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Abstract

This paper estimates various Taylor rules for Norway based on the observed money market rate (Nibor). We begin by examining standard Taylor rules from the literature, applying them to Norwegian data to assess their fit. Next, we estimate a benchmark Taylor rule that is included in Norges Bank's monetary policy report and compare it with alternative specifications and explore the potential for nonlinearities. Finally, we analyze how the Taylor rule framework has evolved over time and its out-of-sample fit.

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1 Introduction

Since the seminal contribution of Taylor (1993), monetary policy rules have become key tools for describing the relationship between central banks' policy rates and indicators of real economic activity and inflation. The Taylor rule provides a simple and systematic framework for adjusting interest rates in response to deviations in inflation from the target rate and to deviations in output from potential output. According to the rule, central banks should raise interest rates when inflation exceeds the target or when economic output is higher than potential output, and lower rates when inflation falls below the target or the economy weakens.

Today, monetary policy rules are widely used by central banks worldwide, serving both as input in policy-making and a valuable benchmark for evaluating monetary policy. Many variations of the original rule have been introduced, allowing central banks to fine-tune the rule depending on the economic context, see for example Orphanides (2001), Orphanides and Wieland (2008), Gross and Zahner (2021), and Klose (2023). These variations include assigning different weights to the inflation gap and output gap, or incorporating additional factors such as financial stability, asset prices, and exchange rates. Some versions of the rule include interest rate smoothing to avoid abrupt policy changes, while others adapt the framework to address challenges like the zero lower bound or changes in the natural rate of interest.

Taylor rules serve as guidelines when central banks set monetary policy and are often used as cross-checks for policy rate decisions. They help central banks assess how current policy aligns with historical norms and balances competing objectives like price stability and employment. By providing insight into both the direction and level of policy adjustments, Taylor rules can serve as useful tools for communication and transparency. However, these rules are typically limited to a small set of variables and cannot capture the full complexity of economic conditions or central banks' broader objectives, such as fostering financial stability and addressing risks to the economic outlook. Consequently, policymakers often use these rules as one of many tools, alongside discretion and judgment, to ensure flexibility in response to evolving economic conditions.

Norges Bank has, since 2021, included a Taylor rule in its monetary policy reports to highlight the historical pattern of monetary policy and to function as a cross-check of the policy rate level and near-term forecasts (Norges Bank, 2021). This approach underscores the value of Taylor rules as benchmarks for evaluating current and projected policy paths. Our objective is to compare different Taylor rule specifications as cross-checks, evaluating their ability to provide robust insights into Norwegian monetary policy. To this end, we analyze a variety of monetary policy rules for Norway and assess their fit to the Nibor rate. We begin by considering a set of standard Taylor rules commonly used in the literature, including the seminal version and its extensions with features such as inertia, time-varying real interest rates, and inflation expectations. However, these standard rules fail to adequately capture the observed movements in the Nibor rate. As a result, we refine these rules by estimating them to better reflect the historical dynamics of Norwegian monetary policy.

2 Standard Taylor rules in literature

The original Taylor rule (see Taylor (1993)) is a numerical formula that relates the interest rate to the current state of the economy, with equal weighting to deviations of inflation from target and output from potential:

$$i_t = \pi_t + 0.5y_t + 0.5(\pi_t - \bar{\pi}) + r^* \tag{1}$$

where i is the Nibor rate at time t, π_t is inflation over the previous four quarters reflecting the year-over-year change in the price level and y_t is the output gap defined as the deviation of output from potential ($y_t = \frac{Y_t - Y^*}{Y^*}$), $\bar{\pi}$ is the central bank's inflation target and r^* is the equilibrium real rate, assumed to be constant and equal to 2 percent in the original version of the formula. The equilibrium real rate is the real short-term interest rate that is consistent with aggregate production at potential and inflation at the central bank's long-run objective. Potential output Y^* is defined as output when capital and labor are fully employed. The inflation measure π is defined as the price change over the previous four quarters and is a simple proxy for expected inflation. The equation prescribes that, if inflation moves above target, the central bank should increase the Nibor by 1.5 times the inflation increase. If, instead, output exceeds potential, the central bank should decrease the Nibor by 0.5 times the percentage difference between output and potential.

Since the seminal contribution of Taylor (1993), a variety of monetary policy rules have been introduced to account for factors such as interest rate smoothing and different definitions of the inflation measure, the real equilibrium rate, and the output gap. These adaptations aim to enhance the rule's applicability across diverse economic contexts. In the following sections, we consider variations of the simple rule, as they better capture the historical patterns of monetary policy. By incorporating elements like interest rate smoothing, which helps prevent abrupt policy shifts, and alternative measures of economic indicators, these modified rules provide a more nuanced framework for understanding monetary policy decisions.

The first alternative rule we consider is the so-called inertial rule, which includes a lag of the interest rate. This implies that the Nibor rate moves slowly over time rather than immediately adjusting to deviations in output and inflation:

$$i_t = \rho i_{t-1} + (1-\rho)[\pi_t + 0.5y_t + 0.5(\pi_t - \bar{\pi}) + r^*] \tag{2}$$

where ρ measures the degree of persistence, and thus smoothing, of the Nibor rate. The bulk of the literature sets $\rho = 0.8$, reflecting a relatively large degree of persistence (see Rudebusch (2006) for an early reference). This alternative specification reflects what the majority of central banks around the world do in practice, increasing or decreasing policy rates gradually rather than abruptly. This gradual approach, often referred to as interest rate smoothing, is used to minimize the risk of disruptions in financial markets, where sudden changes can lead to sharp movements in asset prices and borrowing costs. It also helps manage public and investor expectations by providing a clearer and more predictable policy path. Additionally, given the uncertainty and time lags associated with the effects of monetary policy, gradual adjustments allow central banks to assess the economy's response and avoid overreacting to short-term fluctuations. Finally, it reduces the likelihood of policy reversals, which could undermine central banks' credibility and effectiveness.

The original Taylor rule assumes that the equilibrium real rate, r^*, is constant. Since the seminal contribution of Laubach and Williams (2003), a large literature has instead argued that r^* is time-varying, implying that the Taylor rule should adjust accordingly to movements in the equilibrium real rate:

$$i_t = \rho i_{t-1} + (1-\rho)[\pi_t + 0.5y_t + 0.5(\pi_t - \bar{\pi}) + r_t^*] \tag{3}$$

where r_t^* is a measure of the time-varying equilibrium real interest rate. The concept of equilibrium real rate is a long-run notion and may vary over time because of factors such as productivity growth, demographic changes, global capital flows and structural changes (see e.g. Meyer et al. (2022)). The equilibrium real interest rate can also be viewed as a neutral real rate. Norges Bank utilizes the five-year five-year forward interest rate swap, commonly known as the 5y5y, as a market-based indicator of the neutral interest rate. In what follows, we will employ the same assumption.

Different measures of inflation can be employed in the monetary policy rule. One can, for example, think of a forward-looking Taylor rule where π is replaced by a measure of inflation expectations:

$$i_t = \rho i_{t-1} + (1-\rho)[\pi^e_{t+j|t} + 0.5y_t + 0.5(\pi^e_{t+j|t} - \bar{\pi}) + r_t^*] \tag{4}$$

where $\pi^e_{t+j|t}$ is a measure of inflation expectations j horizons ahead. A forward-looking equation has two main advantages with respect to the original rule. First, it can account for potential lags in the transmission of monetary policy to the economy. Second, inflation expectations generally contain more information relative to current inflation. Bernanke (2010) suggests $j = 3$, which is what we have in our baseline framework presented in the next section. This suggestion aligns with empirical evidence on monetary policy transmission lags and central bank behavior. Monetary policy operates with a well-documented lag, as it takes time for changes in interest rates to influence output and inflation. Estimates suggest that the full effects of monetary policy adjustments on inflation materialize after 12 to 18 months (see Christiano et al. (1999) and Boivin (2006) for early references). Given these lags, a forward-looking Taylor rule based on expected inflation is necessary to prevent excessive inflation and output fluctuations (see Clarida et al. (2000)).

Empirical studies on Federal Reserve policy suggest that policymakers systematically respond to inflation expectations approximately 3 to 4 quarters ahead rather than focusing solely on current inflation (see Orphanides (2003a)). This aligns with historical Fed decision-making, where policy adjustments anticipate inflationary pressures rather than react ex post. Similarly, Clarida et al. (2000) show that forward-looking rules yield better economic stability compared to simple contemporaneous Taylor rules. Further supporting this approach, Haldane and Batini (1998) analyze forecast-based monetary policy rules and conclude that responding to inflation projections 3–4 quarters ahead provides better stabilization outcomes than reacting to past inflation.

Finally, real-time estimates of the output gap are highly uncertain, as they rely on potentially imprecise measures of potential output (see Orphanides (2001), Orphanides (2003b)). Since there is no single definitive measure, alternative approaches can provide valuable insights and serve as useful complements. One example of this is replacing the output gap with unemployment deviations from the natural rate, the so-called unemployment gap:

$$i_t = \rho i_{t-1} + (1-\rho)[\pi^e_{t+j|t} - 0.5(u_t - u^*) + 0.5(\pi^e_{t+j|t} - \bar{\pi}) + r^*_t] \tag{5}$$

where u_t is unemployment rate and u^* is the non-accelerating inflation rate of unemployment, also referred to as NAIRU. Using the unemployment gap instead of the output gap in the Taylor rule may offer several advantages. The unemployment gap directly reflects labor market slack, a key focus for central banks, and is typically easier to measure and more stable than typical estimates of the output gap. Furthermore, its well-documented relationship with overall economic activity through Okun's Law ensures that it captures broader cyclical conditions without the need for direct, potentially unreliable, estimates of potential output. In addition, the unemployment rate is generally a more tangible concept and easier to communicate to the public.

Next we can illustrate the results of each specification of the simple monetary policy rules above using Norwegian data from 2001 Q2 to 2024 Q2, see Figure 1.[1] None of the standard Taylor rules presented above closely tracks the Nibor rate, implying that the behavior of the interest rate is not well approximated by the rules we consider. This can be due to several factors. The simple weights used on output and inflation gaps (0.5) might fail to represent the actual central bank's objectives, which might respond more or less aggressively to both factors, and with potentially unequal weights. Central banks might also have nonlinear preferences, giving higher or lower weights to deviations from target depending on the interest rate level or the general state of the economy. Policymakers may also deviate from rule-based frameworks to exercise discretion based on context-specific assessments.

[1] In this figure we use the lagged Taylor, the same as we use in Figure 6. The fit is noticeably better when using lagged Nibor instead, see Appendix F.

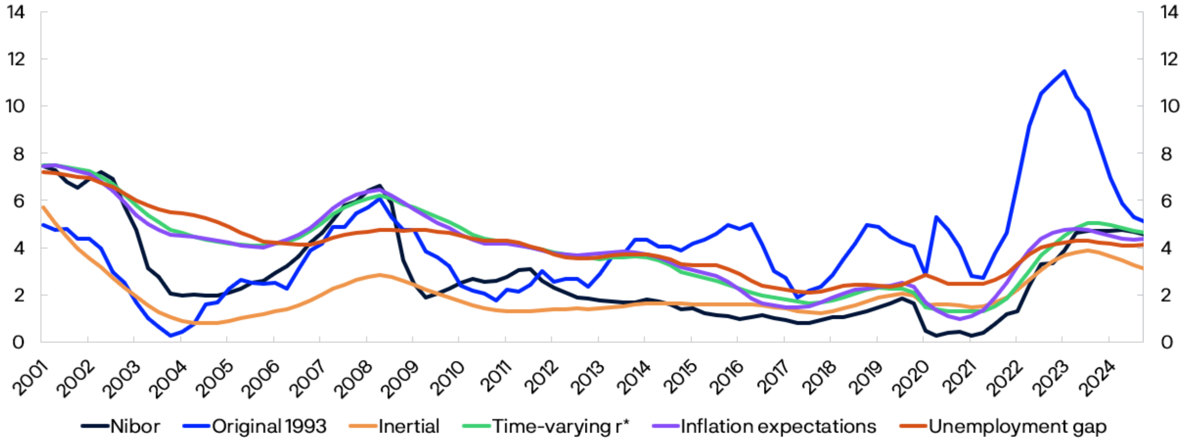

Figure 1: Nibor and different policy rules

In the next section, we estimate several Taylor rules and test their fit to the Nibor rate. We then assess how closely the estimated coefficients align with those in the simple rules described earlier. Additionally, we explore whether using alternative weights or incorporating nonlinear preferences better captures the behavior of interest rates in Norway. The rationale is to determine whether different parametrizations or specifications of the Taylor rules can account for the gap between the actual interest rate in Norway and the standard monetary policy rules in the literature, as shown in Figure 1.

3 Estimated Taylor Rules for Norway

3.1 Main rule

As highlighted in the previous section, several monetary policy rules attempt to explain movements in policy rates in relation to the variables included in Norges Bank's mandate. For the policy rate in Norway, we use a forward-looking inertial monetary policy rule, equation (4), as benchmark. The main objective is to describe Norges Bank's monetary policy through the lens of a simple rule which includes interest rate smoothing, a larger information set with the inclusion of inflation expectations and a time-varying equilibrium interest rate to take account of a range of slow-moving changes in the economy. The objective is to evaluate whether a simple, standard Taylor rule can accurately mimic the Nibor rate. In the next subsections, we evaluate alternative rules based on the discussion above.

Consider the following equation:

$$i_t = c + \alpha_1 i_{t-1} + \alpha_2 i_t^* + \alpha_3(\pi^e_{t+3|t} - \bar{\pi}) + \alpha_4 \hat{y}_t + u_t \tag{6}$$

where i_t is the Nibor rate, i_t^* is the long-term rate (5y5y), $\pi^e_{t+3|t}$ is the inflation forecast for three quarters ahead[2], $\bar{\pi}$ is the inflation target and $\hat{y}_t$ is Norges Bank's estimate of the output

[2]We have used a constructed series for the inflation expectation in order to capture Norges Bank's true projections back to 2005, see Appendix A for more details.

gap. This equation implies, together with equations presented in the previous section (notably, equation (4)), that $\alpha_1 = \rho$, $\alpha_2 = (1-\rho)$, $\alpha_3 = \alpha_4 = (1-\rho)0.5$ and $i_t^* = \pi^e_{t+3|t} + r_t^*$. We thus consider the long-term nominal rate as a proxy for the sum of inflation forecasts and the natural real rate of interest. That is, the coefficient α_3 corresponds directly to $(1-\rho)0.5$, which is associated with the inflation gap rather than inflation alone. Note, however, that we restrict neither the estimation of the coefficients to resemble α_i for $i = 1, ..., 4$ as defined above and we do not restrict the long-run coefficient on inflation (expectations) to fulfill the Taylor principle, namely $\frac{\alpha_2}{1-\alpha_1} + \frac{\alpha_3}{1-\alpha_1} > 1$. As a result, the Taylor rule we estimate does not necessarily adhere to the Taylor principle. This not necessarily an issue, as noted by Svensson (2003), Clarida et al. (2000) and Christiano et al. (2010), among others. These studies argue that, in many cases, a central bank's policy can remain effective without strictly following the Taylor principle, especially when additional factors - such as expectations management, policy inertia, or other monetary policy tools - play a stabilizing role.

We estimate equation (6) using an OLS regression with quarterly data spanning the time period 2001 Q2-2024 Q4.[3] The estimated coefficients are presented in Table 1. In what follows, we report long-run, rather than short-run, coefficients in order to compare these directly to the coefficients for inflation in deviation from target (0.5) and output in deviation from potential (0.5) implied by the standard Taylor rules described in the previous section.[4]

	Nibor rate i_t	
	Estimate	t-stat
i_{t-1}	0.82**	22.89
i_t^*	0.78**	2.73
$\pi^e_{t+3\|t} - \bar{\pi}$	0.83**	3.49
$\hat{y}_t$	1.17**	7.60
Constant	0.00	0.04
	Adjusted R^2	0.97

Long-run coefficients. Asterisks denote significance levels, with * indicating significance at the 5% level and ** at the 1% level. Estimation period: 2001 Q2 - 2024 Q4.

Table 1: OLS regression, main rule

Both α_3 and α_4 are positive and significant, suggesting a positive response of the Nibor rate if inflation expectations increase with respect to target or estimates of the output gap. The coefficient associated with the lag of the Nibor rate (0.82) suggests that movements in the rate are quite persistent over the sample considered, highlighting a high degree of interest rate smoothing over the sample period, in line with findings from the literature (0.8).[5] The weight on inflation for the variables measuring deviation from target and output in deviation from potential appears larger than in the standard monetary policy rules described above (0.5), highlighting

[3] We estimate the alternative rules in the following sections using the same sample span unless otherwise specified.

[4] In Table 1, we thus divide by $(1-\alpha_1)$ the short-run coefficients α_2, α_3 and α_4.

[5] This could also be due to the fact that relevant persistent variables are omitted from the simple estimated Taylor rule, see Rudebusch (2006).

a higher degree of responsiveness of the interest rate to the state of the economy. Finally, the intercept term does not appear to be statistically different from zero, in line with the assumption in all the alternative Taylor rules described in the previous section.[6]

With the estimated coefficients, we compute the fitted value of the Nibor rate:

$$\hat{i}_t = \hat{c} + \hat{\alpha}_1 i_{t-1} + \hat{\alpha}_2 i_t^* + \hat{\alpha}_3(\pi_{t+3|t}^e - \bar{\pi}) + \hat{\alpha}_4 \hat{y}_t \tag{7}$$

The fit of the rule is shown in Figure 2. The fit of the estimated monetary policy rule seems good over the sample considered, as the fitted values (blue line) track the actual Nibor rate (black line) well. This is partly due to the fact that the rule uses lagged Nibor and not the implicit lagged Taylor rate. To evaluate this, we consider the rule using the implicit lagged Taylor rate as well (orange line). A simple forward-looking inertial rule with larger weights (with respect to the simple rules described earlier) on inflation and output gaps explains the Nibor rate quite accurately over the sample considered.

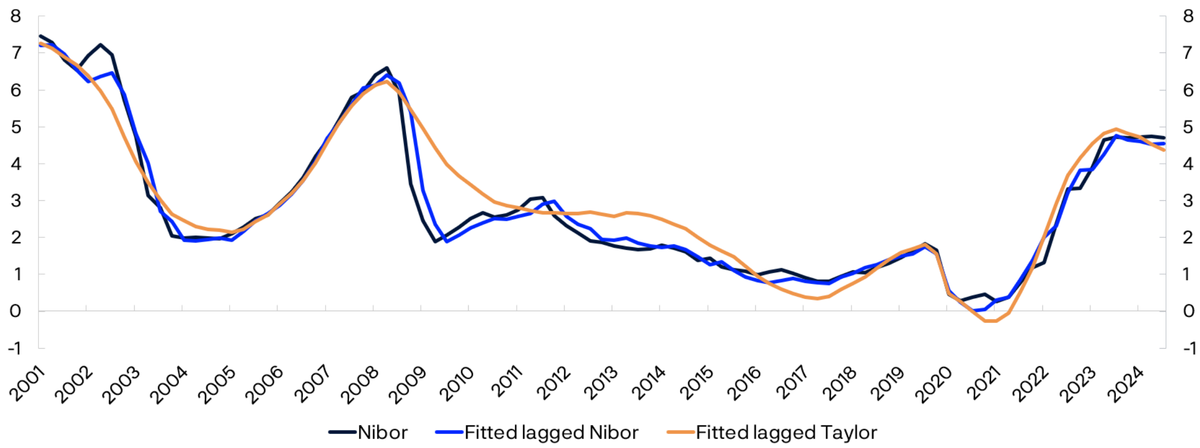

Figure 2: Nibor vs. fitted values (RMSE: -0,34)

Figure 3 shows the estimated residuals, the sample autocorrelation function and a Quantile-Quantile (QQ) plot which relates the estimated residuals to residuals from a normal distribution. This is a simple sanity check to evaluate whether the residuals behave like white-noise processes and appear approximately normally distributed. The residuals are autocorrelated only with their own lag, are left-skewed, with skewness equal to -2.4 and display high kurtosis, 15.4. The residuals being autocorrelated suggests that the simple rule does not fully capture the dynamics of the interest rate. The presence of left-skewness and kurtosis might highlight the presence of non-linearities in the monetary policy rule, which we evaluate in Section 3.2.2.

[6] An estimation of the main rule without a constant can be found in Appendix D and provides results consistent with the baseline specification.

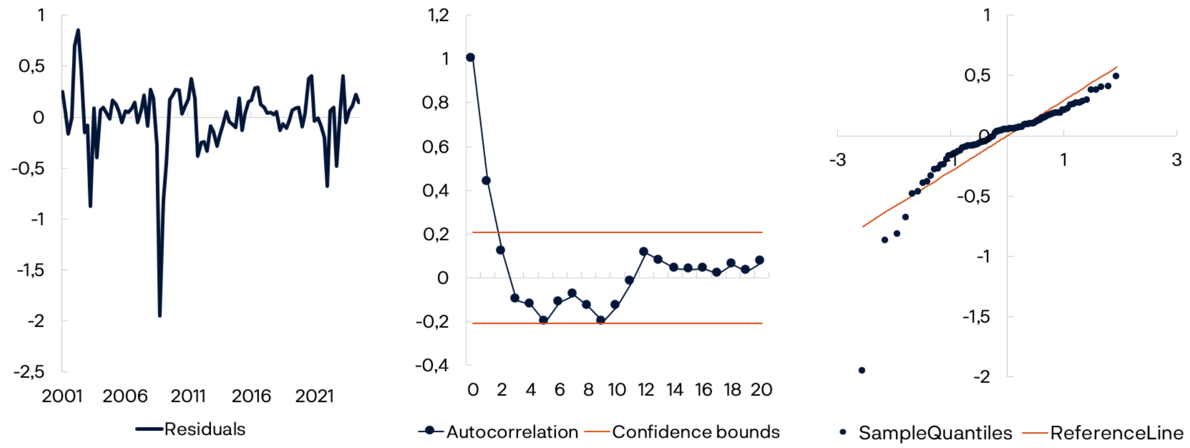

Figure 3: Residuals from the main rule regression

Another check is to compare the main specification of the rule to the current Taylor rule employed by Norges Bank, as shown in Figure 4 below. While the central bank has employed various rules within its monetary policy framework[7], it has published a single Taylor rule since 2021 (Norges Bank (2021) and an updated version in 2022 (Norges Bank (2022)). The key differences between the main rule and the one previously used by Norges Bank are the sample size and the series for inflation expectations. The previous estimation of Norges Bank's Taylor rule uses data from 2009 Q1 to 2021 Q4 and is based on inflation expectations generated by a model called SAM (Aastveit et al., 2011). Since then, Norges Bank has introduced a more advanced forecasting system known as SMART (Bowe et al. (2023)). One possible explanation for the large deviations between the old rule and recent fluctuations in the Nibor rate is that the rule was estimated using forecasts which has historically projected slightly lower inflation than our official forecasts. Additionally, Norges Bank's Taylor rule is based on coefficients estimated from 2009 Q1 to 2021 Q4, thereby excluding data from both the pre-financial crisis period and the recent surge in inflation. As shown in the figure below, the previous version of the Taylor rule fails to capture recent movements in the Nibor rate, particularly the significant overshooting after the pandemic. Another contributing factor to this discrepancy is that greater weight is placed on inflation in the old rule compared to our newly estimated rule. Further details on the different inflation series can be found in Appendix A.

[7] See for example Kravik and Mimir (2019), Mæhlum (2012) Bernhardsen (2011), and Hoen (2012).

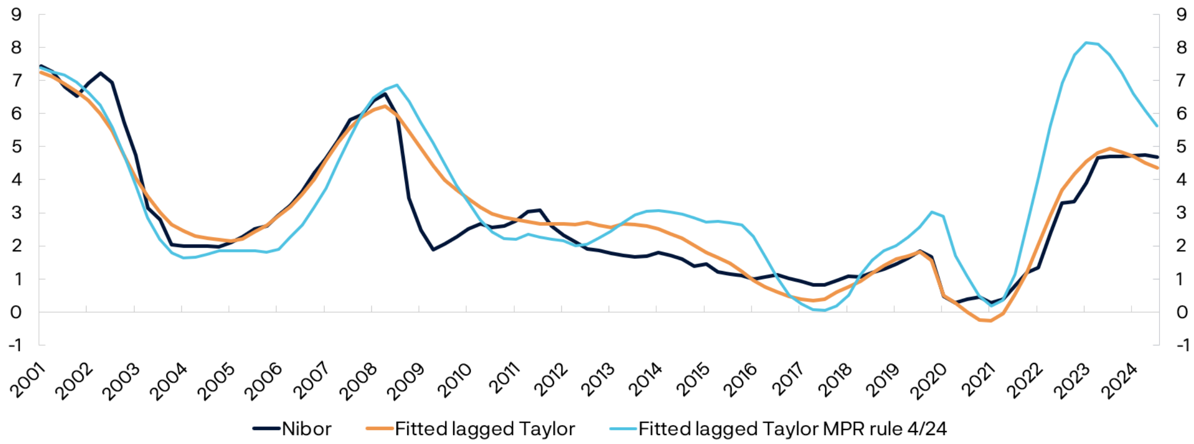

Figure 4: Main rule vs. the current Taylor rule for Norges Bank

3.2 Alternative specifications

Our main rule is one of several possible tools for describing Norges Bank's response to economic changes within its mandate. In the following subsections, we assess the robustness of our results by exploring the estimation of alternative rules, where some are similar to the ones outlined in Section 2.[8] Numerous factors are considered when setting the policy rate, and no single rule can fully capture the Committee's decision-making process. To address this, we have developed a suite of rules that offer a comprehensive view of how Norges Bank has historically responded to macroeconomic changes. The results of these models are summarized in Table 2.

[8]We do not include the estimated version of the original Taylor (1993) rule among our alternative specifications. Such a simple rule is likely to miss important factors to describe historical patterns in the interest rate such as interest rate smoothing. Nonetheless, results from this simple rule are presented in Table 6 in the Appendix.

	Nibor rate i_t						
	Main	**Contemporaneous**	**Asymmetric**	**SMART**	**Alternative i^***	**Unemployment**	**Foreign**
i_{t-1}	0.82**	0.81**	0.81**	0.83**	0.77**	0.81**	0.76**
	(22.89)	(22.86)	(23.10)	(22.75)	(21.60)	(19.85)	(19.76)
i_t^*	0.78**	0.68**	0.74**	0.65*	0.87**	0.79*	0.46*
	(2.73)	(2.76)	(2.93)	(2.28)	(4.08)	(2.56)	(2.34)
$\pi^e_{t+3\|t} - \bar{\pi}$	0.83**	0.63**	0.84**	0.71**	0.61**	1**	0.54**
	(3.49)	(3.65)	(3.68)	(2.87)	(4.06)	(3.83)	(3.11)
$\hat{y}_t$	1.17**	1.21**	1.37**	1.29**	0.87**		0.71**
	(7.60)	(8.69)	(6.95)	(7.94)	(7.36)		(5.60)
$\hat{y}_t * I(i_{t-1} \leq \bar{i})$			-0.58				
			(1.95)				
$\hat{u}_t$						-1.42**	
						(4.78)	
i_t^f							0.54**
							(3.23)
Constant	0.00	0.01	-0.05	0.06	0.01	-0.01	0.07
	(0.04)	(0.08)	(0.37)	(0.50)	(0.14)	(0.08)	(0.64)
Adjusted R^2	0.97	0.97	0.97	0.97	0.96	0.96	0.97

Long-run coefficients. t-statistics in parentheses. Asterisks denote significance levels, with $*$ indicating significance at the 5% level and ** at the 1% level. Estimation period: 2001 Q2 - 2024 Q4. Note that the contemporaneous rule uses the actual inflation gap $\pi_t - \bar{\pi}$, the SMART rule uses $\pi^{Se}_{t+3|t} - \bar{\pi}$ and the alternative i* rule uses another series for i*.

Table 2: OLS regression results from the different estimated rules

3.2.1 Contemporaneous rule

The first rule we consider is a version of the standard inertial rule as given in equation (2), and we test how well it aligns with the calibrations given in the previous section. The difference with respect to the main specification is the use of actual inflation, rather than inflation expectations. We therefore call this a contemporaneous rule. Thus, it does not necessarily account for the lag in monetary policy effects, where the true impact of an interest rate change is best observed in inflation expectations, as captured by the forward-looking rule. We therefore consider the following equation:

$$i_t = c + \alpha_1 i_{t-1} + \alpha_2 i_t^* + \alpha_3(\pi_t - \bar{\pi}) + \alpha_4 \hat{y}_t + u_t \tag{8}$$

As stated, the current specification differs from our main rule only by not including forward-looking inflation in the inflation gap. The results are presented in Table 2, column (2). The results differ slightly from our main rule. The coefficient for the output gap is slightly higher, while the coefficient for the inflation gap is lower. These findings support those of our main rule and suggest that the policy response assigns a slightly higher weight to the real economy and lower to inflation in deviation from the target when inflation expectations are not considered.

3.2.2 Asymmetric rule

The next specification we consider is a so-called asymmetric rule which might reflect the potentially nonlinear preferences of Norges Bank. We augment the main rule by including an interaction term, which characterizes the fact that the Nibor rate might respond differently to output deviations from potential output depending on the state of the economy. To this end, we consider the following regression:

$$i_t = c + \alpha_1 i_{t-1} + \alpha_2 i_t^* + \alpha_3(\pi_{t+3|t}^e - \bar{\pi}) + \alpha_4 \hat{y}_t + \gamma \hat{y}_t * I_t + u_t \tag{9}$$

where I_t is a dummy indicator which takes the value 1 if certain conditions are in place. In the following, we define the dummy as 1 when the Nibor rate is below its mean and 0 otherwise. This is motivated by the idea that monetary policy's response to changes in the output gap may be weaker when interest rates are low because there is less room for policy action, highlighting the potential role of the zero lower bound. Alternative interaction terms were considered, such as distinguishing between expansion and recession, but the chosen specification was the only one consistently significant across various rules. We interact the output gap only, as it was the only variable that produced a significant interaction effect. The results are presented in Table 2 column (3).

While the coefficients for the lag of the Nibor rate, the long-term rate, and inflation expectations (in deviation from the target) align largely with the Taylor rule equation (1), the interpretation and value of the coefficient related to the output gap differ. Specifically, the response of the Nibor rate to changes in the output gap is more pronounced when the Nibor rate is above its mean. This reflects the idea that monetary policy becomes more responsive to changes in the output gap when the economic context provides greater flexibility for adjustment. For instance, at higher interest rates, central banks can reduce rates significantly to counteract a negative output gap without encountering the zero lower bound or diminishing returns from monetary easing.

3.2.3 Inflation expectations from SMART

In our main rule we use a constructed series to capture the real-time forecasts from Norges Bank. Official projections for each quarter are only available from 2013. We therefore test the robustness of our results using an alternative inflation series for inflation expectations which reflects real-time forecasts. A suitable series to use is the newly developed SMART forecasts for inflation as documented in Bowe et al. (2023). The SMART system creates real-time projections for inflation forecasts from 2003 onwards. Consider, as in the main rule, the following equation:

$$i_t = c + \alpha_1 i_{t-1} + \alpha_2 i_t^* + \alpha_3(\pi_{t+3|t}^{Se} - \bar{\pi}) + \alpha_4 \hat{y}_t + u_t \tag{10}$$

where $\pi_{t+3|t}^{Se}$ is the three-quarter-ahead inflation expectation as estimated by SMART. We estimate equation (10) using an OLS regression with quarterly data on the same sample as in the main rule. The estimated coefficients are presented in Table 2 column (4).

Projections from the SMART system differ slightly compared with the main rule but remain significant, except for the t-statistic, which is lower for the long-term rate. The estimation suggest that changes in inflation relative to target, as well as changes in the long-term equilibrium interest rate, now result in a smaller adjustment to the Nibor rate compared to the main rule, while changes in the output gap display a larger coefficient.

3.2.4 Alternative i*

As for the case of the inflation series, we can also test the implications of using a different measure of the neutral interest rate in our rule. The neutral interest rate is not directly observable and is thus modeled in various ways by researchers (see Laubach and Williams (2003), Lubik and Matthes (2015), Holston et al. (2017), Del Negro et al. (2017), among others). This unobservability introduces significant uncertainty in its estimation, causing central banks to often rely on proxies. While there is no universally accepted variable to represent the neutral interest rate in a Taylor rule, there is a growing consensus that it should be closely linked to long-term interest rates. Long-term rates incorporate expectations about future short-term rates and inflation, reflecting the market's view of a neutral stance over an extended horizon. Additionally, long-term yields capture underlying structural factors such as productivity growth and demographic trends, which are central to the natural rate of interest. This makes long rates a compelling choice for approximating the equilibrium interest rate. In our main rule, we use the five-year five-year forward interest rate swap. We want to test how robust our findings are by investigating an alternative way of capture i*, by taking the average of our existing 5y5y rate as well as the five and 10-year government bonds. [9] The results with an alternative i* are given in Table 2 column (5).

The results are in line with the estimates of the main rule, showing robustness to alternative specifications of the long run interest rate. By confirming that the core relationships remain intact under different parameterizations of the main rule, our findings reinforce the credibility of the rule in capturing monetary policy dynamics, irrespective of the approach taken to define long-term interest rates.

3.2.5 Unemployment rule

Another variation we wish to look at is an unemployment rule. Norges Bank's mandate states that monetary policy shall maintain monetary stability by keeping inflation low and steady, but that it should also contribute to high and stable output and employment. In our main rule, as well as in most rules in the literature, we use the output gap to capture the Committee's reaction function to fluctuations in inflation and output, among other things. In this extension, we test the effects of using an unemployment gap rather than an output gap, similar to equation (5). The unemployment gap used by Norges Bank is defined as the deviation in unemployment from the lowest level that is compatible with price stability over time (for further information see Hagelund et al. (2018)).

The unemployment gap and the output gap, as used by Norges Bank, are closely related. The models used to estimate the output gap incorporates various cyclical indicators, such as unemployment. Consequently, changes in unemployment projections can influence output gap projections. Although these two gaps are related, they offer different perspectives on the Norwegian economy. The output gap reflects a broader range of cyclical indicators, providing a more comprehensive view of economic conditions. In contrast, the unemployment gap is a measure of

[9] We have also tested the average of government bonds only, as well as more alternatives to i*. The results do not differ appreciably.

the labor market, specifically designed around unemployment data and the NAIRU. Therefore, it offers a more direct measure of labor market conditions compared to the output gap. The two different gaps are shown in Figure 5.

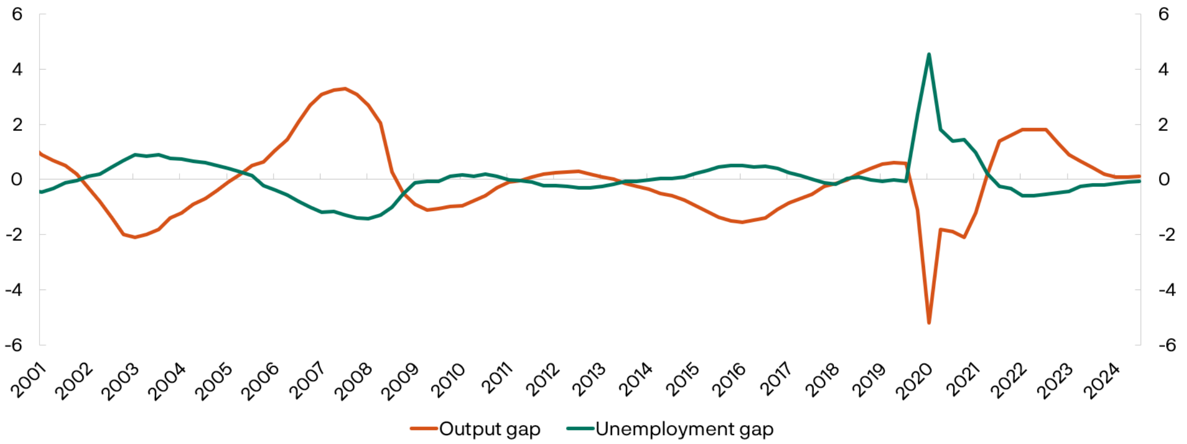

Figure 5: Output gap and unemployment gap

Our unemployment rule is defined as follows:

$$i_t = c + \alpha_1 i_{t-1} + \alpha_2 i_t^* + \alpha_3(\pi_{t+3|t}^e - \bar{\pi}) + \alpha_4 \hat{u}_t + u_t \tag{11}$$

where $\hat{u}_t$ is the unemployment gap used by Norges Bank. The results are shown in Table 2 column (6).

The estimated coefficient for the unemployment gap is negative, reflecting Norges Bank's tendency to lower interest rates as unemployment rises. Notably, this coefficient is larger in magnitude (in absolute terms) than the coefficient for the output gap in the main rule. This difference is likely due to the fact that, while both the unemployment gap and the output gap are expressed in percentage terms, the output gap exhibits larger fluctuations over the business cycle (see Figure 5). As a result, its coefficient may appear smaller in absolute terms compared to that of the unemployment gap, and thus the absolute sizes of the coefficients are not directly comparable.

However, what is comparable is the coefficient on inflation in deviation from its target, which is higher than in the main rule. Thus, monetary policy tends to react more strongly to inflation when the unemployment gap is included instead of the output gap. This could be due to several factors. For example, the unemployment gap is often more directly linked to inflation through the Phillips curve. A tighter labor market (low unemployment gap) is associated with upward wage pressures, which can translate into higher inflation (see Bates et al. (2025), Barnichon and Mesters (2021) and Mankiw (2001) for early references). If monetary policy is responding to unemployment, it may need to react more aggressively to inflation to counteract these wage-driven price pressures. Another reason could be that the output gap is harder to estimate in real time, making the unemployment gap a potentially more reliable measure of economic slack. As a result, central banks may rely more on the unemployment gap while placing greater emphasis on stabilizing inflation.

3.2.6 Foreign interest rate

Our final alternative specification is a rule that includes the foreign interest rate. Norway is a small, open economy, highly integrated into global financial and trade networks. As such, external factors, including foreign interest rates and exchange rates, can significantly influence domestic monetary policy transmission. In this context, it is important to assess whether incorporating foreign interest rates into Taylor rules rules improves their ability to describe Norwegian monetary policy decisions. This is particularly relevant given the potential for spillover effects from global financial markets on the domestic economy.

To explore this, we test whether adding foreign interest rates to the main Taylor rule provides a better fit for the observed movements in the Nibor rate. While the exchange rate was also considered as an additional explanatory variable, our tests showed it to be statistically insignificant, suggesting it plays a more limited role in this framework. Consequently, our focus remains on evaluating the role of foreign interest rates and their potential to enhance the explanatory power of Taylor rules for a small, open economy like Norway. Specifically, we estimate this modified Taylor rule:

$$i_t = c + \alpha_1 i_{t-1} + \alpha_2 i_t^* + \alpha_3(\pi_{t+3|t}^e - \bar{\pi}) + \alpha_4 \hat{y}_t + \alpha_5 i_t^f + u_t \tag{12}$$

where i_t^f is a weighted average of the policy rates of Norway's main trading partners, as used by Norges Bank. The results are shown in the last column of Table 2.

While the persistence coefficient is similar to the main rule, we observe smaller coefficients for both inflation and output gaps. This can be due to several factors. First, including foreign interest rates may help correct for omitted variable bias, as previous estimates of inflation and output gap coefficients might have been partly capturing the influence of global factors which are now reflected by the foreign interest rate. Second, monetary policy spillovers - such as the effect of foreign interest rates on capital flows and exchange rates - can reduce the need for strong domestic policy responses. Indeed, if policymakers take foreign interest rates into account to maintain exchange rate stability or align with global monetary trends, they may respond less aggressively to domestic inflation and output fluctuations. Third, multicollinearity between foreign rates and domestic macroeconomic variables may lead to smaller coefficient estimates.

4 Comparison across different Taylor Rules

Monetary policy rules provide a simple and structured framework for describing how central banks set interest rates in response to economic conditions. While these rules serve as useful benchmarks, their real-world outcomes often deviate due to various economic complexities. In this section, we evaluate the historical accuracy of different Taylor rule specifications in describing Norwegian monetary policy. By comparing multiple estimated rules with the actual Nibor rate, we aim to assess how well these rules capture Norges Bank's decision-making process. Our approach refines the standard framework by incorporating a lagged Taylor rule value, ensuring a more precise representation of interest rate adjustments over time. This comparison not only highlights the systematic nature of policy responses but also reveals key periods where deviations occur - offering insight into the broader factors influencing monetary policy beyond simple rule-based prescriptions.

We now use the coefficients from Table 2 to evaluate the evolution of seven different monetary policy rules against the Nibor rate. Unlike the previous equations, we replace the lag of the interest rate with the lagged value of the Taylor rule. This substitution provides a more accurate representation of policy behavior when evaluating the fit of the Taylor rule to the actual interest rate. By focusing on the lagged Taylor rule value, the analysis highlights the systematic response of the policy rate to economic fundamentals, as prescribed by the rule, rather than persistence in interest rates driven by serial correlation or external factors. The lagged rule value reflects the central bank's gradual adjustment of rates toward their policy-implied level, capturing interest rate smoothing without conflating inertia with deviations from the rule. This approach provides a clearer assessment of how well the Taylor rule describes Norges bank's behavior while maintaining theoretical consistency.[10]

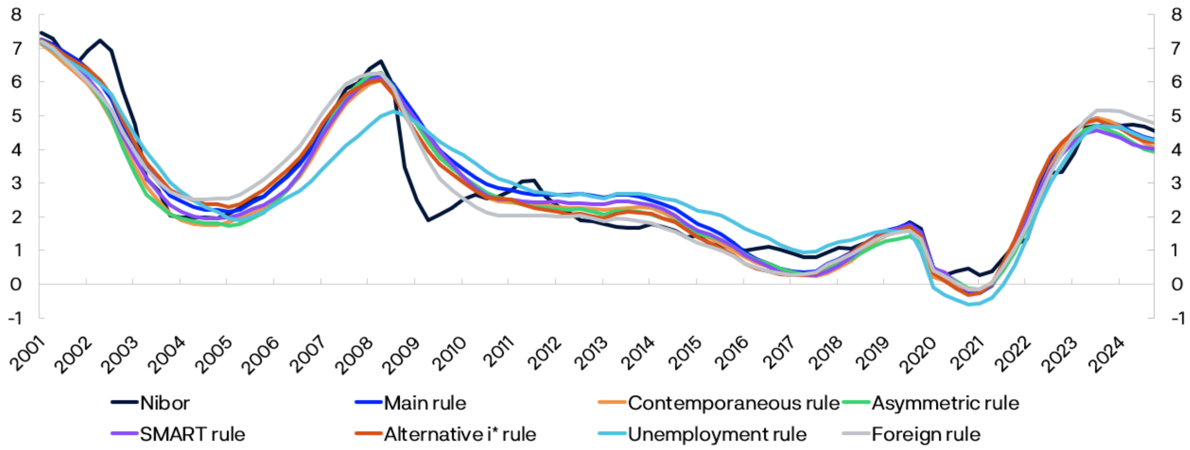

Figure 6: The estimated Taylor rules

Figure 6 plots the evolution of the Nibor rate implied by the different calibrations of the rules considered above. Overall, the different monetary policy rules considered very closely track the Nibor rate over the sample considered. In other words, the estimated rules provide a good representation of Norges Bank's decision-making process regarding interest rate changes in response to economic conditions. This consistency suggests that the rules accurately reflect how Norges Bank responds to key economic variables such as inflation and output gap. It also highlights the systematic nature of monetary policy, with the rules providing a good fit for past interest rate movements and offering potential predictive power for future decisions.

There are periods in which the actual Nibor rate deviates substantially from the implied rules as, for example, during the financial crisis. The interest rate can depart from the different monetary policy rules for several reasons, reflecting the complexities of real-world economic conditions. First, central banks may adjust rates in response to unforeseen economic shocks,

[10]See Appendix E for the figure obtained using the lagged Nibor rate.

such as financial crises or pandemics, which require more immediate policy action. Furthermore, central banks may prioritize broader goals, like financial stability or full employment. Economic conditions also involve nonlinearities, where the effects of interest rate changes are not always proportional to the adjustments suggested by the Taylor rule. Finally, central banks may also act preemptively, addressing current economic conditions before the delayed effects of past policy actions materialize.

5 Out-of-sample analysis

The coefficients of the Taylor rule are assumed to be constant over time. However, it is possible that monetary policy actions differ depending on the state of the economy. For example, the response of monetary policy to deviations in inflation might be different during periods of high inflation or economic overheating, compared to the response during recessions. Additionally, structural changes in the economy, shifts in monetary policy regimes, and significant external shocks could lead to changes in how the central bank responds to economic variables.

These considerations highlight the importance of estimating and evaluating the Taylor rule out-of-sample. If monetary policy responses vary over time, a rule estimated on past data may not accurately predict future policy actions, especially during periods of economic stress or regime shifts. For instance, estimating the Taylor rule using data up to the pre-pandemic inflation period and then evaluating its performance out-of-sample during the pandemic-era inflation surge can provide insights into how well the estimated rule explains actual policy decisions in an unprecedented economic environment. If the rule estimated pre-pandemic significantly deviates from observed policy responses during the pandemic and post-pandemic periods, this would indicate that the central bank's reaction function changed due to extraordinary conditions such as supply chain disruptions, fiscal stimulus, and labor market shifts.

Out-of-sample evaluation is particularly useful for detecting whether estimated coefficients remain stable or if policy adjustments in response to inflation and output shocks vary across different periods. Clarida et al. (2000) find that the Federal Reserve's response to inflation strengthened after the early 1980s, indicating a regime shift in monetary policy. Orphanides (2001) and Orphanides (2003b) highlight the importance of using real-time data and assessing policy rule robustness out-of-sample. Boivin and Giannoni (2006) provides evidence that monetary policy responses change over time, further justifying out-of-sample evaluations. Judd and Rudebusch (1998) test Taylor rules out-of-sample and find that while simple rules perform well in some cases, they can break down when structural changes occur.

Table 3 presents the estimated results from a sub-sample estimation of the different Taylor rules given in Section 3, using data from 2001 Q2 to 2019 Q4.

	Nibor rate i_t						
	Main	**Contemporaneous**	**Asymmetric**	**SMART**	**Alternative i^***	**Unemployment**	**Foreign**
i_{t-1}	0.76**	0.79**	0.78**	0.81**	0.70**	0.77**	0.70**
	(15.35)	(16.13)	(15.26)	(16.79)	(14.55)	(13.37)	(13.03)
i_t^*	0.83**	0.76*	0.86**	0.68*	0.97**	0.87*	0.57*
	(2.95)	(2.52)	(2.70)	(2.04)	(4.63)	(2.57)	(2.53)
$\pi^e_{t+3\|t} - \bar{\pi}$	0.96*	0.66	1**	0.47	0.9**	0.74	1.07**
	(2.44)	(1.89)	(2.30)	(1.18)	(3.38)	(1.57)	(3.41)
$\hat{y}_t$	1**	1.24**	1.18**	1.26**	0.77**		0.5**
	(6.99)	(7.13)	(6.57)	(6.80)	(7.27)		(3.40)
$\hat{y}_t * I(i_{t-1} \leq \bar{i})$			-0.45				
			(1.22)				
$\hat{u}_t$						-1.83**	
						(4.46)	
i_t^f							0.6**
							(3.03)
Constant	-0.33	-0.19	-0.45	0.00	0.00	-0.74	0.3
	(0.57)	(0.26)	(0.68)	(0.03)	(0.02)	(1.00)	(0.56)
Adjusted R^2	0.97	0.97	0.97	0.97	0.97	0.96	0.97

Long-run coefficients. t-statistics in parentheses. Asterisks denote significance levels, with $*$ indicating significance at the 5% level and ** at the 1% level. Estimation period: 2001 Q2 - 2019 Q4. Note that the contemporaneous rule uses $\pi_t - \bar{\pi}$, the SMART rule uses $\pi^{Se}_{t+3|t} - \bar{\pi}$ and the alternative i* rule uses another series for i*.

Table 3: OLS regression results from the different estimated rules with a smaller sample

From the sub-sample analysis, it is evident that the weight placed on inflation in recent years has been somewhat lower than in periods when inflation was closer to target. This shift might reflect a range of factors tied to the unique challenges of the current economic environment.

One factor might be that the risks associated with aggressive interest rate hikes may have encouraged a more cautious approach. Anchored inflation expectations may also have reduced the urgency to react strongly as policymakers may have anticipated that inflationary pressures are temporary. Uncertainty about the persistence and underlying causes of inflation, along with a desire to avoid overshooting policy adjustments into deflation or recession, further supports a lower weight on inflation deviations. By adopting a more balanced stance, central banks likely aimed to address both price stability and broader economic health, recognizing the complex trade-offs in a period of heightened uncertainty and stress.

However, it is worth noting that for our main rule and the contemporaneous rule, the out-of-sample performance remains similar to that obtained using the entire sample, see Figure 7. This suggests that while monetary policy responses may have adjusted to specific circumstances, the overall reaction function estimated from the full sample still provides a reasonable approximation of Norges Bank's policy behavior, even during recent years. This finding indicates a degree of consistency in policy reactions, despite the unique economic challenges that have emerged in the post-2019 period.

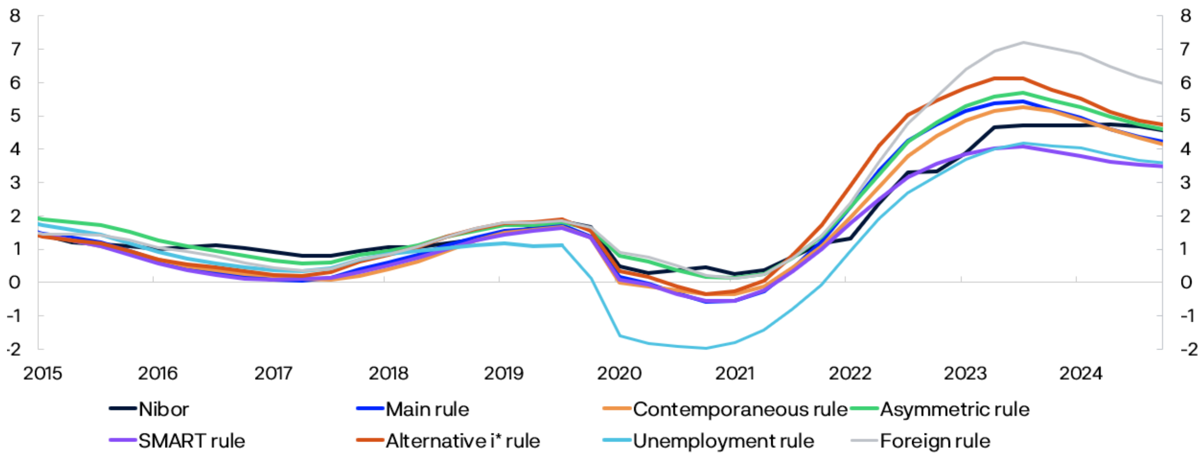

Figure 7: The estimated Taylor rules, out-of-sample

5.1 Expanding window estimation of the main rule

The out-of-sample analysis in the previous section revealed that the main rule and the contemporaneous rule exhibited similar overall reaction functions both before and after the pandemic. To further explore the evolution of the estimated Taylor rule coefficients, particularly during the inflationary period of the pandemic, we reestimate the main rule. Specifically, we estimate five variations of the main Taylor rule using different sample periods: 2001 Q2 - 2019 Q4, 2001 Q2 - 2020 Q4, 2001 Q2-2021 Q4, 2001 Q2 - 2022 Q4, and 2001 Q2 - 2023 Q4, see Table 4.

	Nibor rate i_t					
	Main rule	**M. 2023 Q4**	**M. 2022 Q4**	**M. 2021 Q4**	**M. 2020 Q4**	**M. 2019 Q4**
i_{t-1}	0.82**	0.81**	0.81**	0.77**	0.77**	0.76**
	(22.89)	(21.16)	(20.96)	(16.40)	(15.96)	(15.35)
i_t^*	0.78**	0.79**	0.74**	0.78**	0.83**	0.83**
	(2.73)	(2.87)	(2.71)	(2.85)	(2.85)	(2.95)
$\pi^e_{t+3\|t} - \bar{\pi}$	0.83**	0.79**	0.74*	0.96*	1*	0.96*
	(3.49)	(3.38)	(2.60)	(2.44)	(2.50)	(2.44)
$\hat{y}_t$	1.17**	1.11**	1.11**	96**	1**	1**
	(7.60)	(7.48)	(7.54)	(7.75)	(7.64)	(6.99)
Constant	0.00	-0.02	-0.01	-0.02	-0.03	-0.09
	(0.04)	(0.18)	(0.08)	(0.15)	(0.23)	(0.57)
Adjusted R^2	0.97	0.97	0.97	0.97	0.97	0.97

Long-run coefficients. t-statistics in parentheses. Asterisks denote significance levels, with $*$ indicating significance at the 5% level and ** at the 1% level. Estimation period for main rule is 2001 Q2 - 2024 Q4, titles of other rules indicate different end-periods of estimation.

Table 4: OLS regression results from different sample estimations

Our findings reveal minimal changes in the coefficients related to the output gap across the five samples. The coefficients associated with the inflation gap show more variation. The fourth sample (2001 Q2 - 2020 Q4) exhibits the highest inflation coefficient, while the second sample

(2001 Q2 - 2022 Q4) has the smallest coefficient while also displaying a high degree of persistence.

The year 2022 saw the most significant inflation surge relative to target within the entire sample period. The estimation suggests that interest rates did not rise as aggressively as they would have if the inflation-response coefficient had remained at pre-pandemic levels, this is reflected in a smaller coefficient for inflation in deviation from target. Regardless of the specific sample specification for the estimation of the Taylor rule, the implied Nibor rate would have been higher than what we observe in the actual data, indicating a more accommodative stance than historical norms would suggest.

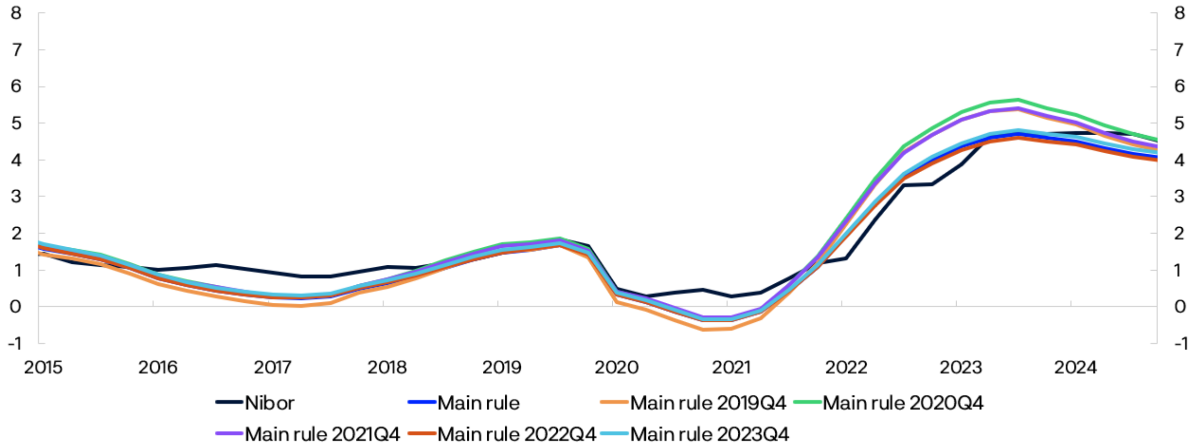

Figure 8: Main rule with different estimation samples

6 Conclusions

Since 2021, Norges Bank has included a Taylor rule in its monetary policy report to highlight historical policy patterns and serve as a cross-check for the policy rate and near-term forecasts. Building on this, we analyze a variety of standard monetary policy rules commonly used in the literature to assess their relationship with the Nibor rate. We find that these standard rules do not fully capture the observed fluctuations in the Nibor rate over time. To better reflect the dynamics of the Norwegian economy, we estimate our own set of monetary policy rules.

Our analysis reveals that rules incorporating policy inertia, characterized by gradual interest rate adjustments, and greater sensitivity to deviations in inflation and output from their respective targets, best reflect Norges Bank's historical actions. An out-of-sample exercise shows that while monetary policy responses have adapted to recent economic challenges, such as post-pandemic inflation, the overall reaction function estimated from the full sample remains a reasonable approximation of Norges Bank's policy behavior. The similar out-of-sample performance of rules with inertia suggests that, despite the evolving economic landscape, there remains a degree of consistency in Norges Bank's policy responses.

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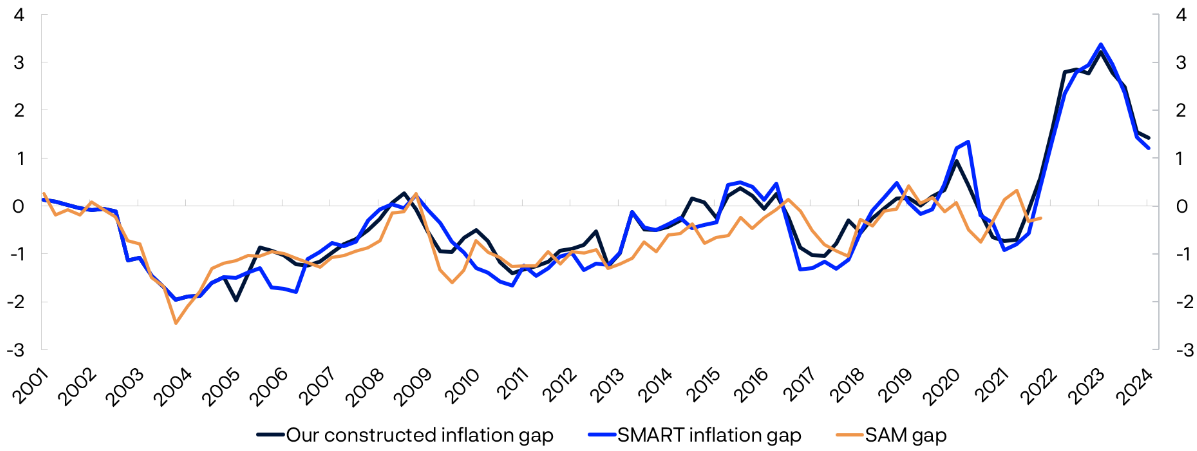
Appendix

A The constructed inflation gap

Since monetary policy works with a lag, we include forward looking inflation in our Taylor rule. π^e_{t+3} denotes the inflation forecasts three quarters ahead and is a constructed series in our estimation. Since 2013, Norges Bank has published inflation forecasts for four quarters each year. Between 2005 and 2013 Norges Bank only published three reports a year, and prior to that there are no public record of published inflation forecasts. We have therefore constructed a continuous time series for the forecasts three quarters ahead using different data samples.

In the first sample, running from 2001 Q1 to 2002 Q4, historical data is used due to lack of inflation forecast data. From 2003 Q1 until 2005 Q1 Norges Bank's modellingsystem SMART is used to construct three-quarter-ahead inflation forecasts (Bowe et al., 2023). From 2005 Q2 and onwards we use the official MPR projections. Between 2005 Q1 and 2013 Q1 data are only available for three quarters per year. We have therefore used data from the second quarter to simulate third quarter forecasts.

Figure 9 shows the constructed inflation series compared to the gap estimated by the SMART forecasts and the SAM gap used by the previous rule.



Two quarter moving average of three quarter-ahead inflation forecasts relative to the inflation target

Figure 9: Different inflation gaps

B Sample with only official projections

In our main rule, we use a constructed series to capture Norges Banks inflation expectations back in time. Official projections from each quarter are only available from 2013. While results from a shorter sub-sample should be interpreted with caution, it is nonetheless insightful to examine what our main rule reveals when relying solely on Norges Bank's official projections. To this end, we re-estimate the benchmark rule using data from 2013 Q1 to 2024 Q4. The results are presented in Table 5.

	Nibor rate i_t	
	Estimate	t-stat
i_{t-1}	0.88**	24.26
i_t^*	0.42	0.90
$\pi_{t+3}^e - \bar{\pi}$	1**	3.49
$\hat{y}_t$	1.42**	6.09
Constant	0.13	1.07
	Adjusted R^2	0.98

Asterisks denote significance levels, with $*$ indicating significance at the 5% level and ** at the 1% level.
Estimation period: 2013 Q1-2024 Q4.

Table 5: OLS regression, main rule with only official projections

The results show a higher degree of persistence for the lag of the interest rate and an insignificant effect of the long-term interest rate. The coefficients on inflation and the output gap are smaller in absolute terms, but accounting for the persistence of the process these appear slightly larger than in the baseline framework. The results indicate that the main rule, with the constructed series for inflation, is roughly in line with the sample using only official projections. One can therefore argue that the main rule reliably captures Norges Bank's reaction pattern dating back to 2001.

C Original Taylor rule estimation

	Nibor rate i_t	
	Estimate	t-stat
π_t	0.14	0.83
$\hat{y}_t$	0.56**	4.16
Constant	2.87**	15.40
	Adjusted R^2	0.17

Asterisks denote significance levels, with $*$ indicating significance at the 5% level and ** at the 1% level.
Estimation period: 2013 Q1 - 2024 Q2.

Table 6: OLS regression, original Taylor (1993) rule

D Main rule estimation without a constant

In Table 7 we show an estimation of the main rule without including a constant. The constant is insignificant, as shown in Table 1 and here we show that the results given in this *Memo* are also robust for an estimation without a constant.

	Nibor rate i_t	
	Estimate	t-stat
i_{t-1}	0.82**	26.67
i_t^*	0.78**	5.31
$\pi_{t+3}^e - \bar{\pi}$	0.83**	4.02
$\hat{y}_t$	1.16**	8.05
	Adjusted R^2	0.97

Asterisks denote significance levels, with $*$ indicating significance at the 5% level and ** at the 1% level.
Estimation period: 2001 Q2 - 2024 Q4.

Table 7: OLS regression, main rule without a constant

E Estimated Taylor rules using lagged Nibor

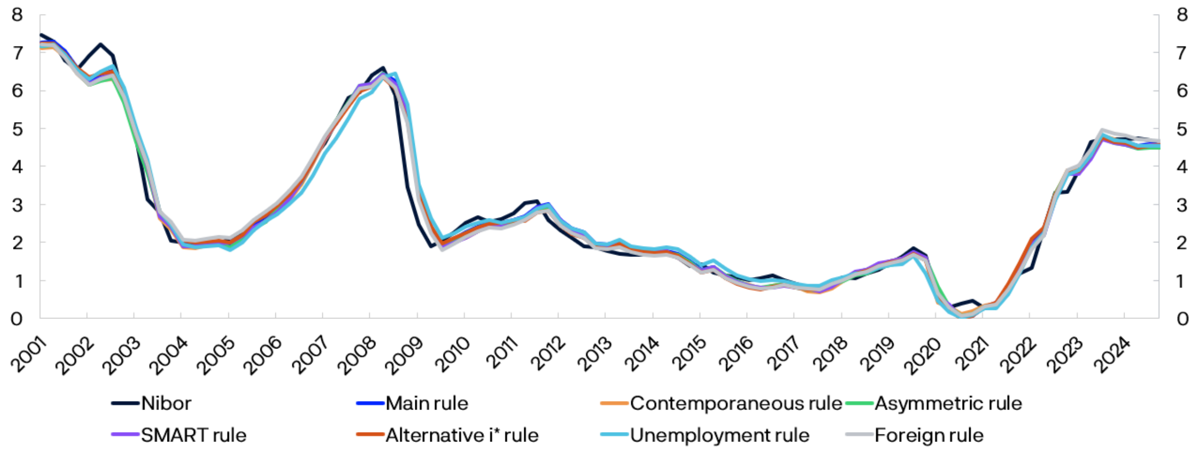


Figure 10: Estimated Taylor rules using lagged Nibor

F Taylor rules in literature using lagged Nibor

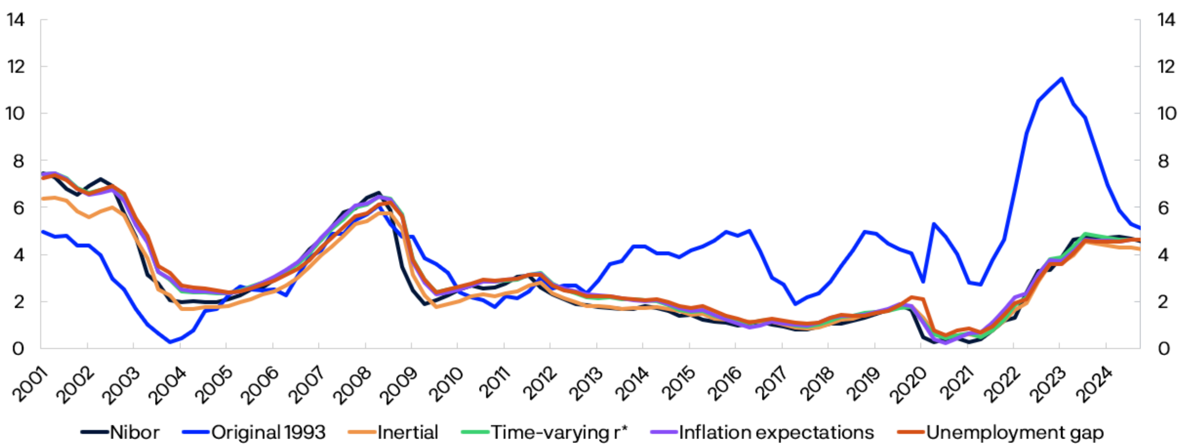


Figure 11: Taylor rules in literature using lagged Nibor