted in reasonable coefficients with the correct sign for the remaining variables in the model.

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Chart 1 3-month real interest rate[1], 10-year real interest rate[2] and the normal real interest rate in Norway[3]. Per cent. Quarterly figures. 96 Q1 − 07 Q4
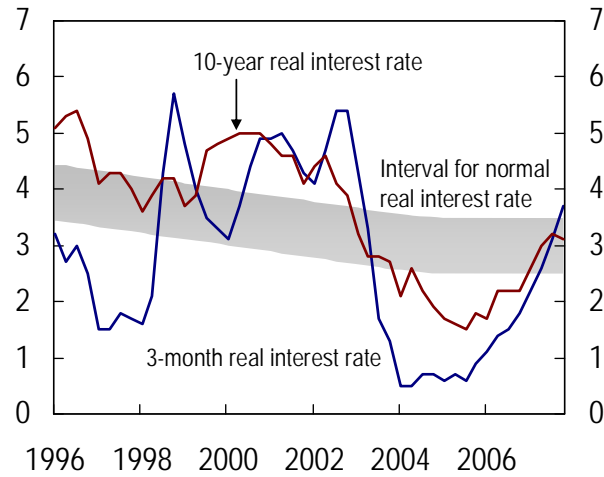
[1] 3-month money market rate deflated by the 12-quarter moving average (centred) of inflation measured by the CPI. Projections for the CPI from this *Report* form the basis for this estimate.
[2] 10-year swap rate deflated by the inflation target.
[3] Calculations may indicate that the normal real interest rate for Norway is currently in the lower end of the interval 2½ - 3½%.

Sources: Statistics Norway and Norges Bank

Chart 2. Key policy rate and interest rate developments that follow from Norges Bank's average pattern of interest rate setting according to model 2. Per cent. Quarterly figures. 00 Q1 − 08 Q1