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PRICE STABILITY AS A TARGET FOR MONETARY POLICY: DEFINING AND MAINTAINING PRICE STABILITY

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ABSTRACT

This paper discusses how price stability can be defined and how price stability can be maintained in practice. Some lessons for the Eurosystem are also considered.

With regard to defining price stability, the choice between price-level stability and low (including zero) inflation and the decisions about the price index, the quantitative target and the role of output stabilization are examined. With regard to maintaining price stability, three main alternatives are considered, namely a commitment to a simple instrument rule (like a Taylor rule), forecast targeting (like inflation-forecast targeting) and intermediate targeting (like money-growth targeting). A simple instrument rule does not provide a substitute for a systematic framework for monetary policy decisions. Such a framework is instead provided by forecast targeting. Forecast targeting can incorporate judgmental adjustments, extra-model information, and different indicators (including indicators of "risks to price stability"). By extending mean forecast targeting to distribution forecast targeting, nonlinearity, nonadditive uncertainty and model uncertainty can be incorporated. Eurosystem arguments in favor of its money-growth indicator and against inflation-forecast targeting are scrutinized and found unconvincing.

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1 Introduction

The purpose of this paper is to provide an up-to-date discussion of monetary policy with "price stability" as the primary objective. The paper discusses how price stability can be defined, and how price stability can be maintained in practice. It also discusses some lessons for the Eurosystem.

Defining price stability involves deciding between price-level stability and low (including zero) inflation, choosing the appropriate price index, and selecting the appropriate level for a quantitative target. It also involves deciding on the role of real variables, like output, in the objectives for monetary policy. Thus, defining price stability boils down to defining the monetary-policy loss function.

Maintaining price stability involves meeting the objectives of price stability, that is, minimizing the monetary-policy loss function. I consider three main alternatives, namely *commitment to a simple instrument rule* (for instance, a commitment to following a Taylor rule), *forecast targeting* (for instance, inflation-forecast targeting) and *intermediate targeting* (for instance, monetary targeting). A sizeable part of the literature on monetary policy seems to focus on the properties of optimal and simple reaction functions for monetary policy, like the performance of Taylor-type reaction functions (that is, linear reaction functions responding to deviations of inflation from an inflation target and to the output gap). This literature provides considerable insights into the characteristics of optimal monetary policy and the properties of different reaction functions, and thereby provides considerable guidance and benchmarks for actual monetary policy, but I argue that a commitment to any of these reaction functions is, for several reasons, neither a good nor a practical way of conducting monetary policy, if monetary policy is to achieve price stability in an efficient way. Such commitment is not a substitute for a systematic operational framework for policy decisions by central banks.

Instead, I believe forecast targeting provides such a systematic and operational framework. Indeed, I believe that the current best practice of conducting real-world monetary policy can be interpreted as the application of forecast targeting. Thus, most of this paper is a discussion of forecast targeting. I examine its theoretical background and how, in practice, it can incorporate judgemental adjustments and extra-model information, the role of different indicators (including indicators of "risks to price stability") and, in particular, how it can incorporate complications like nonlinearity and model uncertainty.

The discussion of forecast targeting builds on Svensson [96]. The new elements include a more explicit discussion of policy multipliers, judgemental adjustments, the choice between mean, median and mode forecasts, and the role of indicators (the latter builds on Svensson and Woodford [101]). In particular, I discuss forecast targeting under nonlinearities, nonadditive uncertainty and model uncertainty, and the related generalization of what can be called *mean* forecast targeting to *distribution* forecast targeting.

Intermediate targeting, in particular monetary targeting, is treated fairly briefly, for several reasons. The recent interest in monetary targeting has mainly been motivated by the view that monetary targeting is the reason behind Bundesbank's outstanding record on inflation control and the possibility that the Eurosystem would choose monetary targeting as its monetary-policy strategy. However, with regard to whether monetary targeting lies behind Bundesbank's success, as discussed for instance in Svensson [98], a number of studies of Bundesbank's monetary policy, by both German and non-German scholars, have come to the unanimous conclusion that, in the frequent conflicts between stabilizing inflation around the inflation target and stabilizing money-growth around the money-growth target, Bundesbank has consistently given priority to the inflation target and disregarded the monetary target.[1] Thus, Bundesbank has actually been an inflation targeter in deeds and a monetary targeter in words only. Furthermore, although the Eurosystem has adopted a money-growth *indicator*, it has strongly rejected monetary *targeting* as a suitable strategy, on the grounds that the relation between prices and money may not be sufficiently stable and that the monetary aggregates with the best stability properties may not be sufficiently controllable (see Issing [56]). (Furthermore, an extensive and convincing discussion some 25 years ago concluded that intermediate targeting was generally inferior (see, for instance, Kareken, Muench and Wallace [58], Friedman [45] and Bryant [19]).)

The discussion of the lessons for the Eurosystem builds on Svensson [98]. The new elements includes further scrutiny of Eurosystem arguments in favor of its money-growth indicator and against inflation-forecast targeting.

In discussing monetary-policy strategy, as in Svensson [98], I find it helpful to distinguish two of its elements, namely *the framework for policy decisions* and *communication*. By the framework for policy decisions, I mean the monetary policy procedures inside the central bank, which, from observations of various indicators, eventually result in decisions about the central bank's instruments, in short, the principles for setting the instruments (which, in the Eurosystem's

[1] This litureature includes Neumann [71], von Hagen [109], Bernanke and Mihov [12], Clarida and Gertler [27], Clarida, Gali and Gertler [25] (note a crucial typo: the coefficient for money supply in Table 1 should be 0.07 instead of 0.7), Laubach and Posen [63], and Bernanke, Laubach, Mishkin and Posen [11].

case, will be a two-week repurchase rate). By communication, I mean the central bank's way of communicating with outsiders (the general public, the financial market, governments, policy-makers and policymaking institutions, which, in the Eurosystem's case, includes EU institutions and national governments and parliaments). Communication is part of the implementation of monetary policy, in that it affects the efficiency of monetary policy by, for instance, influencing expectations, predictability and credibility of the policy. Communication also influences how transparent policy is, which is crucial for central-bank incentives and for accountability and arguably also for the political legitimacy of the policy.

In terms of the distinction between decision framework and communication, this paper almost exclusively deals with the decision framework. I have extensively discussed communication and transparency in inflation targeting in [90] and [96] and the same issue with regard to the Eurosystem in [98]. The concluding section 5 includes some comments on transparency and forecast targeting.

A large part of the monetary-policy literature uses the concept of "rules" in the narrow sense of a prescribed reaction function for monetary policy. As in previous papers, for instance [90] and [96], I find it helpful to use monetary-policy rules in a wider sense, namely as "a prescribed guide for monetary policy." This allows "instrument rules," prescribed reaction functions, as well as "targeting rules," prescribed loss functions or prescribed conditions that the target variables (or forecasts of the target variables) shall fulfill.

Furthermore, (as in Cecchetti [23], for instance) "targeting" here refers to loss functions and "target variables" refer to variables in the loss function. Thus "targeting variable Y_t" means minimizing a loss function that is increasing in the deviation between the variable and a target level. In contrast, in some of the literature "targeting variable Y_t" refers to a reaction function where the instrument responds to the same deviation. As discussed in Svensson [96, section 2.4] and [94], these two meanings of "targeting variable Y_t" are not equivalent. "Responding to variable Y_t" seems to be a more appropriate description of the latter situation.

Section 2 discusses the definition of price stability, section 3 discusses maintaining price stability, section 4 discusses lessons for the Eurosystem, and section 5 presents some conclusions.

2 Defining price stability

2.1 Price-level stability vs. low inflation

How to define "price stability"? The most obvious meaning of price stability would seem to be a stable price level, "price-*level* stability." Nevertheless, in most current discussions and formulations of monetary policy, price stability instead means a situation with low and stable inflation, "low inflation" (including zero inflation). The former definition implies that the price level is stationary (or at least trend-stationary). The latter definition implies base drift in the price level, so that the price level will include a unit root and be non-(trend-)stationary. Indeed, the price-level variance increases without bound with the forecast horizon. Thus, to refer to low inflation as price stability is indeed something of a misnomer.

Let me refer to a monetary-policy regime as *price-level targeting* or *inflation targeting,* depending upon whether the goal is a stable price level or a low and stable inflation rate. We can represent (strict)[2] price-level targeting with an intertemporal loss function

$$\mathrm{E}_t \sum_{\tau=0}^{\infty} \delta^{\tau} L_{t+\tau}, \tag{2.1}$$

to be minimized, where δ $(0 < \delta < 1)$ is a discount factor and the period loss function is the quadratic loss function

$$L_t = \frac{1}{2}(p_t - p_t^*)^2. \tag{2.2}$$

Here, p_t denotes the (log) price level in period t and p_t^* denotes the (log) price-level target. The price-level target could be a constant or a (slowly) increasing path,

$$p_t^* = p_{t-1}^* + \pi^*, \tag{2.3}$$

where $\pi^* \geq 0$ is a constant (low or zero) inflation rate.[3] Similarly, we can represent (strict) inflation targeting with a period loss function given by

$$L_t = \frac{1}{2}(\pi_t - \pi^*)^2, \tag{2.4}$$

where $\pi_t \equiv p_t - p_{t-1}$ denotes (the) inflation (rate) and π^* denotes a low (or zero) inflation target.

Following Cecchetti [23], we can use more compact notation by representing inflation targeting in (2.2) by the state-dependent price-level target

$$p_t^* = p_{t-1} + \pi^* \tag{2.5}$$

[2] "Strict" and "flexible" targeting is defined below.
[3] If arguments in favor of a small positive inflation rate is accepted, an upward-sloping price-level target path may be preferable.

instead of (2.3), or by representing price-level targeting in (2.4) by the state-dependent inflation target

$$\pi_t^* = p_t^* - p_{t-1} \tag{2.6}$$

instead of a constant π^*. Hence, (2.5) illustrates the base drift in inflation targeting; the inflation target applies from the realized price level p_{t-1} rather than from the target price level p_{t-1}^*. Similarly, (2.6) illustrates that the inflation target becomes endogenous and time-varying under price-level targeting.

In the real world, there are currently an increasing number of monetary-policy regimes with explicit or implicit inflation targeting, but there are no regimes with explicit or implicit price-level targeting. Whereas the Gold Standard may be interpreted as implying implicit price-level targeting, so far the only regime in history with explicit price-level targeting occurred in Sweden during the 1930s (see Fisher [44] and Berg and Jonung [10]; this regime was quite successful in avoiding deflation).

Even if there are no current examples of price-level targeting regimes, price-level targeting has been subject to an increasing interest in the monetary policy literature. At the Jackson Hole Symposium 1984, Hall [51] argued for price-level targeting. Several recent papers compare inflation targeting and price-level targeting, some of which are collected in Bank of Canada [7]. Some papers compare inflation and price-level targeting by simulating the effect of postulated reaction functions. Other papers compare the properties of postulated simple stochastic processes for inflation and the price level (see Fischer [42]). A frequent result, which has emerged as the conventional wisdom, is that the choice between price-level targeting and inflation targeting involves a trade-off between low-frequency price-level variability on the one hand and high-frequency inflation and output variability on the other. Thus, price-level targeting has the advantage of reduced long-term variability of the price level. This should be beneficial for long-term nominal contracts and intertemporal decisions, but it would come at the cost of increased short-term variability of inflation and output. The intuition is straightforward: In order to stabilize the price level under price-level targeting, higher-than-average inflation must be succeeded by lower-than-average inflation. This would seem to result in higher inflation variability than under inflation targeting, since base drift is accepted in the latter case and higher-than-average inflation need only be succeeded by average inflation. Via nominal rigidities, the higher inflation variability would then seem to result in higher output variability.[4]

[4] An interesting issue is to what extent the degree of nominal rigidity depends on whether there is inflation or

However, this intuition may be misleadingly simple. In more realistic models of inflation targeting and price-level targeting with more complicated dynamics, the relative variability of inflation in the two regimes becomes an open issue. As shown in Svensson [91, appendix], this is the case if there is serial correlation in the deviation between the target variable and the target level; for instance, if the price level displays mean reversion towards the price-level target under price-level targeting and inflation displays mean reversion towards the inflation target under inflation targeting. Svensson [100] gives an example where the absence of a commitment mechanism and at least moderate persistence in the Phillips curve imply that inflation variability becomes *lower* under price-level targeting than under inflation targeting, without output variability becoming higher.[5] For some empirical macro models (both small and large), reaction functions with responses of the instrument to price level deviations from a price level target lead to as good or better overall performance (in terms of inflation and output variances) than with responses to inflation deviation from inflation targets.[6]

I believe these results show that the relative properties of price-level targeting and inflation targeting are far from settled. In particular, the potential benefits from reduced long-term price level variability and uncertainty are not yet well understood. Still, I believe that low and stable inflation may be a sufficiently ambitious undertaking for central banks at present. However, once central banks have mastered inflation targeting, in perhaps another five or ten years, it may be time to increase the ambitions and consider price-level targeting. By then, research and experience may provide better guidance about which regime is preferable.

The rest of the paper will refer to "low inflation," corresponding to (2.4), with possible additional terms in the loss function, rather than "price-level stability," corresponding to (2.2). Reluctantly, I will occasionally refer to "low inflation" as "price stability," even without using quotation marks. Some of the discussion below is applicable to both price-level stability and low inflation, though.

2.2 The loss function

Is (2.4) an appropriate loss function for a monetary policy aimed at low inflation? As reported below, there seems to be considerable agreement among academics and central bankers that the

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price-level targeting.

[5] This result requires at least moderate output persistence with a Lucas-type Phillips curve, and does not hold for a Lucas-type Phillips curve without persistence. Kiley [59] shows that the result does not hold for a Calvo-type Phillips curve without persistence.

[6] See, for instance, McCallum and Nelson [70] and Williams [113].

appropriate loss function is instead of the form

$$L_t = \frac{1}{2}[(\pi_t - \pi^*)^2 + \lambda(y_t - y_t^*)^2], \tag{2.7}$$

where y_t is (log) output, y_t^* is potential output, so that $y_t - y_t^*$ is the output gap, and $\lambda > 0$ is the relative weight on output-gap stabilization. As in Svensson [97] and [99], the case when $\lambda = 0$ and only inflation enters the loss function, can be called *strict* inflation targeting, whereas the case when $\lambda > 0$ and the output gap (or concern about stability of the real economy in general) enters the loss function can be called *flexible* inflation targeting.[7]

Whereas there may previously have been some controversy about whether inflation targeting involves concern about real variability, represented by output-gap variability and corresponding to the second term in (2.7), there is now considerable agreement in the literature that this is indeed the case. Inflation targeting central banks are not what King [62] called an "inflation nutter." For instance, Fischer [43], King [61], Taylor [103] and Svensson [89] in Federal Reserve Bank of Kansas City [39] all discuss inflation targeting with reference to a loss function of the form (2.7) with $\lambda > 0$. As shown in Svensson [90] and Ball [5], concern about output-gap stability translates into a more gradualist policy. Thus, if inflation moves away from the inflation target, it is brought back to target more gradually. Equivalently, inflation-targeting central banks lengthen their horizon and aim at meeting the inflation target further in the future. As further discussed in Svensson [97], concerns about output-gap stability, simple forms of model uncertainty, and interest rate smoothing all have similar effects under inflation targeting, namely a more gradualist policy. Sveriges Riksbank has explicitly expressed very similar views.[8] The Chancellor's remit to Bank of England [54] mentions "undesired volatility of output."[9] The Minutes from Bank of England's Monetary Policy Committee [8] are also explicit about stabilizing the output gap.[10] Several contributions and discussions by central bankers and academics in Lowe [68] express similar views. Ball [6] and Svensson [93] give examples of a gradualist approach of the Reserve Bank of New Zealand. Indeed, a quote from the ECB [37, p. 47] also gives some support for an interpretation with $\lambda > 0$, as well as some weight on minimizing interest rate variability:

[7] As inflation-targeting central banks, like other central banks, also seem to smooth instruments, the loss function (2.7) may also includes the term $\mu(i_t - i_{t-1})^2$ with $\mu > 0$.

[8] See box on p. 26 in Sveriges Riksbank [102] as well as Heikensten and Vredin [53].

[9] "...actual inflation will on occasions depart from its target as a result of shocks and disturbances. Attempts to keep inflation at the inflation target in these circumstances may cause undesirable volatility in output."

[10] See Bank of England [8], para. 40: "... [I]n any given circumstances, a variety of different interest rate paths could in principle achieve the inflation target. What factors were relevant to the preferred profile of rates?... There was a broad consensus that the Committee should in principle be concerned about deviations of the level of output from capacity."

> "... a medium-term orientation of monetary policy is important in order to permit a gradualist and measured response [to some threats to price stability]. Such a central bank response will not introduce unnecessary and possibly self-sustaining uncertainty into short-term interest rates or the real economy..."

Thus, it is seems noncontroversial that real-world inflation targeting is actually flexible inflation targeting, corresponding to $\lambda > 0$ in (2.7).

The loss function (2.7) highlights an asymmetry between inflation and output under inflation targeting. There is both a level goal and a stability goal for inflation, and the level goal, that is, the inflation target, is subject to choice. For output, there is only a stability goal and no level goal. Or, to put it differently, the level goal is not subject to choice; it is given by potential output. Therefore, I believe it is appropriate to label minimizing (2.7) as "(flexible) inflation targeting" rather than "inflation-and-output-gap targeting," especially since the label is already used for the monetary policy regimes in New Zealand, Canada, U.K., Sweden and Australia.

2.3 What index and which level?

Which price index would be most appropriate? Stabilizing the CPI should simplify consumer's economic calculations and decisions. The CPI has the advantage of being easily understood, frequently published, published by authorities separate from central banks, and very rarely revised. Interest-related costs cause well-known problems with the CPI, though: An interest-rate increase to lower inflation has a perverse short-term effect in increasing inflation. It makes sense to disregard this short-term effect in monetary-policy decisions, but it still presents a pedagogical problem in the central bank's communication with the general public. To avoid this problem, Bank of England and the Reserve Bank of New Zealand have inflation targets defined in terms of CPIX (RPIX in Britain), the CPI less interest-related costs.[11] The Eurosystem has also defined price stability in terms of the HICP, which excludes interest costs. Furthermore, changes in indirect taxes and subsidies can have considerable short-run effects on the CPI. Different measures of underlying inflation, core inflation, try to eliminate such effects. Eliminating components over which monetary policy has little or no influence serves to avoid misleading impressions of the degree of control. The disadvantage with subtracting too many components from the index used for the inflation target is that the index becomes more remote from what matters to consumers and less transparent to the general public. It may also be difficult to compute in a

[11] The Reserve Bank's target was previously defined in terms of a somewhat complex underlying inflation rate. In the Policy Target Agreement of December 1997, there was a change to the more transparent CPIX .

well-defined and transparent way. Opinions generally differ on what components to deduct from the CPI. My own view is that deducting interest-related costs and using CPIX, together with transparent explanation of index movements caused by changes in indirect taxes and subsidies, is an appropriate compromise for making the index an operational target for monetary policy.

What level of the inflation target is appropriate? Although zero inflation would seem to be a natural focal point, all countries with inflation targets have selected positive inflation targets. The inflation targets (point targets or midpoints of the target range) ranging between 1.5 percent (per year) in New Zealand, 2 percent in Canada, Sweden and Finland (before joining the EMU), and 2.5 percent in the United Kingdom and Australia (the Reserve Bank of Australia has an inflation target in the range 2–3 percent for average inflation over an unspecified business cycle). The Bundesbank had a 2 percent inflation target for many years (called "unavoidable inflation," "price norm," or "medium-term price assumption"). During 1997 and 1998, it was lowered to 1.5–2 percent (which could perhaps be translated into a point inflation target of 1.75 percent). EMI [38] defined price stability as 0–2 percent. The Eurosystem has announced "annual increases in the HICP below 2 percent" as its definition of price stability, which has been interpreted as the intervals 0–2 percent or 1–2 percent; the Eurosystem used a point inflation target of 1.5 percent in constructing its reference value for money growth. The Eurosystem's definition of price stability is further scrutinized in section 4.1.

That the inflation target exceeds zero can be motivated by measurement bias, nonnegative nominal interest rates and possible downward nominal price and wage rigidities.[12] Two percent is the borderline in Akerlof, Dickens and Perry [1], who study the effects of downward rigidity of nominal wages. One percent is the borderline in Orphanides and Wieland [74], who examine the consequences of non-negative nominal interest rates. These studies indicate that inflation targets below those borderlines risk reducing average output or increasing average unemployment.[13] Altogether, announcing an explicit inflation target (a point target or a range) may be more important than whether the target (the midpoint of the range) is 1.5, 2 or 2.5 percent.

A symmetric inflation target implies that inflation below the target is considered equally

[12] On the other hand, the argument that inflation increases capital-market distortions, examined in Feldstein [40] and [41], would, under the assumption of unchanged nominal taxation of capital, motivate a zero or even a negative inflation target.

[13] For reasons explained in Gordon [48], I believe that Akerlof, Dickens and Perry [1] reach too pessimistic a conclusion. On the other hand, their data is from the United States and Canada, and downward nominal wage rigidity may be more relevant in Europe. The conclusions of Orphanides and Wieland [74] are sensitive to assumptions about the size of shocks and the average real interest rate; the latter is taken to be 1 percent for the United States. If the average real rate is higher in Europe, and the shocks not much larger than in the United States, nonnegative interest rates may be of less consequence in Europe. Wolman [115] and [114] provides a rigorous examination of the consequences of nonnegative interest rates in a more explicit model, and finds relatively small effects.

bad as inflation the same distance above the target (which is the case if inflation targeting is represented by a symmetric loss function like (2.7)). This would seem to be a precondition for inflation expectations being focused on the inflation target. A point target with or without a tolerance interval would, from this point of view, be better than just a range. A range would, in turn, be better than an asymmetric formulation like "below 2 percent." These aspects may be particularly important when persistent deflation is a possibility, of which recent developments in Japan remind us. A symmetric inflation target would seem to be the best defence against persistent deflation and against the appearance of deflationary expectations.

Interestingly, a price-level target may have special advantages relative to an inflation target in avoiding persistent deflation, since an unanticipated deflation which makes the price level fall below the price-level target will, if the price-level target is credible, result in increased inflation expectations that will, in themselves, reduce the real interest rate and stabilize the economy.[14]

3 Maintaining price stability

The basic problem of maintaining price stability is thus to set the monetary policy instrument (or instruments) so as to minimize the intertemporal loss function (2.1) with the period loss function (2.7), subject to current information about the current and future state of the economy and the transmission mechanism.

The transmission mechanism is taken to be represented by a linear model on state-space form

$$\begin{bmatrix} X_{t+1} \\ x_{t+1|t} \end{bmatrix} = A \begin{bmatrix} X_t \\ x_t \end{bmatrix} + Bi_t + \begin{bmatrix} u_{t+1} \\ 0 \end{bmatrix}, \tag{3.1}$$

where $X_t = (\pi_t, y_t, y_t^*, .., 1)'$ (where $'$ denotes transpose) is a column vector of n_X *predetermined variables* (also called state variables), x_t is a column vector of n_x *forward-looking variables* (also called non-predetermined variables), i_t is a column vector of n_i central bank *instruments* (also called control variables), u_{t+1} is a column vector of n_X exogenous iid shocks with zero means and a constant covariance matrix Σ_{uu}, and A and B are matrices of appropriate dimensions. The predetermined variables include inflation, output, potential output, and other variables. I use the convention that the last element of the vector of predetermined variables is unity. This is a convenient way of allowing non-zero means of the variables; the last column of A is then a function of these means.

[14] Also, Wolman [115] finds that a reaction function responding to price-level deviations from a price-level target (rather than inflation deviation from an inflation target) has good properties for low inflation rates.

Although the framework is general enough for handling multiple monetary policy instruments, I will, realistically, assume that there is only one instrument ($n_i = 1$) and take that instrument to be a short nominal interest rate (for instance, an overnight interest rate or a one- or two-week repurchase rate).

The expression $x_{t+1|t}$ denotes $\mathrm{E}_t x_{t+1}$, the expectation of x_{t+1} conditional upon all information available in period t, including any information about the state of the economy and the model of the economy. The forward-looking variables include asset prices, like exchange rates and interest rates of longer maturity than the instrument, and other variables partially or fully determined by the expectations of future variables.

Thus, at this stage I assume that there are no nonlinearities in the transmission mechanism (or that shocks and deviations from a steady state are moderate so a linear approximation is acceptable). Furthermore, I make the assumption that the model is known, that the central bank and the private sector have the same information, and that the predetermined and forward-looking variables in period t are observable in period t. I will discuss generalizations of those assumptions below.

A more general representation of the monetary-policy loss function is to let Y_t denote a column vector of n_Y *target variables*, given by

$$Y_t \equiv C \begin{bmatrix} X_t \\ x_t \end{bmatrix} + C_i i_t,$$

where C and C_i are matrices of appropriate dimension. Let Y^* denote the column vector of n_Y *target levels*, and let the period loss function be

$$L_t = (Y_t - Y^*)' W (Y_t - Y^*),$$

where W is positive-semidefinite weight matrix. The period loss function (2.7) is a special case of this more general loss function, where the target variables are given by $Y_t \equiv (\pi_t, y_t - y_t^*)'$, the target levels by $Y^* \equiv (\pi^*, 0)$ and the weight matrix W is a diagonal matrix with the diagonal $(1/2, \lambda/2)$.

Given this representation of the loss function and the transmission mechanism, the problem is now to find the principles for setting the instrument i_t in each period t. I will consider two such main principles, first what can be called "commitment to an instrument rule" or "interest-rate targeting" in section 3.1, and then "forecast targeting" in section 3.2. A third principle, "intermediate-variable targeting," especially monetary targeting, is briefly considered in section 3.5.

3.1 Commitment to a simple instrument rule: Interest-rate targeting

Make the unrealistic assumption that the central bank can commit, once and for all, in period $t = 0$ to a particular reaction function for all future periods. Furthermore, assume that the model (3.1) is known, that the predetermined and forward-looking variables are observable in each period, and that X_0 is given. Under these assumption, it is possible to find the *optimal reaction function under commitment* that minimizes (2.1) in period 0 (see Backus and Driffill [4], Currie and Levine [30] and Söderlind [85]). This reaction function will be a linear function of the predetermined variables and the predetermined Lagrange multipliers (shadow prices) of the forward-looking variables,

$$i_t = fX_t + \varphi\Xi_t, \tag{3.2}$$

for $t \geq 0$ and X_0 given, where f and φ are row vectors with n_X and n_x elements (called response coefficients, or reaction coefficients), respectively. Furthermore, the multipliers Ξ_t fulfill

$$\Xi_{t+1} = M_{21}X_t + M_{22}\Xi_t, \tag{3.3}$$

for $t \geq 0$ and $\Xi_0 = 0$, where M_{21} and M_{22} are matrices of appropriate dimension. It follows from (3.2) and (3.3) that the optimal reaction function under commitment can be written as a distributed lag of past predetermined variables,

$$i_t = fX_t + \varphi \sum_{\tau=1}^{t} M_{22}^{\tau-1} M_{21} X_{t-\tau}. \tag{3.4}$$

If there are no forward-looking variables, there is no distinction between commitment and discretion. Furthermore, the optimal reaction function is a linear function of the current predetermined variables only,

$$i_t = fX_t. \tag{3.5}$$

Even when there are forward-looking variables, many papers consider the optimal reaction function under commitment over the class of reaction functions (3.5) of the current predetermined variables only (mostly without notifying the reader that this is a restriction).

The optimal reaction function under commitment is normally a function of all the predetermined variables (and the lagged predetermined variables) and is, in this sense, a rather complex construction. Consider also the class of *simple* reaction functions, the class of linear reaction functions restricted to being simple in the sense of having few arguments (for instance, some of the elements of vector f and all the elements of vector φ are restricted to zero). A typical simple reaction function is the much discussed Taylor rule, where the instrument only responds to current or lagged inflation and the output gap. Let the *optimal simple reaction function under commitment* be the reaction function in a particular class of simple reaction functions that minimizes (2.1) in period 0, given X_0.

An optimal reaction function under commitment is likely to be too complex, in the sense of involving specific responses to a large number of predetermined variables, to be verifiable. Therefore it is difficult to conceive of a commitment of the central bank to this reaction function. A simple reaction function is easier to verify. Therefore, in principle we can conceive of a commitment to a simple reaction function, a commitment to a simple instrument rule.

Such a commitment could also be expressed as a targeting rule, more precisely a commitment to the particular loss function corresponding to "interest-rate targeting." Then, for a particular simple reaction function f^*, a time-varying interest-rate target, i_t^*, is defined as

$$i_t^* \equiv f^* X_t. \tag{3.6}$$

Then, instead of the period loss function (2.7), the central bank is committed to the new period loss function

$$L_t = \frac{1}{2}(i_t - i_t^*)^2. \tag{3.7}$$

Clearly, a trivial first-order condition for minimizing (3.7) is given by[15]

$$i_t = i_t^*. \tag{3.8}$$

Thus, (3.8) can either be interpreted as a targeting rule, a first-order condition resulting from the commitment to the particular loss function (3.7) with the interest target (3.6), or it can be interpreted directly as an instrument rule, a prescribed rule for setting the instrument as a function of observed variables.

As an example, we can consider a Taylor-type reaction function with smoothing, which corresponds to an interest rate target given by

$$i_t^* \equiv (1-\rho)[\bar{r} + \pi^* + g_\pi(\pi_t - \pi^*) + g_y(y_t - y_t^*)] + \rho i_{t-1},$$

[15] Note that this simple first-order condition only arises if the variables in X_t are predetermined.

where $\bar{r}$ is the average real interest rate, g_π and g_y are the long-run response coefficients, and ρ $(0 \leq \rho < 1)$ is a smoothing parameter.

Furthermore, we realize that under this commitment to a simple policy rule, the central bank need no longer be forward-looking. It need only be forward-looking once and for all in period 0, when it decides to which simple reaction function it will commit. After that, it need never be forward-looking; to set the instrument according to the prescribed reaction function, or it simply needs to minimize the period loss function each period with the prescribed interest rate target.

Although most of the current and previous discussion of monetary-policy rules is in terms of commitment to alternative instrument rules (see, for instance, McCallum [69] and the contributions in Bryant, Hooper and Mann [20] and Taylor [105]), I do not believe that a commitment to an instrument rule is either a practical or desirable way of maintaining price stability, for several reasons.

First, there are overwhelming practical difficulties in deciding once and for all which instrument rule to follow. The optimal reaction function will involve specific responses to a large number of (current and lagged) information variables and is therefore unlikely to be verifiable. Furthermore, results by Levin, Williams and Wieland [66]) indicate that the optimal reaction function (in their case with the restriction that φ is zero) is quite sensitive to the model. This is problematic, since the model is, in practice, not precisely known. A simple reaction function may be more robust, in the sense of performing reasonably well in different models. This is an idea promoted and examined in several papers by McCallum and recently restated in McCallum [69]. The results of Levin, Williams and Wieland also indicate that a simple reaction function may be quite robust in this sense. On the other hand, as shown by Currie and Levin [29], the optimal simple reaction function does not only depend on the model and the loss function but also on the stochastic properties of the shocks and the initial state of the economy, X_0, so that the performance of simple rules generally depends on these stochastic properties (certainty-equivalence does not hold for simple reaction functions in linear models with quadratic loss functions, in contrast to the case for the optimal unrestricted reaction function).[16]

Second, a commitment to an instrument rule does not leave any room for judgemental adjustments and extra-model information. As argued further below, the use of judgemental

[16] There is an additional philosophical objection to once-and-for-all commitment: How come the once-and-for-all commitment can be done in period 0? Why was it not already done before, so nothing remains to be committed to in period 0? Why is there something special about period 0?

adjustments and extra-model information is both unavoidable in practice and desirable in principle. Also, there is no room for revision of the instrument rule, when new information results in a revision of the model. By disregarding such information, a commitment to an instrument rule would be inefficient.

Third, although a commitment to a complex instrument rule also seems inconceivable in principle, since it will hardly be verifiable, a commitment to a simple instrument rule is, in principle, feasible, for instance by an interest-rate targeting regime as above. Still, such a commitment is unheard of in the history of monetary policy, for obvious reasons. It would involve committing the decision-making body of the central bank to reacting in a prescribed way to prescribed information. Monetary policy could be delegated to the staff, or even to a computer. It would be completely static and not forward-looking. Such a degradation of the decision-making process would naturally be strongly resisted by any central bank and, I believe, arguments about its inefficiency would easily convince legislators to reject it as well. In practice, there is therefore no commitment mechanism that commits the decision-making body to reacting in a prescribed way to prescribed information. In practice, decision-making under considerable discretion is unavoidable, and nothing prevents the decision-making body from reconsidering their decisions more or less from scratch, without being bound by previous decisions and commitments. As Blinder [15, p. 49] puts it, "Enlightened discretion is the rule".

Fourth, in the absence of a commitment mechanism, a prescribed simple instrument rule would not be incentive-compatible. There would be frequent incentives to deviate, often for very good reasons, due to new, unforeseen, information (stock-market crash, Asian crisis, Brazil floating) and corresponding sound judgemental adjustment.

Although alternative instrument rules can serve as informative guidelines (see, for instance, the contributions in Taylor [105] or, with regard to the performance of a Taylor rule for the Eurosystem, Gerlach and Schnabel [46], Peersman and Smets [77] and Taylor [104]) and decisions ex post may sometimes be similar to those prescribed by the simple instrument rules, they are not a substitute for a decision-making procedure for the central bank. Interest-rate targeting for the Eurosystem was indeed rejected by the European Monetary Institute, the predecessor of the European Central Bank, in [38, p. 1] (with, arguably, not the most exhaustive argument):

> "[T]he use of an interest rate as an intermediate target is not considered appropriate given difficulties in identifying the equilibrium real interest rate which would be consistent with price stability."

Indeed, instead of having a decision-making procedure and being forward-looking only once and for all, at the time of a commitment to a simple rule, the central bank needs to have a continuous decision-making procedure and be continuously forward-looking. To quote Greenspan [50, p. 244],

> "Implicit in any monetary policy action or inaction, is an expectation of how the future will unfold, that is, a forecast.
>
> The belief that some formal set of rules for policy implementation can effectively eliminate that problem is, in my judgement, an illusion. There is no way to avoid making a forecast, explicitly or implicitly."[17]

Therefore, I now turn to a practical and realistic, and indeed already practiced, way of maintaining price stability, namely by way of "forecast targeting."[18]

3.2 Forecast targeting

As a background, recall that, with a quadratic loss function and a linear model, with the assumption of a known model and only additive uncertainty, certainty-equivalence applies. The problem of minimizing the loss function can be separated into a deterministic problem involving conditional forecasts, the conditional means of current and future variables, and a stochastic problem involving deviations between realized outcomes and conditional forecasts. The solution to the deterministic problem is the same as to the stochastic problem (see Chow [24] for models with only predetermined variables and Currie and Levin [30] for models with forward-looking variables as well). Thus, the discussion can focus on the deterministic problem involving conditional forecasts.

For any variable ξ_t, let $\xi_{t+\tau|t}$ for $\tau \geq 0$ denote the expectation $\mathrm{E}_t \xi_{t+\tau}$ given information in a fixed period t. The information in period t includes the information available about the state of the economy as well as about the model, (3.1).[19] Let $\xi_{|t}$ denote the future path $\xi_{t|t}, \xi_{t+1|t}, \xi_{t+2|t}, ...$ Consider the set $\mathcal{I}_t$ of given paths $i_{|t} = (i_{t|t}, i_{t+1|t}, ...)$ of instrument settings, for which there exist bounded paths $\pi_{|t}$ and $y_{|t} - y^*_{|t}$ of future inflation and output gaps, respectively. For each $i_{|t} \in \mathcal{I}_t$, let $\xi_{|t}(i_{|t})$ denote the corresponding path for variable $\xi = \pi$ and

[17] I found this appropriate quote in Budd [21].

[18] See Budd [21] for an interesting and detailed discussion of the advantages of explicitly considering forecasts rather than formulating reaction functions from observed variables to the instrument.

[19] It is important that these expectations are conditional on the central bank's model, and hence are "structural," rather than being private-sector expectations, in order to avoid the problems of nonexistence or indeterminacy of equilibria, arising from responding mechanically to private-sector expectations, as has been emphasized in Woodford [116] and further discussed in Bernanke and Woodford [14].

y ($y^*_{|t}$ is taken to be exogenous), and call it the corresponding *conditional forecast* (conditional on information in period t, $i_{|t}$ and the model (3.1)). Let

$$\mathcal{Y}_t \equiv \{\pi_{|t}(i_{|t}), y_{|t}(i_{|t}) - y^*_{|t} | i_{|t} \in \mathcal{I}_t\}$$

denote the set of feasible conditional forecasts of the target variables. Constructing conditional forecasts in a backward-looking model (that is, a model without forward-looking variables) is straightforward. Constructing such forecasts in a forward-looking model raises some specific difficulties, which are explained and resolved in Svensson [92, appendix A].[20]

Due to the certainty-equivalence, the *stochastic* optimization problem of minimizing the expected intertemporal loss function (2.1) over future random target variables in (2.7), subject to (3.1), is equivalent to the *deterministic* problem of minimizing the deterministic intertemporal loss function

$$\sum_{\tau=0}^{\infty} \delta^\tau \tilde{L}_{t+\tau|t} \tag{3.9}$$

with the deterministic period loss function

$$\tilde{L}_{t+\tau|t} \equiv \frac{1}{2}[(\pi_{t+\tau|t} - \pi^*)^2 + \lambda(y_{t+\tau|t} - y^*_{t+\tau|t})^2] \tag{3.10}$$

(where the stochastic $\pi_{t+\tau}$ and $y_{t+\tau} - y^*_{t+\tau}$ have been replaced by the deterministic $\pi_{t+\tau|t}$ and $y_{t+\tau|t} - y^*_{t+\tau}$) subject to

$$(\pi_{|t}, y_{|t} - y^*_{|t}) \in \mathcal{Y}_t. \tag{3.11}$$

Thus, the problem of the central bank is to choose the path $i_{|t}$, such that the resulting $\pi_{|t}$ and $y_{|t}$ minimize (2.1) with (3.10). The first element of $i_{|t}$, $i_{t|t}$, is then the appropriate instrument setting for period t, i_t. If there is no new relevant information in period $t+1$, the instrument setting in period t will be the second element in $i_{|t}$. If there is new relevant information, that information is used for solving the problem again in period $t+1$.[21]

This procedure thus involves making conditional forecasts of inflation, output and the output gap for alternative interest rate paths, using all relevant information about the current and future state of the economy and the transmission mechanism. It involves making consistent assumptions about exogenous and endogenous variables (for instance, that exchange rates and

[20] The conditional forecasts for arbitrary interest-rate path derived in Svensson [92, appendix A] assume that the interest-rate paths are "credible", that is, anticipated and allowed to influence the forward-looking variables. Leeper and Zha [64] discuss an alternative way of constructing forecasts for arbitrary interest-rate paths, by assuming that these interest-rate paths result from unanticipated deviations from a normal reaction function.

[21] The consequences of imposing the restriction of time-consistency of i^t remain to be examined. That is, that the elements $i_{t+\tau|t}$ in i^t shall be consistent with the decision in period $t+\tau$ conditional on $X_{t+\tau|t}$ (see footnote 22).

interest rates are consistent with appropriate parity conditions). As discussed further below, it also allows judgemental adjustments and extra-model information (section 3.2.3), as well as partially observable states of the economy (section 3.3). As discussed in section 3.4, forecast targeting can even be adapted to take nonlinearities and model uncertainty into account, which both result in nonadditive uncertainty.

The procedure requires estimates of policy multipliers, the effects on the conditional forecasts of changes in the instrument. The policy multipliers are easily calculated in a simplified model with only predetermined variables,

$$X_{t+1} = AX_t + Bi_t + u_{t+1} \tag{3.12}$$

(see Svensson [92, appendix A] for a case with forward-looking variables). The conditional forecast for $X_{t+\tau|t}$ then fulfills

$$X_{t+\tau|t} = AX_{t+\tau-1|t} + Bi_{t+\tau-1|t} = A^\tau X_{t|t} + \sum_{s=0}^{\tau-1} A^{\tau-1-s} Bi_{t+s|t} \tag{3.13}$$

for $\tau \geq 1$, so that the policy multipliers $dX_{t+\tau|t}/di_{t+s|t}$, $0 \leq s \leq \tau - 1$, are given by

$$\frac{dX_{t+\tau|t}}{di_{t+s|t}} = A^{\tau-1-s}B. \tag{3.14}$$

3.2.1 Optimality criterion

What is the criterion for having found an optimal interest-rate path and corresponding conditional forecasts of inflation and the output gap? One criterion can be formulated as follows. Suppose the central bank staff have constructed a potential optimal combination of an interest-rate path and such conditional forecasts. Consider a change $di_{|t} = (di_{t|t}, di_{t+1|t}, ...)$ in the interest-rate path $i_{|t}$. This will result in changes $dX_{|t} = (0, dX_{t+1|t}, dX_{t+2|t}, ...)$ in the predetermined variables, given by

$$dX_{t+\tau|t} = \sum_{s=0}^{\tau-1} \frac{dX_{t+\tau|t}}{di_{t+s}} di_{t+s|t}.$$

Let $d\pi_{|t}$ and $dy_{|t}$ denote the corresponding changes in the inflation and output forecasts (the output-gap forecast $y^*_{|t}$ is taken to be exogenous). A necessary condition for optimality is then that the corresponding change in the intertemporal loss function is nonnegative, that is,

$$d\sum_{\tau=0}^{\infty} \delta^\tau L_{t+\tau|t} = \sum_{\tau=0}^{\infty} \delta^\tau [(\pi_{t+\tau|t} - \pi^*)d\pi_{t+\tau|t} + \lambda(y_{t+\tau|t} - y^*_{t+\tau|t})dy_{t+\tau|t}] \geq 0. \tag{3.15}$$

Given $\pi_{|t}$, $y_{|t}$, $y^*_{|t}$ $d\pi^{,}_{|t}$ and $dy_{|t}$, as well as δ, π^* and λ, this expression is easily checked, and a relatively easy way of making pairwise comparisons of alternative interest-rate paths and conditional forecasts. For instance, a delay in an interest rate increase can be compared with an immediate increase, a small increase now can be compared with a larger increase two quarters later, etc.

Within the simple model in Svensson [90] and [97], I have shown that the first-order conditions for an optimum can be expressed as particularly simple targeting rules (in the form of equations for the conditional forecasts of the target variables). For instance, the inflation gap $\pi_{t+\tau+1|t} - \pi^*$ and the output gap $y_{t+\tau|t} - y^*_{t+\tau|t}$ should be of the opposite signs and related according to

$$\pi_{t+\tau+1|t} - \pi^* = -\frac{\alpha_y c(\lambda)}{1 - c(\lambda)}(y_{t+\tau|t} - y^*_{t+\tau|t}), \quad \tau \geq 1,$$

where the coefficient α_y is the sensitivity of the change in inflation to the output gap and the coefficient $c(\lambda)$ is an increasing function of λ that fulfills $0 \leq c(\lambda) < 1$, $c(0) = 0$ and $c(\infty) = 1$. Alternatively, the targeting rule can be expressed as the inflation forecast approaching the inflation target at a constant rate,

$$\pi_{t+\tau+1|t} - \pi^* = c(\lambda)(\pi_{t+\tau|t} - \pi^*), \quad \tau \geq 1.$$

In practice, the decision-making body may get far by just visually examining alternative inflation and output gap forecasts and then choosing the one that is the best compromise between hitting the inflation target at an appropriate horizon and avoiding output-gap stability. If done in a consistent way, this will be equivalent to minimizing the intertemporal loss function. Compared to many other intertemporal decision problems that households, firms and investors solve one way or another (usually without the assistance of a substantial staff of economics PhDs), this particular decision problem does not seem to be overly complicated or difficult.

3.2.2 Instrument assumptions

In the above discussion, the problem is to find the appropriate interest rate path $i_{|t}$, which requires constructing conditional forecasts for exogenous interest-rate paths.

Forecasts for unchanged interest rates, where the interest-rate path fulfills

$$i_{t+\tau|t} = i_{t-1}, \quad \tau \geq 0,$$

can be used as indicating "risks to price stability." They are used by Bank of England and Sveriges Riksbank to motivate changes in the interest rate and their direction (see section 3.3.1).

Conditional forecasts can also be constructed for given reaction functions, in which case the interest rate path is endogenous and fulfills

$$i_{t+\tau|t} = fX_{t+\tau|t}$$

for a given f.[22] Some central banks, notably Bank of Canada and Reserve Bank of New Zealand, construct forecasts conditional on reaction functions involving what Rudebusch and Svensson [80] call "responding to model-consistent forecasts," what Batini and Haldane [9] call "forecast-based" reaction functions. This implies an interest-rate path fulfilling

$$i_{t+\tau|t} = fX_{t+\tau|t} + gX_{t+T+\tau|t},$$

where $T > 0$ is the forecast horizon (typically some 6–8 quarters), and sometimes $f = 0$.

Among reaction functions involving responses to forecasts, it would seem more natural that the forecast responded to is one for unchanged interest rates. Indeed, under strict inflation targeting, the optimal instrument adjustment is proportional to the deviation of the conditional forecast for unchanged interest rate from the inflation target, as demonstrated in Svensson [98].[23]

3.2.3 Judgemental adjustments

A major advantage of forecast targeting relative to commitment to an instrument rule is that it allows a systematic and disciplined way of incorporating judgemental adjustment and extra-model information, by "filtering information through the forecasts."

Given that every model of the transmission mechanism is an abstraction and a simplification, and given that there is considerable uncertainty about the details of the transmission mechanism, monetary policy will never, it seems, be able to rely on models and the information entering models alone. There will always be an important role for additional extra-model information and judgemental adjustments of the instrument. Never using such information and judgement would neither be efficient nor incentive-compatible for the decision-making body of the central bank. At the same time, such information and informal adjustment opens up monetary policy to arbitrariness and potential abuse. Forecast targeting allows some system and discipline in the use of extra-model information and judgemental adjustments.

[22] Note that one way of taking the discretionary nature of decision making into account is to set i_t in period t under the restriction that the reaction function that will apply in period $t+\tau$ for $\tau \geq 1$ will be $i_{t+\tau|t} = f_{t+\tau|t}X_{t+\tau|t}$, where $f_{t+\tau|t}$ is the reaction function that is likely to result from the decision in period $t + \tau$.

[23] Note that an equation like $i_t = gX_{t+T|t}$, where $X_{t+T|t}$ is a model-consistent forecast (including this equation), especially in a model with forward-looking models, is a rather complex equilibrium condition. For reasons detailed in Svensson [96, section 2.3.1], I am rather sceptical about these equilibrium conditions as reaction functions representing inflation targeting.

Judgemental adjustments can be made in several ways in the framework outlined here. One is in the form of adjustments of the coefficients of the model. This means that the coefficients of matrices A and B become time-varying, $A_{t+\tau|t}$ and $B_{t+\tau|t}$, which is easily incorporated when constructing the forecasts (as long as the time-variation is deterministic; see below in section 3.4.2 on non-additive uncertainty).

Another kind of judgemental adjustments consists of simple additive shifts in the forecasts. For the model with only predetermined variables, this means that the model in period t can be represented as

$$X_{t+1+\tau|t} = AX_{t+\tau|t} + Bi_{t+\tau|t} + j_{t+\tau|t},$$

where the column vector $j_{t+\tau|t}$ corresponds to additive judgemental adjustments to $X_{t+\tau}$ in period t. Suppose, as above, that the last element in X_t is unity, in order handle nonzero means. Add the additive judgemental adjustment $j_{t+\tau|t}$ to the last column of the matrix A to form the matrix $A_{t+\tau|t}$. Then, the system can be written

$$X_{t+1+\tau|t} = A_{t+\tau|t}X_{t+\tau|t} + Bi_{t+\tau|t},$$

formally as a model with time-dependent coefficients.[24]

Only if a particular piece of information can be convincingly shown to affect the conditional forecasts at relevant horizons does it warrant a change in the instrument. It is not correct to adjust the instrument without "filtering the information through the forecasts." Thus, targeting rules and forecast targeting bring some system and discipline to the use of judgments and extra-model information, and provide some protection against the arbitrariness in use and temptations of abuse that might easily arise. This is, I believe, one aspect of what Bernanke and Mishkin [13] call "constrained discretion" (although they are not explicit about the role of forecast targeting).[25]

3.2.4 Mean, median or mode forecasts?

Is it the mean, the median or the mode forecast that is relevant in forecast targeting? Under a linear model with additive uncertainty and a quadratic loss function, the previous discussion have demonstrated that certainty equivalence holds and that it is the mean forecast that is

[24] See Tinsely [106] and Reifschneider, Stockton and Wilcox [78] for further discussion of judgemental adjustments.

[25] Mervyn King has emphasized that it is important that the decision-making body of the central bank agrees with the forecast. This requires iterations between the staff and the decision-making body, with the decision-making body having the last say on the forecast.

relevant. When would median or mode forecasts be relevant? Vickers [108] and Wallis [110] have provided systematic discussions of this issue. Under the maintained assumption of a linear model with additive uncertainty and objectives corresponding to minimum expected loss, the nature of the loss function determines which forecast is relevant. Thus, with a quadratic loss function, it is the mean forecast. Under a linear loss function (that is, linear in the deviation from target, V-shaped), it is the median forecast. Under an "all or nothing" loss function with extreme favorable weight on the target level, it is the mode forecast. Finally, under a loss function assigning a constant loss outside a tolerance interval and a zero loss inside, the forecast should maximize the probability of being inside the interval, which implies that the upper and lower bounds should have the same probability density.[26]

The mean, median and mode alternatives differ only when the probability distribution is asymmetric. When they differ, unless certainty equivalence is explicitly assumed not to hold, it seems that the mean forecast should still have prominence and never be excluded, also when the mode and/or the median is reported. Still, both Bank of England and Sveriges Riksbank report the mode forecast as their central forecast, in spite of the mode being associated with a relatively bizarre loss function, the all-or-nothing one.[27]

Bank of England and Sveriges Riksbank, however, aim to illustrate not only a point forecast but the probability distribution of the forecasted variable, so as to indicate the uncertainty of the forecast, as well as the "balance of risks," that is, whether the distribution is symmetric or not. Thus, Bank of England produce its famous fan chart, which can be interpreted as showing iso-level contours for the density function of the probability distribution, where each shade of color (red for inflation, green for the output forecast) encloses a given fraction of the probability mass (see Britton, Fisher and Whitley [18]). Thus, the fan chart displays the density function in the same way as a contour map illustrates a hill (with the difference that maps usually have contours with equal vertical distance whereas the fan chart has equal increments of the enclosed probability mass). Furthermore, the mode will be at the center of the narrow central band, the deepest shade of color which denotes the most likely outcomes, the highest portion of the probability density. As noted by Wallis [110], this means that Bank of England uses non-central prediction (or confidence) intervals, which are different from standard central prediction intervals

[26] Thus, for the "strict" case with inflation as the only argument in the loss function, the four loss functions are (1) $L_t = \frac{1}{2}(\pi_t - \pi^*)^2$, (2) $L_t = |\pi_t - \pi^*|$, (3) $L_t = k - \delta(\pi_t - \pi^*)$, where $\delta(x)$ is the so-called Dirac delta function with the properties $\delta(x) = 0$ for $x \neq 0$, $\delta(0) = \infty$, and $\int_{-\infty}^{\infty} \delta(x)dx = 1$, and (4) $L_t = 0$ for $|\pi_t - \pi^*| \leq a > 0$, $L_t = k > 0$ for $|\pi_t - \pi^*| > a$.

[27] Another problem with reporting the mode forecast is evident in the hypothetical case when the forecast is bimodel with approximately equal probability density at the two modes.

in that they do not have the same probability mass above and below the intervals (when the distribution is asymmetric).

Bank of Sweden instead reports the mode together with standard central prediction intervals, with the same probability above and below the prediction interval (see Blix and Sellin [16]). As a consequence, for an asymmetric distribution, the mode will not be at the center of the most narrow confidence interval (instead, the center of the most narrow confidence interval is the median).

As long as these alternative graphs are clearly understood as different ways of illustrating the whole distribution, and policy is based on the whole distribution, the ways of illustrating need not have any effect on the policy. Still, with the ways of illustration that these central banks have chosen, I believe that most observers are led to focus on the mode, when the mean arguably in many cases is a more appropriate focus. Therefore I believe that it might be better plot the mean rather than the mode, together with the different confidence intervals. I believe this might be better also under distribution forecast targeting, to be discussed in section 3.4.3, when the whole distribution matters.[28]

3.3 The role of indicators

So far, the maintained assumption in the discussion has been that the central bank can directly observe the state of the economy, more precisely, observe the predetermined and forward-looking variables, X_t and x_t in period t. In order to discuss the role of indicators, I now assume that the predetermined and forward-looking variables are not necessarily observable. Consequently, introduce a vector of n_Z observable variables, *indicators,* Z_t. The indicators depend on the predetermined and forward-looking variables and the instrument according to

$$Z_t = D \begin{bmatrix} X_t \\ x_t \end{bmatrix} + D_i i_t + v_t,$$

where D and D_i are matrices of appropriate dimension and v_t is a vector of n_Z iid shocks with zero means and constant covariance matrix Σ_{vv}. These shocks may be interpreted as mea-

[28] Two separate arguments are sometimes presented in favor of emphasizing the mode forecast. First, in *presenting and discussing* the forecast, it may often be natural and intuitive to consider a most likely scenario together with one or two alternative scenarios.. The most likely scenario would then correspond to the mode forecast. Second, before that stage, in *constructing* the forecast, it may be practical to start with a most likely scenario and then add various uncertainties and complications later on. Whereas the first argument may be a legitimate argument in favor of the mode, the second is not, since the presentation and the construction can be independent.

Furthermore, the mode and the median have the property that they are not affected by outlines, which may or may not be an advantage, depending on one's view.

surement errors. Assume that the central bank's information in period t is represented by the information set

$$I_t \equiv \{Z_{t-\tau},\ \tau \geq 0; A, B, C, C_i, D, D_i, \Sigma_{uu}, \Sigma_{vv}\}.$$

That is, in period t, the central bank knows the current and past indicators, in addition to the model and the stochastic properties of the shocks.

This formulation allows some variables to be directly observable, some to be observed with measurement error, and some to be completely unobservable. The discussion in previous sections, the full-information case, corresponds to the special case $Z_t \equiv (X_t', x_t', i_t')'$.

For simplicity, assume that there are no forward-looking variables, so that the model is (3.12), and let the indicators depend on the predetermined variables according to

$$Z_t = DX_t + v_t. \tag{3.16}$$

This setup is examined in more detail in Chow [24], Tinsley [106] and LeRoy and Waud [67].[29] The case of partial information with forward-looking variables is examined in Pearlman, Currie and Levin [76], Pearlman [75], Aoki [3] and Svensson and Woodford [101]. The present discussion follows Svensson and Woodford [101] (although without forward-looking variables).

Under these assumptions, certainty-equivalence continues to hold. In period t, the central bank needs to form the estimate $X_{t|t}$ of the predetermined variables in order to construct its conditional forecasts and set its instrument. The optimal estimate is given by a Kalman filter, with the updating equation

$$X_{t|t} = X_{t|t-1} + K(Z_t - Z_{t|t-1}), \tag{3.17}$$

where the matrix K is the Kalman gain matrix.[30]

The elements of the gain matrix give the optimal weights on the indicators in estimating the predetermined variables. Using (3.16), the updating equation can be written

$$X_{t|t} = (I - KD)X_{t|t-1} + KZ_t, \tag{3.18}$$

so the matrices K and $I - KD$ give the weights on the indicators Z_t and the prior information $X_{t|t-1}$. If $D = I$ and $\Sigma_{vv} = 0$, Z_t coincides with the predetermined variables; then $K = I$ and all weight is on the indicators and none on the prior information. Generally, a row in

[29] See Orphanides [73] and Smets [84] for recent related work.

[30] In a steady state, the Kalman gain is given by $K = PD'(DPD' + \Sigma_{vv})^{-1}$, where the covariance matrix P of the forecast errors $X_t - X_{t|t-1}$ is given by $P = M[P - PD'(DPD' + \Sigma_{vv})^{-1}DP]M' + \Sigma_{uu}$, where M is the transition matrix in the transition equation $X_{t+1} = MX_t + u_{t+1}$.

K gives the optimal weights on the indicators in estimating the corresponding predetermined variable. A column in K gives the weights given to the corresponding indicator in estimating the different predetermined variables. Assume that a particular indicator, Z_{jt}, is equal to one of the predetermined variables, X_{kt}, plus a measurement error, v_{jt},

$$Z_{jt} = X_{kt} + v_{jt}.$$

If the variance of the measurement error approaches zero, all the elements in row k of K approaches zero except element j, which approaches unity. Thus, all the weight in estimating X_{kt} falls on Z_{jt}. If the variance of the measurement error goes to infinity, Z_{jt} becomes a useless indicator. The elements in column j of K then all become zero. The indicator Z_{jt} gets zero weight in estimating the predetermined variables.

Assume, for simplicity, that forecast targeting has resulted in a reaction function f in the past. That is, $i_{t-\tau} = fX_{t-\tau|t-\tau}$ for $1 \leq \tau \leq t$. Then, by (3.12),

$$X_{\tau|\tau-1} = (A + Bf)X_{\tau-1|\tau-1}$$

for $1 \leq \tau \leq t$. Using this in (3.18), we can write the updating equation as a distributed lag of past indicators,

$$\begin{aligned} X_{t|t} &= (1 - KD)(A + Bf)X_{t-1|t-1} + KZ_t \\ &= [(1 - KD)(A + Bf)]^t X_{0|0} + \sum_{\tau=0}^{t-1} [(1 - KD)(A + Bf)]^\tau KZ_{t-\tau}. \end{aligned}$$

This gives the weight on indicators $Z_{t-\tau}$ as $[(1 - KD)(A + Bf)]^\tau K$ for $\tau \geq 0$.

These equations illustrate the gradual updating of the estimate of the predetermined variables. We can summarize the effects of the indicators in period t on the forecasts $X_{t+\tau|t}$ in terms of "indictor multipliers," $dX_{t+\tau|t}/dZ_t$, given by

$$\frac{dX_{t+\tau|t}}{dZ_t} = \frac{dX_{t+\tau|t}}{dX_{t|t}} \frac{dX_{t|t}}{dZ_t} = A^\tau K.$$

Thus, the indicator multiplier is the product of the effect of the estimate of the current state of the forecast, $dX_{t+\tau|t}/dX_{t|t}$, which by (3.13) is given by A^τ, and the effect of the indicators on the estimate of the current state, with by (3.17) is given by the gain matrix K. It follows that an indicator will affect the instrument setting via affecting the current state of the economy, then the forecasts, and finally the instrument. Schematically,

$$Z_t \rightarrow X_{t|t} \rightarrow X_{t+\tau|t} \rightarrow i_t.$$

Especially, the weights on any given indicator depends exclusively on its power in predicting future inflation and output gap. Monetary aggregates, for instance, have no special role beyond that, and any weight on monetary aggregates will exclusively depend on its predictive performance.

3.3.1 An indicator of "risks to price stability"

An indicator of what the Eurosystem calls "risks to price stability," that is, inflationary or deflationary pressure, or risks of over- or under-shooting the inflation target, should be useful when discussing monetary policy that aims to maintain price stability. What requirements should such an indicator fulfill? It would seem that, first, it should signal in which direction and to what extent the inflation target will be missed in case policy is not adjusted. Second, it should signal in which direction and to what extent the instrument should be adjusted. Finally, it should be intuitive and easy to understand, so that it can be used to communicate with the public and explain why an instrument change is warranted or not.

The Eurosystem has put forward a money-growth indicator, namely the deviation between current M3 growth and a reference value, as an indicator of risks to price stability, indeed the first of the "two pillars" of its monetary strategy. As discussed in Svensson [98], such a money-growth indicator seems quite unsuitable for this purpose, since it is largely just a noisy indicator of the deviation of current inflation from the inflation target (which deviation can be more easily observed directly).[31] Instead, the obvious candidate is a conditional inflation forecast, conditional upon unchanged monetary policy in the form of an unchanged interest rate. That is, it is constructed for the interest rate path that fulfills $i_{t+\tau|t} = i_{t-1}$, $\tau \geq 0$. Constructing this inflation forecast is straightforward in a model without predetermined variables, as is apparent from (3.13). It is somewhat more complicated in a model with forward-looking variables, as shown in Svensson [92, appendix A].[32] This indicator signals whether and in which direction the inflation target is likely to be missed, if policy is not adjusted, and thereby it also signals in which direction the instrument needs to be adjusted.

Bank of England and Sveriges Riksbank, in their quarterly *Inflation Reports*, use conditional

[31] That such a money-growth indicator is unsuitable on its own is fairly obvious, since money is not the only, not even the major, predictor of inflation at the horizons relevant for monetary policy (see Estrella and Mishkin [33]). What is perhaps less obvious is that the money-growth indicator is unsuitable even for a completely stable money-demand function without velocity shocks (see Svensson [98] and Rudebusch and Svensson [81]).

[32] More specifically, with forward-looking variables, the interest rate is kept unchanged for a few periods (4-6 quarters, say), but then, there is a shift to "normal" policy, or to some policy stabilizing inflation and determining the future forward-looking variables.

inflation forecasts for unchanged interest rates as their main vehicle for motivating why the instruments need to be adjusted or not.

3.4 Complications to mean forecast targeting and generalization to distribution forecast targeting

Nonlinearities and nonadditive uncertainty in the model are two complications to forecast targeting. These complications both imply that the certainty-equivalence underlying conditional mean forecasts no longer holds. These two complications are discussed in sections 3.4.1 and 3.4.2.[33] A solution to the complications is to move from conditional *mean* forecast targeting to conditional *distribution* forecast targeting, which is discussed in section 3.4.3.

3.4.1 Nonlinearites

So far, the maintained assumption has been that the model is linear. Sources of nonlinearity that have been discussed in the literature include nonlinear Phillips curves (see Debelle and Laxton [31], Gordon [49] and Isard and Laxton [55]), nonnegativity of nominal interest rates and downward nominal rigidity of prices and/or wages (see references in section 2.3). Suppose now that the model is nonlinear. Assume that the model remains known, that there are no forward-looking variables, that the predetermined variables are observable, and that the model can be written as

$$X_{t+1} = M(X_t, i_t, u_{t+1}), \tag{3.19}$$

where $M(\,)$ is a nonlinear function. This has two consequences. First, the conditional mean forecasts, $X_{t+\tau|t}$, are now nonlinear functions of the interest-rate path, $i_{|t}$, the current state of the economy, X_t, and the covariances of the shocks, Σ_{uu}. Second, the policy multipliers, $dX_{t+\tau}/di_{t+s|t}$, will be stochastic, and the "forecast" policy multipliers, $dX_{t+\tau|t}/di_{t+s|t}$, will be endogenous and not constant. Then, certainty-equivalence no longer applies, and using the period loss function (3.10) is no longer equivalent to using (2.7).

The reason why certainty-equivalence no longer holds can be demonstrated with reference to the optimality criterion (3.15). Consider the change in the intertemporal loss function (2.1) with (2.7) of a change $di_{|t}$ for the optimal instrument path, which implies the optimality criterion

$$0 \quad \leq \quad d\mathrm{E}_t \sum_{\tau=0}^{\infty} \delta^{\tau} L_{t+\tau}$$

[33] A non-quadratic loss function would also imply that certainty-equivalence no longer holds (see section 3.2.4).

$$
\begin{aligned}
&= d\sum_{\tau=0}^{\infty}\delta^{\tau}\frac{1}{2}\,\mathrm{E}_t[(\pi_{t+\tau}-\pi^*)^2+\lambda(y_{t+\tau}-y^*_{t+\tau})^2] \\
&= \sum_{\tau=0}^{\infty}\delta^{\tau}\left\{\mathrm{E}_t[(\pi_{t+\tau}-\pi^*)d\pi_{t+\tau}]+\lambda\mathrm{E}_t[(y_{t+\tau}-y^*_{t+\tau})dy_{t+\tau}]\right\} \\
&= \sum_{\tau=0}^{\infty}\delta^{\tau}\left\{(\pi_{t+\tau|t}-\pi^*)d\pi_{t+\tau|t}]+\lambda(y_{t+\tau|t}-y^*_{t+\tau|t})dy_{t+\tau|t}]\right\} \\
&\quad+\sum_{\tau=0}^{\infty}\delta^{\tau}\left\{\mathrm{Cov}_t[\pi_{t+\tau},d\pi_{t+\tau}]+\lambda\mathrm{Cov}_t[y_{t+\tau}-y^*_{t+\tau},dy_{t+\tau}]\right\}, \qquad (3.20)
\end{aligned}
$$

where $\mathrm{Cov}_t[\cdot,\cdot]$ denotes the covariance conditional on information available in period t.

With a linear model, the changes $d\pi_{t+\tau}$ and $dy_{t+\tau}$ caused by the change $di_{|t}$ are deterministic and independent of $\pi_{t+\tau}$ and $y_{t+\tau}$, so that the covariance terms in (3.20) vanish. The change $dX_{t+\tau}$ in the random variable $X_{t+\tau}$ is identical to the change $dX_{t+\tau|t}$ in the conditional forecast $X_{t+\tau|t}$. Then the optimality criterion (3.15) applies, and it is sufficient to think in terms of conditional forecasts. With a nonlinear model, the changes $d\pi_{t+\tau}$ and $dy_{t+\tau}$ are stochastic and depend on $\pi_{t+\tau}$ and $y_{t+\tau}$ and therefore the covariance terms in (3.20) are not necessarily zero. In order to see this, note that with the linear model (3.12), the change $dX_{t+\tau}$ from a change $di_{t+s|t}$ $(0 \leq s < \tau - 1)$ is given by

$$
dX_{t+\tau}=\frac{dX_{t+\tau}}{di_{t+s}}\,di_{t+s|t}=\frac{dX_{t+\tau|t}}{di_{t+s|t}}\,di_{t+s|t}=A^{\tau-1-s}B\,di_{t+s|t},
$$

where we use that $dX_{t+\tau}/di_{t+s} = dX_{t+\tau|t}/di_{t+s|t} = A^{\tau-1-s}B$, so $dX_{t+\tau}$ is deterministic and independent of $X_{t+\tau}$ (since the policy multipliers are constant). With the nonlinear model (3.19), the same change is

$$
dX_{t+\tau}=\left(\prod_{r=1}^{r=\tau-s-1}\frac{\partial M(X_{t+s+r},i_{t+s+r},u_{t+s+r+1})}{\partial X}\right)\frac{\partial M(X_{t+s},i_{t+s},u_{t+s+1})}{\partial i}\,di_{t+s|t},
$$

so that $dX_{t+\tau}$ is stochastic and generally correlated with $X_{t+\tau}$ (since the policy multipliers $dX_{t+\tau}/di_{t+s|t}$ are now endogenous and not constant).[34]

With a nonlinear model, the optimal reaction function is nonlinear,

$$
i_t = f(X_t),
$$

and it will generally depend on the covariances Σ_{uu}. The covariance terms in (3.19) also imply that the optimal policy may imply a bias, in the sense that it is optimal to, on average, either over- or under-shoot the inflation target (also, the optimal average output gap may not be zero).

[34] Note that we use the convention that $\Pi_{r=s}^{t}\xi_r = 1$ for $t < s$.

Doing forecast targeting under a nonlinear model and selecting the instrument such that (3.10) is minimized would still imply a nonlinear reaction function, since the conditional forecasts would be nonlinear functions of the instrument path. It would imply disregarding the optimal bias, though. How costly forecast targeting would be relative to the optimal policy would, of course, depend on the degree of nonlinearity in the transmission mechanism, which is an empirical question. My reading of the literature is that there is considerable controversy about the extent and the relevance of any nonlinearity (see for instance Gordon [49] and Isard and Laxton [55]).

3.4.2 Non-additive uncertainty

So far, only additive uncertainty has been considered, appearing as the additive shock u_{t+1} in (3.1). Uncertainty about parameters in the model, that is, uncertainty in the coefficients of the matrices A and B in (3.1), results in multiplicative uncertainty, an example of non-additive uncertainty. Multiplicative uncertainty has consequences similar to nonlinearity, in that certainty equivalence no longer holds, even if the model remains linear and the loss function is quadratic.

Assume that the model is linear, that there are no forward-looking variables, and that the predetermined variables are observable, but assume now that the model has time-varying stochastic parameters, with known stochastic properties. Then the model can be written

$$X_{t+1} = A_{t+1}X_t + B_{t+1}i_t + u_{t+1}, \tag{3.21}$$

where A_t and B_t are stochastic processes with known stochastic properties. It follows that $X_{t+\tau}$ can be written

$$X_{t+\tau} = \prod_{s=0}^{\tau-1} A_{t+1+s}X_t + \sum_{s=0}^{\tau-1}\left(\prod_{r=1}^{\tau-s-1} A_{t+1+s+r}\right)B_{t+s+1}i_{t+s} + \sum_{s=1}^{\tau}\left(\prod_{r=1}^{\tau-s} A_{t+s+r}\right)u_{t+s}.$$

Then the policy multipliers,

$$\frac{dX_{t+\tau}}{di_{t+s}} = \left(\prod_{r=1}^{\tau-s-1} A_{t+1+s+r}\right)B_{t+s+1},$$

for $0 \le s \le \tau - 1$, are stochastic. It follows that a change in the interest rate path, $di_{|t}$, results in stochastic changes $d\pi_{t+\tau}$ and $dy_{t+\tau}$ in inflation and output.

Once more, the covariance terms in (3.20) do not vanish, and certainty equivalence no longer applies. As shown in the classic paper by Brainard [17] and, for instance, in a recent application to strict inflation targeting in Svensson [97], the optimal instrument response to disturbances usually becomes more cautious, and a bias enters such that the optimal policy implies that the inflation either over- or under-shoots the inflation target. However, some covariance patterns for the parameters, as well as uncertainty about the inflation persistency, may make the optimal instrument response more sensitive to disturbances than in the absence of parameter uncertainty (see Söderström [86]).

Monetary policy under model uncertainty is currently a very active research area, with a number of recent papers.[35] Practically all work is directed towards the understanding how the optimal reaction function changes with model uncertainty. But how should practical monetary policy incorporate model uncertainty? This is the issue to be discussed next.

3.4.3 Generalized forecast targeting: Distribution forecast targeting instead of mean forecast targeting

One possibility for handling nonlinearity and model uncertainty might seem to be to commit, once and for all, to a simple instrument rule, either to an optimal reaction function that minimizes the expected intertemporal loss, taking Bayesian priors on the nature of the model uncertainty into account, or a simple rule with reasonable robustness properties across potential models. However, I believe the objections to this solution raised in section 3.1 apply with even greater force under nonlinearity and model uncertainty, since the unavoidability and desirability of judgemental adjustments, extra-model information and updated Bayesian priors are even more apparent. Therefore, I believe that the solution must be found elsewhere, namely in a generalization of forecast targeting.

Nonlinearity and model uncertainty both imply that certainty-equivalence does not apply. This, in turn, means that it is not optimal to rely on forecast targeting with conditional mean forecasts, that is, using conditional mean forecasts as intermediate variables. Thus mean forecast targeting is not optimal. Still, we can consider a kind of generalized forecast targeting, distribution forecast targeting, as a way of handling nonlinearity and multiplicative uncertainty.

Distribution forecast targeting simply consists of constructing conditional probability dis-

[35] Recent work on and discussion of monetary policy under model uncertainty includes Blinder [15], Cecchetti [23], Clarida, Gali and Gertler [26], Estrella and Mishkin [34], Levin, Wieland and Williams [66], McCallum [69], Onatski and Stock [72], Peersman and Smets [77], Rudebusch [79], Sack [82], Sargent [83] Smets [84], Söderström [86] and [87], Stock [88], Svensson [97], and Wieland [111] and [112].

In contrast to the standard Brainard result in favor of caution, recent work on so-called robust control (where the reaction function is chosen so as to minimize expected loss for the most unfavorable model) indicates that model uncertainty may well result in more aggressive optimal responses (see, for instance, Sargent [83] and Stock [88]).

tributions of the target variables instead of means only. For any random variable ξ_t, let ξ^t denote the random path $(\xi_t, \xi_{t+1}, ...)$ (recall that $\xi_{|t}$ denotes the path of the conditional means $(\xi_{t|t}, \xi_{t+1|t}, ...)$). Then, for a given interest-rate path $i_{|t}$, the central bank staff should construct the joint conditional density function of the random path of inflation and the output gap, denoted $\varphi_t(\pi^t, y^t - y^{*t}; i_{|t})$, conditional upon all information available in period t and the interest-rate path $i_{|t}$.

Then, this conditional probability distribution is used to evaluate the loss function (2.1) with (2.7). This can either be done numerically, or informally by the decision-making body of the bank being presented with the probability distributions for a few alternative interest rate paths and then deciding which path and distribution provides the best compromise.

This alternative is actually much more feasible than many readers might think. Bank of England and Sveriges Riksbank have already developed methods for constructing confidence intervals for the forecasts published in their *Inflation Reports* (see Blix and Sellin [16] and Britton, Fisher and Whitley [18]). Bank of England presents fan charts for both inflation and output, and Sveriges Riksbank gives confidence intervals for its inflation forecasts.[36] [37] Furthermore, scrutiny of the motivations for interest rate changes (including the minutes for Bank of England's Monetary Policy Committee and the Riksbank's Executive Board) indicate that both banks occasionally depart from certainty-equivalence and take properties of the whole distribution into account in their decisions, for instance, when the risk is unbalanced and "downside risk" differ from "upside risk."

The result of distribution forecast targeting can be compared with what would result if only conditional mean forecasts were considered. In practice, there may not be a big difference in the resulting instrument setting, in which case there is not much point in letting distribution forecast targeting replace mean forecast targeting. Distribution forecast targeting seems meaningful and worth the effort only if it results in significantly different, and more adequate, instrument settings than mean forecast targeting. This remains to be examined.

[36] Bank of England's fan charts for inflation and output should probably be interpreted as marginal distributions. However, since the distributions for inflation and the output gap are unlikely to be independent, distribution forecast targeting requires the joint distribution to be conveyed. This may require some further innovation in display, beyond the already beautiful fan chart.

[37] As discussed in Wallis [110], Bank of England's fan charts present prediction intervals that differ from normal confidence intervals, central prediction intervals. Sveriges Riksbank, however, presents normal confidence intervals, see Blix and Sellin [16]. Both banks present the mode as their point forecast, whereas it seems to me that it would be more natural and consistent with the theory to present the mean (or, in distribution forecast targeting, at least the median) (see section 3.2.4).

3.5 Intermediate targeting

When would intermediate targeting be optimal? Assume, for simplicity, strict inflation targeting, (2.4). Consider, for simplicity, the model without forward-looking variables, (3.12). Decompose the vector of predetermined variables according to $X_t = (\pi_t, X_{2t}', X_{3t}')'$, where the first element is inflation and the rest of the variables are decomposed into two vectors, X_{2t} and X_{3t}. Suppose that the two vectors X_{2t} and X_{3t} can be chosen such that the model (3.12) of the transmission mechanism fulfills

$$\begin{bmatrix} \pi_{t+1} \\ X_{2,t+1} \\ X_{3,t+1} \end{bmatrix} = \begin{bmatrix} 0 & A_{12} & 0 \\ A_{21} & A_{21} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} \pi_t \\ X_{2t} \\ X_{3t} \end{bmatrix} + \begin{bmatrix} 0 \\ B_2 \\ B_3 \end{bmatrix} i_t + u_{t+1},$$

that is, where the A and B matrices are such that $A_{11} = 0$, $A_{13} = 0$ and $B_1 = 0$. Then inflation fulfills

$$\pi_{t+1} = A_{12} X_{2t} + u_{1,t+1}, \tag{3.22}$$

and is exclusively determined by variables X_{2t}, and variables X_{2t} are the only predictors of inflation (aside from the zero-mean exogenous shock $u_{1,t+1}$). Under these assumptions, the instrument i_t affects inflation exclusively by first affecting $X_{2,t+1}$ and then by $X_{2,t+1}$ affecting π_{t+2}. Schematically, we have

$$i_t \rightarrow X_{2,t+1} \rightarrow \pi_{t+2}.$$

Because of this property of X_{2t}, its elements can be called *intermediate variables.*

Let X_2^* fulfill

$$\pi^* = A_{12} X_2^*. \tag{3.23}$$

Substituting (3.22) and (3.23) into (2.4) for $t+1$ and taking the expectation in period t result in

$$L_{t+1|t} = \frac{1}{2}(\pi_{t+1|t} - \pi^*)^2 + \frac{1}{2}\sigma_{u1}^2 = (X_{2t} - X_2^*)' W (X_{2t} - X_2^*) + \frac{1}{2}\sigma_{u1}^2,$$

where σ_{u1}^2 is the variance of u_{1t} and the weight matrix W fulfills $W = \frac{1}{2} A_{12}' A_{12}$.

Clearly, using the period loss function

$$\tilde{L}_t \equiv (X_{2t} - X_2^*)' W (X_{2t} - X_2^*)$$

is equivalent to using (2.4). Now we can call X_{2t} *intermediate target variables*, X_2^* *intermediate target levels*, and minimizing (2.1) with $\tilde{L}_t$ instead of (2.4) we can call *intermediate targeting.* We thus have a situation where intermediate targeting is as good as strict inflation targeting.

In particular, assume that inflation is exclusively determined by money growth according to

$$\pi_{t+1} = \Delta m_t + u_{1,t+1},$$

where $\Delta m_t \equiv m_t - m_{t-1}$ and m_t is the log of a monetary aggregate. Then, the instrument exclusively affects inflation via first affecting money-growth, that is,

$$i_t \to \Delta m_{t+1} \to \pi_{t+2}.$$

Thus, let $X_{2t} \equiv \Delta m_t$, $A_{12} = 1$, $X_2^* = \pi^*$ and $W = \frac{1}{2}$, and strict inflation targeting can be replaced by strict money-growth targeting with the period loss function

$$\tilde{L}_t \equiv \frac{1}{2}(\Delta m_t - \pi^*)^2.$$

Both kinds of targeting will be equivalent.

In the example above, the transmission mechanism is *recursive* in a special way, such that the target variables (in the above case only inflation) are only determined by a set of intermediate variables (the only exception being zero-mean exogenous shocks). Clearly, this is an extremely special case. In the real world, and in reasonable models, the transmission mechanism is too complex for intermediate variables in this sense to exist, that is, the transmission mechanism is not recursive in the above sense.[38]

Therefore, intermediate targeting in general, and monetary targeting in particular, is not a good monetary policy strategy. However, there is one exception to the general nonexistence of intermediate variables. As discussed in Svensson [90] and [96], one set of intermediate variables always exists, namely conditional forecasts. For any vector Y_t of target variables, we can write

$$Y_{t+\tau} = Y_{t+\tau|t} + \varepsilon_{t+1},$$

where $Y_{t+\tau|t}$ is a conditional forecast of $Y_{t+\tau}$, conditional on information available in period t, and ε_{t+1} is an error term uncorrelated with information in period t. Formally, conditional forecasts can be seen as intermediate variables, and forecast targeting can be seen as intermediate targeting. As King [60] stated early in the history of inflation targeting, inflation targeting means having inflation forecasts as intermediate targets.

[38] See Bryant [19], Friedman [45], Kalchbrenner and Tinsley [57] and Kareken, Muench and Wallace [58] for this and other arguments against intermediate targeting in general and monetary targeting in particular. See Rudebusch and Svensson [81] for simulations of monetary targeting in the U.S. with lessons for the Eurosystem. These simulations show that monetary targeting in the U.S. would be quite inefficient compared to flexible inflation targeting, in the sense of bringing higher variablility of both inflation and the output gap.

4 Lessons for the Eurosystem

4.1 Defining price stability

In its first announcement of its monetary-policy strategy, on October 13, 1998, the Eurosystem [35] stated:

> "Price stability shall be defined as a year-on-year increase in the Harmonised Index of Consumer Prices (HICP) for the euro area of below 2%."

Thus, only an upper bound of 2 percent was unambiguously announced. About a month later, the Eurosystem clarified that "increase" in this definition shall be interpreted as excluding deflation. This might seem to imply that the lower bound for inflation is zero. On the other hand, the Eurosystem also stated that it had *not* announced a lower bound, giving the reason that the size of any measurement bias in the HICP is not known. On December 1, 1998, the Eurosystem [36] announced a monetary reference value for M3 of 4.5 percent. Then, subtraction of the sum of its estimates of potential output growth and trend decline in velocity from 4.5 percent revealed that it had applied an inflation target of 1.5 percent. If this is the middle of an interval with an upper bound of 2 percent, that interval is obviously 1–2 percent. Hence, the Eurosystem seems to have implicitly announced a lower bound of 1 percent.

Clearly, observers should not have to piece together the definition from different statements, including the announcement of the reference value. Any remaining ambiguity with regard to the definition seems to serve no purpose. If the Eurosystem wants to to avoid misinterpretation and to provide a clear anchor for inflation expectations, it should replace the ambiguous and asymmetric statement "below 2%" and state an unambiguous and symmetric inflation target, say in the form of a point target of 1.5 percent or in the form of the interval 1–2 percent, possibly with the addendum that this definition may be somewhat modified when more evidence about the quality of the HICP becomes available. Absent such a statement, it seems that observers should currently interpret the Eurosystem as having an inflation target of 1.5 percent, and evaluate its policy accordingly.

As argued in section 2, it is by no means clear that interpreting price stability as an inflation target should be the final word, since that implies accepting a unit root and nonstationarity of the price level, making "price stability" a misnomer. After some 5 or 10 years of successful inflation targeting, the Eurosystem may want to seriously consider the pros and cons of moving to price-level targeting.

4.2 Maintaining price stability

In addition to the definition of price stability, on October 13, the Eurosystem announced what was later called the "two pillars" of its strategy, namely

- "a prominent role for money with a reference value for the growth of a monetary aggregate" and
- "a major role for a broadly-based assessment of the outlook for future price developments."[39]

With regard to the role of money, the Eurosystem has emphasized that the reference value should not be interpreted as an intermediate target for money growth. Indeed, it has rejected monetary targeting, on the grounds that the relationship between money and prices may not be sufficiently stable, and that it is not clear that the monetary aggregates with the most stable relationship is sufficiently controllable in the short run. As Issing [56] summarizes:

> "In these circumstances, relying on a pure monetary targeting strategy would constitute an unrealistic, and therefore misguided, commitment."

Instead, the Eurosystem plans to use money growth as an indicator of "risks to price stability," such that deviations of current money growth from the reference value signals risks to price stability.

> "The reference value will be derived in a manner that ensures, as far as possible, that deviations of monetary growth from the value will signal risks to price stability. In the first instance, such a deviation will prompt further analysis to identify and interpret the economic disturbance that caused the deviation, and evaluate whether the disturbance requires a policy move to counter risks to price stability." (Issing [56])

As I argue in some detail in Svensson [98], there is little ground for such a prominent role for money. It is easily shown in the simple and conventional model used there, that such a money-growth indicator will be a relatively useless indicator of risks to price stability and, indeed, mostly a noisy indicator of the deviation of current inflation from the inflation target. As argued in section 3.3, the weight on money as an indicator should be strictly determined by its predictive power in forecasting inflation. As argued in section 3.3.1 and demonstrated

[39] Since the first version of this paper was written, an extensive discussion and motivation of Eurosystem strategy has been presented by Angeloni, Gaspar and Tristani [2].

in some detail in Svensson [98], the best indicator of "risks to price stability" is an inflation forecast conditional for an unchanged interest rate.[40]

I believe it worthwhile to look more closely at the Eurosystem's arguments in favor of a prominent role to money, stated very clearly in Issing [56]. Three arguments for giving a prominent role for money are provided: (1) "Inflation is fundamentally monetary in origin over the longer term," (2) "It creates a firm 'nominal' anchor for monetary policy and therefore helps to stabilise private inflation expectations at longer horisons," and (3) "[It] emphasizes the responsibility of the ESCB for the monetary impulses to inflation, which a central bank can control more readily than inflation itself."

With regard to argument (1), it is based on the empirical high long-run correlation between money and prices. This correlation, however, holds in any model where demand for money is demand for real money, for instance in the simple model used in Svensson [98] to demonstrate the inferiority of the Eurosystem's money-growth indicator. The correlation is actually a relation between two endogenous variables, and says nothing about causality. The direction of causality is determined by the monetary policy pursued. Under strict monetary targeting, when the central bank aims at maintaining a given money growth rate regardless of what happens to prices, money growth becomes exogenous in the relation and causes inflation, which is endogenous. Under inflation targeting, when the central bank aims at maintaining a given inflation rate regardless of what happens to money, inflation becomes exogenous in the relation and causes money growth, which is endogenous. Hence, argument (1) is neutral to the monetary strategy.

With regard to argument (2), it seems that the definition of price stability provides the best nominal anchor and is the best stabilizer of inflation expectations. Emphasizing a second nominal anchor seems redundant and even misguided, since more than one nominal anchor could confuse, rather than stabilize, private expectations.

[40] Rudebusch and Svensson [81] examine monetary targeting in empirical model of inflation, output and money for U.S. data and draw some lessons for the Eurosystem. They find that monetary targeting would be a very inefficient compared to inflation targeting, in the sense of increasing the variability of both inflation and output. Counter to conventional wisdom, this is the case also if money-demand shocks are set to zero so the money demand is completely stable.

Gerlach and Svensson [47] examine the indicator properties of monetary aggregates for the euro area. Somewhat surprisingly, they find considerable empirical support for the so-called P^* model of Hallman, Porter and Small [52], adapted to Germany by Tödter and Reimers [107]. This implies that monetary aggregates, in the form of the "real money gap," the gap between current real balances and long-run equilibrium real balances, has considerable predictive power for future inflation. They find little or no empirical support for the Eurosystem's money-growth indicator, though.

Indeed, the theoretical analysis in Svensson [95] shows that the P^* model, although emphasizing the role of the real money gap in forecasting and controlling inflation, does not provide any support for a Bundesbank-style money-growth target or a Eurosystem-style money-growth indicator.

With regard to argument (3), it is not clear how "monetary impulses to inflation" can be defined in any unambiguous and useful way. I am not sure the argument means anything but monetary aggregates being easier to control than inflation. Furthermore, it seems obvious that the Maastricht Treaty does not assign "stability of monetary impulses to inflation" as the primary objective of the Eurosystem; it assigns "price stability," period.

Thus, the first pillar is unlikely to provide much support for the maintenance of price stability. Instead, this must to rely on the second pillar, the "broadly-based assessment of the outlook for future price developments." This is, of course, nothing but a long euphemism for inflation-forecast targeting. Indeed, I believe the success of the Eurosystem maintenance of price stability depends strongly on its learning to do forecast targeting, as practiced by an increasing number of inflation-targeting central banks.

Strangely enough, Eurosystem statements argue that inflation-forecast targeting would be unsuitable for the Eurosystem, on the grounds that forecasting inflation will be difficult and that the understanding of the transmission mechanism is imperfect. To quote Issing [56] further:[41]

> "In the uncertain environment likely to exist at the outset of Monetary Union, forecasting inflation will be difficult, not least because of the many conceptual, empirical and practical uncertainties faced by the ESCB at the start of Stage Three. Forecasting models estimated using historic data may not offer a reliable guide to the behaviour of the euro area economy under Monetary Union. Forecast uncertainty is likely to be relatively large.
>
> Forecasting inflation requires thorough knowledge of the properties of the new euro area-wide data series and experience and understanding of the transmission mechanism of monetary policy in the new euro area economy. Both are likely to be quite different from what we have been used to in the existing environment of eleven distinct national economies prior to Monetary Union."

Certainly, forecasting and forecast targeting will not be easy, and forecast uncertainty is likely to be relatively large. Nevertheless, forecasting is simply necessary, given "the need for monetary policy to have a forward-looking, medium-term orientation" that Issing and the Eurosystem emphasizes. Furthermore, forecast targeting implies using existing information in the most efficient and flexible way. It incorporates both model and extra-model information, allows judgemental adjustments, takes additive uncertainty for granted and even allows imperfect understanding of the transmission mechanism and model uncertainty, as I have tried to explain in this paper. Of course, the less the uncertainty and the better the understanding of the transmission mechanism, the more successful forecast targeting is likely to be. But this does not

[41] See also Angeloni, Gaspar and Tristani [2].

mean that there is some better way of maintaining price stability, if there is more uncertainty and less understanding of the transmission mechanism.[42]

5 Conclusions

This paper argues that forecast targeting is likely to be the best way of maintaining price stability, on the grounds that with lags and uncertainty in the transmission mechanism, forecast targeting is the most efficient and flexible way of using available information. By generalizing forecast targeting from mean forecast targeting to distribution forecast targeting, it should also be the best way of handling model uncertainty. Indeed, I believe the current best practice in central banks' maintaining price stability must be understood as forecast targeting.

The paper has, so far, only discussed the framework for policy decisions and not at all the central bank's communication, degree of transparency and degree of accountability. Under forecast targeting, the conditional forecasts for inflation and the output gap are the crucial inputs in the policy decision. Therefore, policy decisions are best explained and motivated, and policy is best understood and anticipated by the public, with reference to these conditional forecasts. This has the beneficial effect that any criticism of the policy must be more specific: for instance, is it the target or the central bank's forecast that is wrong? Furthermore, making these forecasts public provides the best opportunity for outside observers to monitor and evaluate the central bank's policy, and making sure that its decisions are consistent with its objective. Then policy can be evaluated almost in real time, without waiting some two years to see the outcome of an inflation rate that is, by then, contaminated by a number of intervening shocks. Finally, making the forecasts public provides the strongest incentives for the central bank to improve its competence and do the best possible job.

These are strong argument in favor of making these forecasts public, which practice is already followed by Reserve Bank of New Zealand, Bank of England, and Sveriges Riksbank. Against

[42] As I argue in Svensson [98], it may be sobering to recall that the introduction of inflation targeting in the United Kingdom, Sweden and Finland occurred under rather dramatic circumstances. The countries went through dramatic boom-bust experiences, very serious banking and financial-sector crises, and a dramatic sudden shift from a fixed exchange rate to a new monetary policy regime with a floating exchange rate. Furthermore, this occurred in a situation with very low credibility for monetary policy, with high and unstable inflation expectations, much above the announced inflation targets. At least for Sweden (where I am naturally more informed) the central bank's commitment to the fixed exchange rate was so strong, that there was no contingency planning. When the krona was floated in November 1992, the new inflation-targeting regime, which was announced in January 1993, had to be conceived from scratch (although, of course, with the benefit of the experiences mainly from New Zealand and Canada). It is not easy to rank difficulties and uncertainty about the transmission mechanism, but it seems to me that the difficulties facing the Eurosystem are still not of the same magnitude as the difficulties that the central banks of the United Kingdom, Sweden and Finland were facing. Since those central banks have, nevertheless, managed quite well, the odds for the Eurosystem may be quite good, provided it adopts a similar framework for policy decisions.

this background, the Eurosystem's refusal to publish its forecasts, citing far from convincing arguments,[43] is very difficult to understand, except perhaps as an expression of an initial lack of confidence and experience and a desire to further improve its competence before going public (but if so, why not announce that the forecasts will eventually be public?). I see no reason why the Eurosystem should not aim for the current best standard of transparency, as demonstrated by the mentioned central banks.

[43] See, for instance, Duisenberg [32]: "... publishing an inflation forecast would obscure rather than clarify what the Governing Council is actually doing. The public would be presented with a single number intended to summarise a thorough and comprehensive analysis of a wide range of indicator variables. However, such a summary would inevitably be simplistic. Moreover, because publishing a single inflation forecast would be likely to suggest that monetary policy reacts mechanistically to this forecast, publication might mislead the public and therefore run counter to the principle of clarity."

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