Monetary policy and the trade-off between inflation and output variability

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This article explores the consequences of various approaches to the conduct of monetary policy. A small, calibrated model of the Norwegian economy is used, which highlights the short-run trade-off between stabilising inflation and stabilising output. Some approaches to policy can be shown to be unambiguously better than others. However, when policy is efficient, the central bank must decide how much output variability it is willing to tolerate in order to attain more stable inflation.

1. Introduction

Since the beginning of the 1990s, several countries have adopted an inflation targeting framework for monetary policy. Since 2001, the operational target of monetary policy in Norway has been annual consumer price inflation of 2.5 per cent over time. Norges Bank operates a flexible inflation targeting regime, so that weight is given to both variability in inflation and variability in output and employment.

Within this type of framework there is considerable leeway regarding how policy is conducted. Subject to maintaining the inflation target in the long-run, the central bank has to decide how closely it will attempt to stabilise inflation around the target, at a cost of higher variability in output. This trade-off is particularly stark in the case of a shock that causes inflation and output to move in different directions (a cost-push or supply shock). The central bank's chosen course of action will depend on the perceived costs of variability in output and inflation respectively.

The aim of this article is to illustrate the consequences of various approaches to the conduct of monetary policy, using a small model for the Norwegian economy. We model different approaches to monetary policy by altering the interest rate response to different signals from the economy and examine the resulting variability in inflation and output. Some of the accepted "stylised facts" regarding inflation targeting monetary policy are illustrated. It is not the goal of this analysis to reach conclusions regarding what objectives the central bank should have, or what manner of conducting monetary policy might be optimal for Norges Bank. Two main points are illustrated:

- A move from flexible towards stricter inflation targeting implies accepting higher variability in output in order to keep inflation closer to the target on average. Stricter inflation targeting is illustrated in three different ways: i) responding relatively more strongly to inflation than to the output gap, ii) responding to nearer-term inflation forecasts, and iii) overall stronger policy responses.
- Some approaches to the conduct of policy are unambiguously more *efficient* than others, that is, they attain the desirable result of lower variability in both output and inflation. For example, the central bank can generally achieve better outcomes by being forward-looking in its behaviour.

Section 2 presents the model used in the analysis, while Section 3 discusses the concept of an efficient policy frontier (EPF). Section 4 examines the implications of varying the coefficients in a simple policy rule. Section 5 concludes.

2. The model

This section describes the small, calibrated macroeconomic model that is used in the analysis. We give only a broad overview here; for a more detailed description of the model and its calibration see Husebø, McCaw, Olsen and Røisland (2004).[2]

2.1 A general overview

The model is highly aggregated, and provides a stylised representation of the key mechanisms in the economy, with a particular emphasis on the transmission mechanisms of monetary policy. It can be viewed as the smallest model necessary to explain the interaction of output, interest rates, exchange rates and inflation, under an inflation-targeting framework.[3] Although very simple and highly aggregated, the model has a considerable theoretical content. Starting with the classic small-scale open-economy model by Dornbusch (1976), many similar models have been developed both in the academic literature and in central banks around the world. The quarterly model is calibrated to match salient features of

[1] Thanks to colleagues in Norges Bank for useful comments, and to Douglas Laxton (IMF) for sharing useful Dynare code. All views expressed here are those of the authors and do not necessarily represent the views of Norges Bank.

[2] The model used for the analysis here is not exactly the same as that described in Husebø et al. (2004). We model the real rather than nominal exchange rate, and the inflation target does not appear explicitly in expectations formation in the Phillips Curve. The differences are not material for the very general points we illustrate in this article.

[3] A distinguishing feature of this model is its fairly simple specification of price-setting behaviour, where inflation is assumed to be proportional to an excess demand (output gap) term, as well as its own lag, reflecting nominal rigidities. Wages are not modelled explicitly. More sophisticated price- and wage-setting specifications for closed economies can be found in Taylor (1980) and Fuhrer and Moore (1995); the more recent of these models also allow for inflation persistence. More recent simple open-economy models in the same class include Svensson (1998), Ball (1999), Batini and Haldane (1999) and Leitemo and Røisland (2002).

the Norwegian economy, drawing on theory and a wide range of empirical estimates to choose parameter values for the model that result in appropriate aggregate properties.

Expectations play an explicit role in the model. First, expectations of future inflation are of importance as they will affect price- and wage-setting behaviour today. Second, expectations of future interest rate developments affect today's exchange rate. Finally, expectations of future economic cycles will affect today's spending decisions.

The model aims to explain how deviations from equilibrium develop and dissipate over the medium to long term.[4] There is a clear role for monetary policy in the model: to provide the economy with a nominal anchor, that is, to prevent actual and expected inflation from drifting away from the target. When the central bank fulfils its role, the economy converges to a well-defined equilibrium. The model is designed such that the monetary authorities cannot boost output above its supply-determined level[5] in the long run. In other words, in the long-run, monetary policy is neutral and there is no trade-off between the levels of output and inflation.

The model consists of just four key equations:

1) *An aggregate demand (IS) equation* for an open economy that expresses the dynamic relationship between the output gap (i.e. output relative to its sustainable or trend level), the real interest rate, the real exchange rate and world output;

2) *An inflation-adjustment equation (Phillips Curve)* characterising the dynamic response of inflation to inflation expectations, the output gap and the real exchange rate;

3) *An uncovered interest parity (UIP) equation* expressing the dynamic relationship between the exchange rate and the spread between domestic and foreign interest rates;[6]

4) *A monetary policy rule* describing how the central bank sets interest rates in order to balance the short-run trade-off between stabilising inflation around target and stabilising developments in the real economy. We discuss a simple rule specification in more detail later.

Each of these equations has a shock term that represents effects on the dependent variable from all sources other than the dynamics of the other variables appearing in the equation. These shocks will be important in our analysis. A demand shock could for example represent changes in tastes and preferences or the effects of fiscal policy. A shock to the Phillips curve could represent the growing importance of cheaper imports from China or stronger competition in the product market. A shock to the UIP equation could represent a change in the risk premium associated with Norwegian financial assets. Finally, there is also the possibility of adding exogenous shocks to the monetary policy rule, representing interest rate responses to changes in variables that are not included in the monetary policy rule.

Even though the model is simple, its strength is the focus on the role of monetary policy, a property that makes it well suited for the analysis carried out in this paper. Monetary policy affects inflation and the real economy through three main channels in the model.

First, there is a traditional *demand channel*. An increase in the nominal interest rate also increases the real interest rate, due to nominal rigidities. This discourages expenditure. Less demand pressure, in turn, results in lower inflation through both lower wage inflation and profit margins (not modelled explicitly).

Second, there is an *exchange rate channel*. Higher domestic nominal interest rates relative to those abroad cause the currency to appreciate, all else equal. Imported goods become cheaper and inflation falls. However, a stronger currency also has a negative effect on demand and output, via both an expenditure switching effect towards imports, and reduced competitiveness for industries that compete with firms internationally. Lower demand and output reduce inflation, as above.

Finally, there is the *expectations channel*. Expectations concerning future inflation and economic growth play an important role in price and wage setting. If monetary policy is credible, inflation will be expected to be equal to or close to the inflation target. This in itself contributes to stabilising inflation around the target. If the inflation-targeting framework lacks credibility, on the other hand, stabilising inflation is correspondingly more difficult.

2.2 A rule for monetary policy

We now discuss the monetary policy rule in more detail, since it is at the heart of the analysis in this paper. In the small macro model described above, monetary policy is the key factor that brings the economy back to equilibrium. There are no self-regulating mechanisms that will bring inflation back to target if policy does not adequately respond to disturbances in the economy.

We assume that the central bank sets the interest rate directly, and that monetary policy is oriented towards keeping inflation close to a specified inflation target on average over time. Monetary policy is represented by a simple rule that specifies how the central bank sets the interest rate in response to inflation and the output gap. In practice, no inflation-targeting central bank follows such a simple rule literally, due to the complex and ever-changing nature of the economy. For example, the central bank will typically take into account the entire path of inflation and output when setting the interest rate.

[4] "Equilibrium" here is a theoretical situation with inflation at target, an output gap of zero, and no shocks hitting the economy.

[5] Variously referred to, with subtleties of meaning we need not concern ourselves with here, as "potential," "natural," "trend," "sustainable" or "equilibrium" output.

[6] Given only weak evidence that UIP holds in practice, we use a dampened version where exchange rate expectations have both a forward-looking and a backward-looking component.

However, the simple rule captures key features of contemporary central bank policy and is therefore useful for our current model exercise.

Our policy rule takes the form:

$$i_t = \alpha i_{t-1} + (1-\alpha)[r^* + \pi^* + \theta(\beta(\pi_{t+k} - \pi^*) + (1-\beta)(y_t - y^*))] \quad (2.1)$$

$$0 \le \alpha < 1, \quad 0 \le \beta \le 1, \quad \theta > 1$$

where i_t is the nominal short-term interest rate in period t, r^* is the equilibrium real interest rate, π^* is the inflation target and π_t is inflation in period t. The equilibrium nominal interest rate, i^*, is defined by $i^* = r^* + \pi^*$. $(y_t - y^*)$ is the output gap in period t, that is, a deviation of output y_t from its trend or potential level y^*.

The coefficient α represents *interest rate smoothing*, i.e. making the interest rate response to shocks more gradual by including a weight on the previous quarter's interest rate. Interest rate smoothing reflects the fact that central banks are faced with uncertainty, for example regarding the effects of interest rate changes and difficulties in identifying the amplitude and timing of shocks. In practice most central banks prefer to avoid policy reversals and therefore tend to adjust interest rates gradually.

The coefficient θ indicates the overall vigour of the central bank's interest rate responses to deviations in output and inflation from their equilibrium values. We will refer to this as the *aggressiveness* coefficient.

The coefficient β is the *weight on inflation*, i.e. how much the central bank responds to deviations of inflation from its target, with the remaining $(1 - \beta)$ response being placed on the output gap.[7] It is worth noting that this coefficient is a description of how interest rates respond to the two variables, and does not in itself represent the central bank's preferences between stabilising them. However, as we will see, the two are closely related.

The index k represents the *response horizon* with respect to inflation, that is, whether the interest rate is moved in response to today's observed inflation ($k = 0$) or in response to a forecast of future inflation at time $t + k$. It is useful to clarify the concept of "horizon", as it is used in two different ways in the literature. The response horizon, which is what we examine here, refers to the forecast of inflation, e.g. 4 or 8 quarters ahead, to which monetary policy mechanically responds in a simple rule. The term "policy horizon" is often used to refer to how long it typically takes for monetary policy to bring inflation back to target. The policy horizon will depend not only on the response horizon, but on *all* coefficients in the policy rule, on the entire model of the economy and on the nature of the shocks.

We will change the parameters α, β and θ and the index k in order to illustrate different policy approaches by the central bank and their implications for output and inflation variability. The results will be presented within the framework of efficient policy frontiers (EPFs). The next section discusses the concept of EPFs.

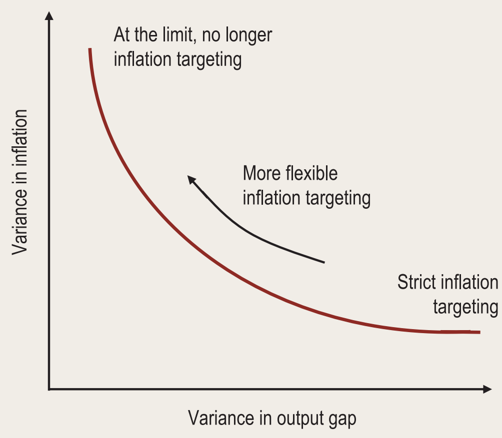
3. Efficient monetary policy frontiers

3.1 The concept of an efficient monetary policy frontier

In theory, the central bank could follow any of an infinite number of possible monetary policy rules. Each rule results in a certain combination of inflation and output variability, which can be plotted in terms of the variance of the two variables. It is standard to assume that the central bank dislikes variability in both output and inflation, which means that points that are nearest the origin are preferable. The *efficient policy frontier* (EPF) (Chart 1) is the series of points where it is not possible to attain lower inflation variability without increasing variability in output.[8] Any policy rule that results in an inflation-output variability outcome above the frontier is not "efficient"; unambiguously better outcomes are theoretically possible with a different rule.[9] For example, we will show that some rules that ignore information about future inflation are outperformed by rules that make use of this information. However, it is not possible to say which of the efficient rules on the frontier is best without making explicit assumptions about the central bank's preferences regarding stabilising the two variables.

The EPF is downward sloping. Thus, when policy is efficient, reducing variability in inflation will be at the cost of higher variability in output.[10] The standard channels through which monetary policy operates, outlined in Section 2, work primarily via output movements. For

Chart 1 Efficient policy frontier (EPF)



Source: Norges Bank

[7] For simplicity, we disregard the possibility of the central bank reacting to forecasts of the output gap.

[8] The central bank may also wish to stabilise other variables in the short-run, such as interest rates and the exchange rate. However, for the purposes of this simple analysis we assume that the central bank is interested in the variability of these variables only to the extent that they affect the variability of output and inflation.

[9] The position and the slope of the EPF will depend heavily on the model, the strength and nature of the shocks and on the structure of the monetary policy rule. Results regarding which rules are the most efficient must be interpreted with these caveats in mind.

[10] This is not to say that there is a long-run trade-off between the *levels* of output and inflation. As discussed in Section 2, monetary policy is assumed neutral in the long-run.

example, raising interest rates reduces both output and inflation. Therefore, if a shock affects these two variables differently, the short-term trade-off is particularly evident. The more the central bank aims to stabilise inflation, the more output will vary.

Under standard assumptions about how the economy works, the EPF is convex to the origin. In linear models such as the one considered here, there is an increasing marginal cost of stabilising either inflation or output. For example, if the central bank already has a strong preference for keeping inflation close to the target, attempting even stricter inflation targeting would imply a large increase in output variability but only a small reduction, if any, in inflation variability.

The position and slope of the frontier represent the boundary of what monetary policy can achieve. This is determined by first, the constraints arising from the structure of the economy (and in particular the impact of monetary policy), and second, the nature of the shocks to which the economy is subjected. For example, if inflation is fairly sluggish and difficult to influence, the frontier will be further from the origin than if the monetary policy channels were fast-acting. If people give credence to the inflation target when forming their inflation expectations, then inflation shocks are much easier to counteract. Hence, the frontier will be closer to the origin.

Which of the points on the efficient policy frontier is preferable depends on objectives. As central banks can be assumed to dislike both deviations from the inflation target and large fluctuations in output, the central bank's objectives are usually described in the literature as minimising a loss function.[11] The bank sets the interest rate so as to minimise a weighted sum of the variability in the two variables (and potentially other variables as well, such as the interest rate). The greater the weight on output gap variability, λ, the more flexible the inflation targeting regime.[12] A central bank that has a low λ (*a strict inflation targeter*) will choose a rule that results in a point to the right on the EPF, tolerating high output variability in order to keep inflation as close as possible to the target at all times. On the other hand, a central bank that has a higher λ also wishes to take into account output variability, and will choose a rule more to the left on the EPF. This increasingly *flexible inflation targeting* becomes more and more expensive in terms of variability in inflation, until monetary policy can eventually no longer be characterised as inflation targeting.

3.2 An efficient policy frontier for Norway

To construct an EPF for the Norwegian economy, we use the model of the economy presented in Section 2. We must make assumptions about the average size and variability of the shocks to which the economy is subjected. We derive reasonable shocks from historical data, and assume for simplicity that the shocks to output, prices and the exchange rate hit the economy independently of each other. Shocks to the interest rate are disregarded. We must also specify the monetary policy rules we wish to examine. For our simple rule (2.1) the coefficient ranges examined are specified in Table 1. We vary:

1) the aggressiveness of the overall monetary policy response: θ ;
2) the response to inflation deviations from target relative to the output gap: β ;
3) the response horizon, i.e. the central bank responds to projected inflation deviation k quarters ahead; and
4) the degree of interest rate smoothing, i.e. gradualism in policy: α.

Table 1. Coefficient ranges

Coefficient	Description	Lower Bound	Upper Bound	Step
θ	Policy aggression	1	40	1
β	Weight on inflation gap vs output gap	0.1	1	0.1
k	Response horizon	0 quarters	16 quarters	2 quarters
α	Interest rate smoothing	0.1	0.9	0.2

Each possible combination of the above coefficients defines one policy rule. For each rule, we calculate the average variance of output and inflation that results under the range of shocks we have specified. Thus, each rule gives one point on the chart.[13] As described above, the EPF is then the series of points that results in the lowest inflation variability for a given output variability. Not all rules are efficient; most rules lie above the frontier.

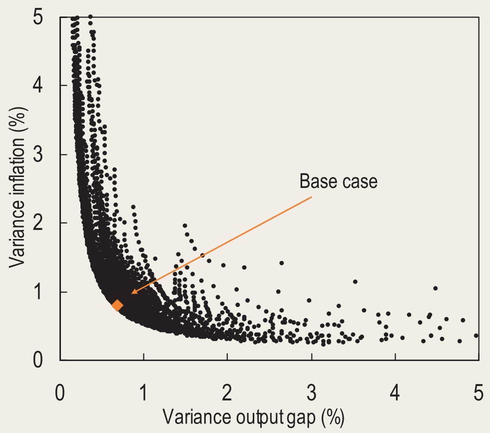
The above coefficient ranges result in about 16 500 different rules. However, some of the rules imply sharper moves in interest rates than tend to be observed in practice. Hence, when deriving the frontier we exclude the rules that result in quarterly interest rate movements of more than 2 percentage points more than 5 percent of the time (more than once every 5 years on average). Almost two thirds of the coefficient combinations are thereby excluded. The coefficients still vary over the full ranges described above. It is various *combinations* of coefficients, particularly of aggression and interest rate smoothing, that determine interest rate volatility. The outcomes from the remaining rules are shown in Chart 2. Imposing such a constraint is fairly standard practice, but it is not important for our qualitative illustrations. If the constraint is not imposed, the frontier has the same shape but lies slightly nearer the origin.

[11] See for example Svensson (1998).

[12] Note again that λ, the preference weight on output gap variability in the loss function, is distinct from β, the response weight on the level of the output gap in the policy rule.

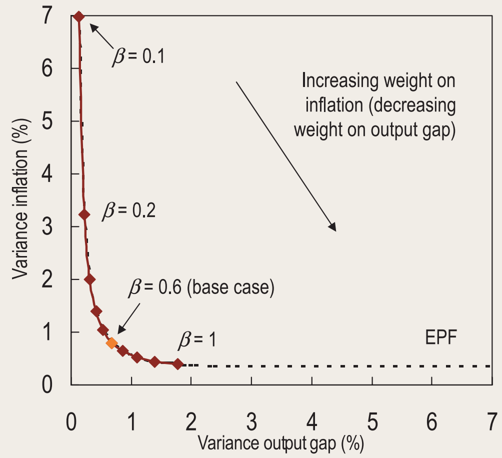
[13] Simulations were run in Dynare. For more information, see http://www.cepremap.cnrs.fr/~michel/dynare/

Chart 2 An efficient policy frontier: a simple model for Norway



Source: Norges Bank

Chart 3 Increasing the relative weight on inflation deviations. Varying β from 0.1 to 1, step 0.1
$\alpha = 0.3$, $k = 4$, $\theta = 6$



Source: Norges Bank

4 Exploring the consequences of different monetary policy approaches

4.1 A base case

We will now explore the consequences of different monetary policy approaches by examining the impact of altering the parameters in the policy rule. To facilitate comparisons between different policy approaches, we first choose a base case policy rule from which to vary the parameters one by one. This particular point on the EPF is not necessarily a better policy than other rules on the frontier. However, it represents a good starting point for our comparisons as it lies centrally on the EPF and does not contain any extreme coefficients (see Chart 2):

$$i_t = 0.3i_{t-1}+(1-0.3)[i^*+6(0.6(\pi_{t+4}-\pi^*)+0.4(y_t-y^*))] \qquad (4.1)$$

In this rule, the central bank has a moderate degree of interest rate smoothing ($\alpha = 0.3$), responds slightly more to inflation than to the output gap ($\beta = 0.6$), responds to inflation one year ahead ($k = 4$), and responds with an overall aggression parameter of 6 ($\theta = 6$).

This is a fairly activist rule, as are all the rules on the EPF, with implied interest rate volatility close to the upper limit we imposed when deriving the EPF. However, this rule does not imply that if a shock were to raise the forecast of inflation one year ahead from 2.5 percent to 3.0 percent, interest rates would immediately be raised by 0.7 x 6 x 0.6 x 0.5 = 125 basis points, all else equal. An interest rate response would immediately act to reduce the inflation forecast, meaning that the actual interest rate increase implied by this rule would be less than 125 basis points. This illustrates that a monetary policy rule cannot be evaluated separately from the model in which it resides.

Sections 4.2 to 4.5 analyse the effects of varying, one by one, the coefficients in the monetary policy rule, starting from this base case. In the charts that follow, the EPF is drawn in as a thin dotted line.

4.2 Relative weight on inflation vs output gap deviations

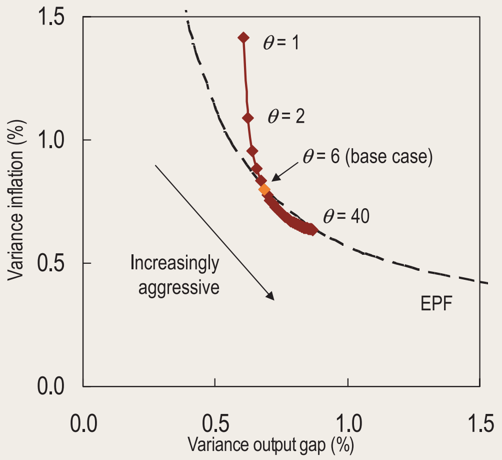
The β coefficient in the policy rule (2.1) characterises the extent to which the central bank responds to inflation deviations from target, relative to the output gap. Chart 3 shows the effect on the variability of inflation and output of increasing β from 0.1 to 1 by steps of 0.1. The parameter on smoothing (α), the aggression of the overall policy response (θ) and the response horizon (k) are fixed as in the base case (4.1).

As the weight on inflation (β) increases, the points shift down and to the right. This is consistent with a move towards stricter inflation targeting, as discussed in Section 3. That is, all else as in the base case rule, if the central bank reacts increasingly to inflation deviations from target and correspondingly less to the output gap when setting interest rates, the variability of inflation is reduced while output variability increases. We can also see the increasing marginal costs discussed in Section 3.1; for example when β is increased to a very high level, there is little gain in terms of reduced inflation variability, but a considerable cost in terms of increased output variability.

Although β is not a direct representation of the central bank's objectives (which are usually described by λ in a loss function), an increase in the response weight on either inflation or the output gap is consistent with a focus on stabilising that variable.[14] This is also illustrated by the fact that if the other coefficients are held fixed as in

[14] There may also be other factors, not captured in our model, that will influence the choice of how much weight to place on the two variables. For example, it is generally considered that the current output gap is very difficult to measure. This may be an argument for reducing the monetary policy response to this variable.

Chart 4 Increasingly aggressive monetary policy. Varying θ from 1 to 40, step 1. $\alpha = 0.3$, $\beta = 0.6$, $k = 4$



Source: Norges Bank

the base case, changing β traces out the EPF. This implies that β is close to a pure "preference" coefficient in the policy rule, whereas we will see that the other coefficients also have clear implications for the *efficiency* of policy, i.e. whether outcomes lie on the EPF or not.

4.3 Overall policy aggression

We now vary θ, the coefficient determining the aggressiveness of the overall policy response. Chart 4 displays the average effects of increasing the overall aggressiveness of policy. The coefficient θ in equation (2.1) is increased from 1 to 40 in steps of 1. The other coefficients are as in the base case (4.1).

The chart shows that increasing the general aggressiveness of monetary policy responses moves the central bank towards stricter inflation targeting, tolerating greater variability in output in order to reduce inflation variability. As policy becomes more aggressive, there are at first large benefits in terms of reducing inflation variability at little cost in terms of output variability. However, the returns soon diminish. Note that rules with an aggression coefficient greater than 6, all other coefficients equal to the base case, have higher interest rate volatility than we allowed when constructing the EPF. This is why these rules are able to achieve outcomes below the EPF.

The chart shows that low values of θ are inefficient, as the outcomes lie well above the EPF. This finding is not contingent on the base case values for the other coefficients; all the rules on the EPF have aggressiveness of at least 5. This reflects that monetary policy has a clear role to play in stabilising the economy after shocks. It is also partly a result of the fact that we disregard uncertainty in our analysis. If the central bank knows exactly how the economy works and the nature of the shocks it faces, then a fairly activist policy response will be efficient. In practice, very aggressive policy increases the possibility of making mistakes. In addition, our more general simulation experiments revealed that, even without uncertainty, extremely aggressive policy can be inefficient, destabilising both inflation and output. In our particular model this occurs only at very high levels of interest rate volatility.

4.4 Changing the response horizon for the inflation forecast

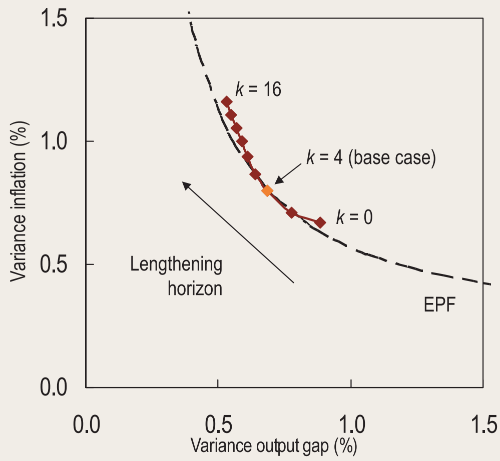
We now examine the implications of lengthening the response horizon, i.e. the implications of whether interest rates respond to what inflation is now, what it is expected to be in a year, or even further ahead.

The response horizon could be a single point in time or a moving average (for example five to eight quarters ahead). In the simple exercise here we take a single quarter horizon, k, which we vary between 0 and 16 with steps of 2 quarters. Chart 5 shows the results, with all other coefficients in the policy rule the same as in the base case rule (4.1).

A very short response horizon results in fairly high variability in output. Attempting to offset near-term movements in inflation may lead to very volatile monetary policy and destabilise the economy. Lengthening the response horizon in our base case rule reduces the variability in output at the cost of increasing the variability in inflation. It can therefore be interpreted as a move towards more flexible inflation targeting.

In the base case rule, the outcomes with very short and very long response horizons all lie above the EPF, i.e. they are not efficient. It can be shown that in the general case, where the other coefficients in the rule are allowed

Chart 5 Lengthening the response horizon. Varying k from 0 to 16 quarters, step 2. $\alpha = 0.3$, $\beta = 0.6$, $\theta = 6$



Source: Norges Bank

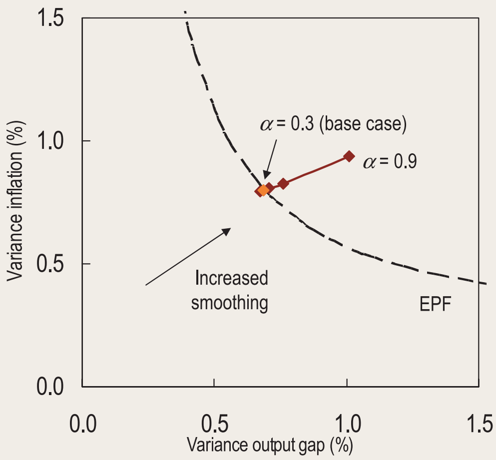
to vary in their full scope, the vast majority of rules that lie on the EPF have a response horizon of 2 to 8 quarters. Hence, it is generally not efficient to have an extremely short (k = 0) or an extremely long response horizon.

As mentioned in Section 2, the *response horizon* should not be confused with the *policy* horizon, which can be considerably longer. For example, responding to current inflation (k = 0) does not imply that the central bank aims to return inflation to target immediately. At higher values of k, the response and policy horizons also need not be identical. For a given response horizon, increased interest rate smoothing, less aggressive policy responses or a higher weight on the output gap relative to inflation will all tend to lengthen the policy horizon. Hence, while a longer response horizon implies a longer policy horizon, all else equal, the efficient range for the response horizon does not correspond to a 1:1 prescription for how quickly the central bank should aim to return inflation to target.

A very short response horizon is inefficient because interest rate changes affect inflation with a long lag. With a longer response horizon, the central bank takes this into account and makes use of the information available about future inflation developments. In other words, they "look through" the near-term inflation effects of shocks if forecasts indicate that these will not be persistent. On the other hand, a very long response horizon allows shocks to play through the economy to a greater extent and therefore increases the risk that the inflation effects of shocks will become embedded in inflation expectations. As explained in Section 2, this makes the central bank's job much harder.

Note also that in our simplified analysis the central bank recognises the shock immediately and knows exactly what its effect on the economy and inflation will be. In practice, forecasts far ahead are increasingly unreliable. Looking too far ahead could therefore lead to monetary policy mistakes, with associated increased variability in both inflation and output.

Chart 6 Increasing interest rate smoothing. Varying α from 0.1 to 0.9, step 0.2. β = 0.6, θ = 6, k = 4



Source: Norges Bank

4.5 Interest rate smoothing

Chart 6 shows the effect on the variance of inflation and output of increasing the degree of interest rate smoothing. The coefficient a in equation (2.1) is increased from 0.1 to 0.9 by steps of 0.2. The other coefficients are as in the base case rule (4.1).

Smoothing interest rates leads to increased variability in both inflation and output, i.e. unambiguously worse outcomes moving away from the EPF.[15] It can be shown that this is a general result, true not just for the base-case rule, but for all values of the other coefficients. This result is not surprising. Given that we assume that the central bank knows exactly how the economy works and also the exact nature of the shock, delaying the policy response is inefficient. In practice, on the other hand, the central bank has to evaluate the cost of delaying the response versus the potential cost of making a policy mistake should the shock, or the economy's response to it, turn out to be different than expected. Interest rate smoothing may therefore be quite reasonable in practice.

5 Conclusion

We have explored the implications of different approaches to monetary policy in a small model of the Norwegian economy and discussed the following general points.

First, central banks face a choice between stabilising inflation or output in the short-run. An efficient policy frontier maps out the limits of what monetary policy can achieve in terms of stabilising these two variables. These limits are contingent on the assumptions built into the model, such as the sluggishness of inflation and how monetary policy affects the economy.

Second, this choice can be demonstrated by changing the coefficients in a simple policy rule for monetary policy. Starting from an efficient base case rule, i) increasing the overall aggression of policy, ii) increasing the weight on inflation relative to the output gap, or iii) responding to nearer-term inflation forecasts, all move policy towards stricter inflation targeting. That is, they imply lower variability in inflation at the cost of higher variability in output. Changing these coefficients in the opposite direction is a move towards more flexible inflation targeting, with lower variability in output at the cost of higher variability in inflation.

However, more general investigations reveal that some ways of conducting policy are more efficient than others, resulting in lower variability in both inflation and

[15] Our base case rule with 0.3 smoothing nonetheless lies on the EPF because of the interest rate volatility constraint we imposed when deriving the frontier.

output. The following results, all standard in the literature, are found to hold in our small model:

- Neither very mild nor very aggressive policy is efficient. Monetary policy has a clear role to play in offsetting shocks, but can also destabilise the economy.
- Interest rate smoothing is never efficient. However, this finding is a result of the simplified nature of our analysis, which does not allow for monetary policy uncertainty or mistakes.
- Because of the lags with which monetary policy influences the economy, it is not optimal to respond only to current inflation. The central bank can do better by taking future inflation developments into account. On the other hand, responding to inflation more than 2 years ahead is usually not efficient in our model. Such a long response horizon increases the risk that inflation expectations may become entrenched away from the inflation target, which makes the central bank's job harder. However, this does not imply that the central bank should always aim to bring inflation back to target within 2 years. A given response horizon can be consistent with a wide range of policy horizons, depending on the specification of both the other coefficients in the monetary policy rule and the model itself.

It is important to bear in mind caveats to our results. The variability in output and inflation will be entirely contingent on the specification of the model and the shocks. Moreover, uncertainty is not taken into account in this exercise. We assume, for the sake of simplicity, that the central bank has perfect knowledge of the way the economy works (i.e. the model is correct) and of the distribution of shocks. The analysis of the implications of uncertainty for monetary policy is an important and complex field. We do not draw any conclusions here, but note that the efficient coefficient values are conditional on uncertainty assumptions. Our results are illustrative and intended to be interpreted qualitatively.

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