Optimal Inflation Targeting: Further Developments of Inflation Targeting

Lars E.O. Svensson
Princeton University, Centre for Economic Policy Research, and National Bureau of Economic Research

Inflation targeting was first introduced in 1990, in New Zealand. Since then it has been adopted by more than twenty countries. This period of fifteen years has seen major progress in practical monetary policy. In particular, the practice of inflation targeting has led to a more systematic and consistent internal decision process (Brash, 2000; Sims, 2002; Svensson 2001a); much more transparent communication with the private sector (Blinder and others, 2001; Fracasso, Genberg, and Wyplosz, 2003; Leeper, 2003); and an unprecedented degree of accountability. The monetary and real stability achieved is exceptional from a historical perspective (King, 2002).

Given this progress, many might think that further improvement is hardly possible, and that monetary policy bliss, or something very close to it, may have been reached. I believe that there is still room for further development and improvement, even though past achievements by inflation-targeting central banks have been very impressive. This paper provides a very selective discussion of points on which I believe further improvements are both possible and desirable.

Good inflation targeting shares these characteristics:

- An explicit monetary policy objective in the form of a numerical inflation target, now with an increasingly explicit concern not

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only about stability of inflation around the target but also about stability of the real economy. The target variables under inflation targeting include both inflation and a real variable, such as the output gap.[1]

- An internal decision process—"forecast targeting"—in which projections of the target variables have a prominent role and the central bank sets the instrument rate such that the forecast of the target variables "looks good" relative to the monetary policy objective.[2]
- A very high degree of transparency and accountability, with the central bank typically publishing its internal projections and providing detailed motivations of them and of its instrument-rate decisions, in order to both implement the policy effectively and allow detailed external scrutiny of the bank's performance.

I believe that further improvements are possible and desirable on all three points. With regard to the first point, the monetary policy objective—that is, the inclusion of not only an inflation stability objective but also an objective of stabilizing the real economy—has been called "flexible" inflation targeting.[3] Inflation-targeting central banks normally acknowledge in different ways that they are flexible inflation targeters.[4] However, they are not very explicit and transparent and probably not very consistent about the relative weight they attach to stability of variables other than inflation. They may not be very consistent about intertemporal substitution between the target variables either. Some refer to a fixed horizon, such as eight quarters, by which the inflation target shall be met, but a fixed horizon is easily shown not to be appropriate for most circumstances (Faust and Henderson, 2004). I believe specifying operational objectives in terms of an explicit intertemporal loss function—initially for internal use within the central bank, later, after a trial period, to be published—is an easy way to make substantial progress in this regard.

1. By *target variables*, I mean the variables that are arguments of the central bank's explicit or implicit loss function.

2. By *instrument rate*, I mean the short-term nominal interest rate that the central bank is using as an instrument or operating target.

3. The terms *flexible* and *strict* inflation targeting were to my knowledge first introduced in a paper of mine presented at a conference at the Bank of Portugal in 1996, later published as Svensson (1999).

4. Norges Bank (the Bank of Norway) is a model of transparency in this respect (and many others): Each Inflation Report contains the statement "Norges Bank operates a flexible inflation targeting regime, so that weight is given to both variability in inflation and variability in output and employment." Norges Bank also puts the inflation forecast and the output gap forecast in the same graph, in order to emphasize both.

With regard to the second point, the internal decision process, the instrument-rate assumption under which projections of the target variables are made has received considerable attention. Several central banks have used the assumption of a constant instrument rate during the entire forecast horizon. This assumption is very problematic for several reasons (see Archer, 2004; 2005; Bean, 2003; Goodhart, 2001; Heikensten, 2005; Honkapohja and Mitra, 2005; Leitemo, 2003; Lomax, 2005; Svensson, 2003a; Woodford, 2005). A few central banks have shifted to the assumption of an instrument-rate path given by market expectations of future instrument rates. This is a considerable improvement but is arguably not the best alternative.

Furthermore, central banks normally make explicit decisions and announcements only about the current instrument rate (the instrument rate for the next month or two) and its level during the period until the next monetary policy decision. However, the current instrument rate matters very little for the central banks' internal projections. What matters for those projections is the entire instrument-rate path assumed.

Similarly, the current instrument rate matters very little for private sector decisions and the economy. What matter are private sector expectations about the entire future path of the instrument rate. These expectations feed into the yield curve and thereby longer-term interest rates and asset prices, which do affect private sector decisions. The current central bank decision and announcement actually matter only to the degree that they affect private sector expectations of the path of future instrument rates. This means that when the central bank decides on a particular current instrument-rate level, it implicitly decides on and announces an expected future instrument-rate path, an instrument-rate plan. For these reasons I believe that substantial progress can be made if central banks explicitly think in terms of entire instrument-rate plans and corresponding projections of target variables and develop a decision process in which the central bank explicitly chooses such an instrument plan. Indeed, the decision process should be designed so as to end with an optimal instrument-rate plan and a corresponding optimal projection of the target variables—a projection of the instrument rate and the target variables that minimizes the central bank's loss function.

With regard to the third point, the high degree of transparency and accountability, inflation-targeting central banks typically publish their internal projections of their target variables (although some may publish projections of output or output growth rather than the output gap). Since these projections are normally based on an assumed instrument-rate path that differs from the optimal instrument-rate plan (especially if there is no explicit optimal instrument-rate plan), the resulting projections are not the best forecasts, in the sense of minimizing expected squared forecast errors. The projections are biased one way or another. Hence they are not the best information for the private sector. Since monetary policy has an impact on the economy via the private sector expectations of inflation, output, and interest rates that it gives rise to, announcing the optimal projection (including the instrument-rate projection) and the analysis behind it would have the greatest impact on private sector expectations and be the most effective way to implement monetary policy. Since the optimal projection is the best forecast, in the sense of minimizing expected squared forecast errors, it also provides the private sector with the best aggregate information for making individual decisions. Announcing the optimal projection also allows the most precise and sophisticated external evaluation of the monetary policy framework and decisions. For these reasons I believe that substantial progress can be made if inflation-targeting central banks publish and explain optimal projections, including the optimal instrument-rate plan. The Reserve Bank of New Zealand has been doing this since 1997; Norges Bank, the central bank of Norway, has been doing so since 2005.

In short, I believe that inflation-targeting central banks can make substantial progress by being more specific, systematic, and transparent about their operational objectives (by using an explicit intertemporal loss function), their forecasts (by deciding on optimal projections of the instrument rate and the target variables), and their communication (by announcing optimal projections of the instrument rate and target variables).

Substantial progress can also be made regarding the systematic use of central bank judgment—that is, information, knowledge, and views beyond the scope of a particular model. Although formal models are very useful in practical monetary policy, they are drastic simplifications of a complex economy. Judgment will always be necessary. The challenge is to apply good judgment in a disciplined and systematic way rather than in a completely discretionary and ad hoc way. Svensson (2005b) discusses in greater detail how central bank judgment can be incorporated into optimal projections in a consistent way. Svensson and Tetlow (2005) describe a practical way to do so, the method of optimal policy projections, which is to some extent in use at the Federal Reserve Board.

Monetary policy is always conducted under substantial uncertainty. As long as the uncertainty is mainly in the form of exogenous additive shocks, the combination of linear models and quadratic loss functions implies that certainty equivalence holds and that projections in the form of probability means are sufficient for optimal policy. When certainty equivalence is violated—for instance, because the uncertainty is multiplicative and not just additive—mean projections are no longer sufficient for optimal policy. In this case the entire probability distribution of future random target variables matters. Svensson and Williams (2005) develop a flexible and powerful but still tractable framework for optimal monetary policy under quite general form model uncertainty that allows simple multiplicative uncertainty as well as more complex structural model uncertainty. Although certainty equivalence is violated, forecast targeting can still be undertaken, with the projections probability distributions rather than mean projections. The decision process can then be seen as distribution forecast targeting rather than mean forecast targeting.[5] A systematic approach to model uncertainty and distribution forecast targeting is another area in which substantial progress in inflation targeting can be made.

The next section discusses how an explicit intertemporal loss function can be introduced and used by a central bank. Section 2 discusses the instrument-rate assumption. Section 3 discusses transparency and communication issues. Section 4 discusses how central bank judgment can be incorporated in a systematic way. Section 5 discusses model uncertainty and distribution forecast targeting. Section 6 briefly examines optimization under commitment, the timeless perspective, and discretion. Section 7 briefly examines the output gap, the potential output, the interest-rate gap, and the neutral interest rate. Section 8 presents some conclusions. The appendix contains technical material on the loss function and the interest-rate gap.

1. The Loss Function

All real world inflation targeting is flexible. Flexible inflation targeting means that monetary policy objectives include not only stability of inflation around the inflation target but also stability of the real economy, such as the stability of the output gap.[6]

5. The terms mean forecast targeting and distribution forecast targeting were, to my knowledge, introduced in Svensson (2001b).

6. " Strict" inflation targeting, when the central bank is concerned exclusively about inflation, is an abstraction that is sometimes used in pedagogical examples.

Although inflation-targeting central banks normally acknowledge that they are flexible inflation targeters, they are normally not very explicit or transparent—and probably not very consistent— about the relative weights they attach to the stability of variables other than inflation. They may not be very consistent about the intertemporal substitution between the target variables either. Some central bankers refer to a fixed horizon, such as eight quarters, over which the inflation target shall be met, but a fixed horizon is easily shown to be inappropriate for most circumstances (Faust and Henderson, 2004). Some state that they have a medium-term objective, without specifying what this means.

The most direct way to resolve this ambiguity and lack of transparency is to specify an explicit intertemporal loss function as the operational objective for the central bank. This clarifies what the target variables are and what relative weights they have. It clarifies both intra- and intertemporal substitution between levels and stability of the target variables and allows an unambiguous ranking of alternative projections of the target variables.

Flexible inflation targeting implies that the central bank is not concerned exclusively about stabilizing inflation around the inflation target but is also concerned with the stability of the real economy, as represented by the output gap, the employment gap, or the unemployment gap.[7] This can conveniently be expressed as a conventional quadratic loss function,

$$L_t \equiv (\pi_t - \pi^*)^2 + \lambda x_t^2, \tag{1}$$

where L_t denotes the period loss in period t (where the period may be a quarter, for instance); π_t denotes a measure of inflation in period t; π^* denotes the inflation target; x_t denotes a measure of the output gap in period t; and $\lambda > 0$ denotes the relative weight on output-gap stabilization relative to inflation stabilization.[8] The central bank may also be concerned about the variability of instrument-rate changes or exchange-rate changes, which would correspond to additional terms $\lambda_{\Delta i}(i_t - i_{t-1})^2$ or $\lambda_{\Delta i}(s_t - s_{t-1})^2$, where i_t denotes the instrument rate

7. I use the output gap (the difference between output and potential output) as the generic variable representing the business cycle status of the economy. The unconditional mean of the output gap is taken to be zero.

8. The index of inflation, π_t, can be quarterly inflation, four-quarter inflation, or an average of inflation over a longer period (Nessén and Vestin, 2005).

and s_t denotes the (log) exchange rate in period t. In this case the instrument rate or the exchange rate are also target variables.[9]

The corresponding intertemporal loss function in period t can then be written as the sum of current and expected discounted future losses,

$$\mathrm{E}_t \sum_{\tau=0}^{\infty} \delta^{\tau} L_{t+\tau}, \tag{2}$$

where E_t denotes central bank expectations conditional on information available in period t and δ is a discount factor that fulfills $0 < \delta \leq 1$.[10] Whereas the period loss function and the weight λ express the substitution between inflation and output-gap variability within a given period, the intertemporal loss function and the discount factor δ express the substitution between expected losses in different periods.

Let $\pi_{t+\tau,t}$ and $x_{t+\tau,t}$ for $\tau \geq 0$ denote (mean) projections in period t of inflation and the output gap τ periods ahead, respectively, and let $\pi^t \equiv (\pi_{t,t}, \pi_{t+1,t}, \ldots)$ and $x^t \equiv (x_{t,t}, x_{t+1,t}, \ldots)$ denote (mean) projections in period t of the current and future inflation and output gaps, respectively. That is, $\pi_{t+\tau,t}$ and $x_{t+\tau,t}$ denote the projection in period t of inflation and the output gap in period $t + \tau$, whereas π^t and x^t denote the entire projection paths of current and future inflation and output gap.

Let $L_{t+\tau,t}$ denote the period loss associated in period t with the projections $\pi_{t+\tau,t}$ and $x_{t+\tau,t}$ of inflation and the output gap for period $t + \tau$,

$$L_{t+\tau,t} \equiv (\pi_{t+\tau,t} - \pi^*)^2 + \lambda x_{t+\tau,t}^2, \tag{3}$$

and let $\mathcal{L}(\pi^t, x^t)$ denote the intertemporal loss associated in period t with the entire projection paths π^t and x^t of inflation and output gap,

$$\mathcal{L}(\pi^t, x^t) = \sum_{\tau=0}^{\infty} \delta^{\tau} L_{t+\tau,t} \,. \tag{4}$$

Once the two parameters δ and λ have been determined, the intertemporal loss function $\mathcal{L}(\pi^t, x^t)$ provides a convenient and consistent way to rank different inflation and output-gap projections. Suppose that the central bank staff presents the monetary policy committee with two different instrument-rate plans, which result in

9. Rudebusch (2005) surveys recent work on instrument-rate smoothing. Woodford (2003) and Svensson (2003c) provide further discussion of interest rates as target variables.

10. When $\delta = 1$, the loss function (2) should be interpreted as the limit (from below) $\lim_{\delta \to 1} (1 - \delta) E_t \sum_{\tau=0}^{\infty} \delta^{\tau} L_{t+\tau}$ in order to ensure convergence (see appendix).

two different projections of inflation and the output gap.[11] Suppose that the first instrument-rate plan results in the projection (π^{t1}, x^{t1}) and that the second instrument-rate plan results in the projection (π^{t2}, x^{t2}). Which instrument plan should the monetary policy committee choose? If the parameters δ and λ correspond to the monetary policy committee's preferences, it should simply choose the instrument plan that results in the inflation and output-gap projection with the lowest loss. Suppose that $\mathcal{L}(\pi^{t1}, x^{t1}) < \mathcal{L}(\pi^{t2}, x^{t2})$. Then the monetary policy committee should choose the first instrument-rate plan and associated inflation and output projections.

How can the monetary policy committee determine the parameters δ and λ? A discount factor δ equal to one implies that the loss in future periods has the same weight as current losses. My guess is that most committee members would agree that a discount factor equal to or close to one is appropriate, given the frequent emphasis on the medium and long run and a desire to avoid myopia. Then only λ remains to be determined.

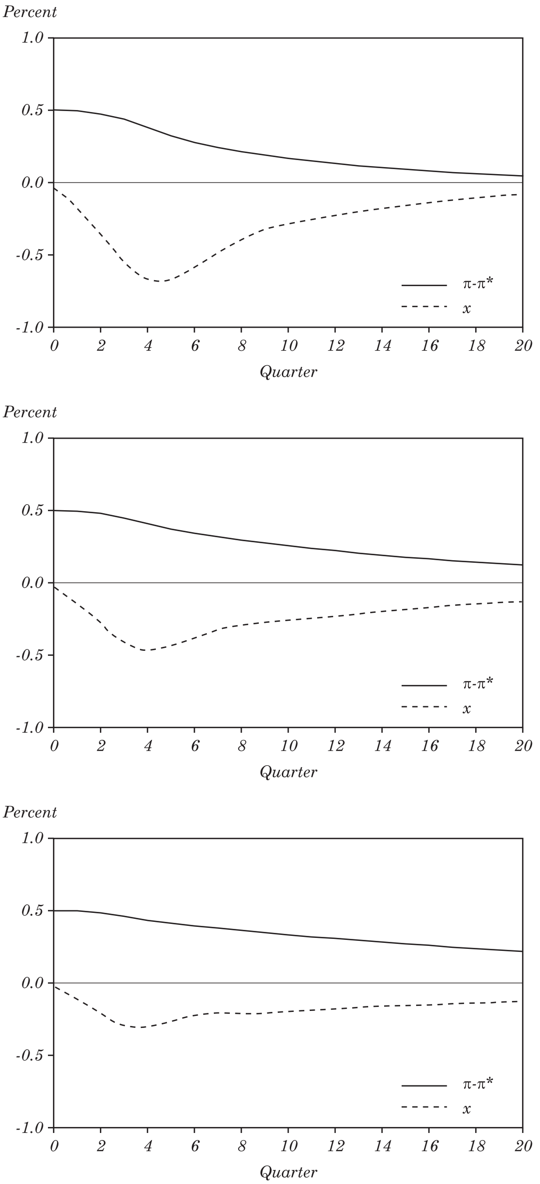
The monetary policy committee can determine λ explicitly or implicitly in several ways. It can determine λ explicitly by majority voting. In this case, by the median voter theorem, the resulting λ will be the median of the distribution of the committee members' individual λs. This is a convenient and practical way of aggregating the committee members' preferences. Majority voting has the general advantage that single extreme views do not affect the outcome, since outliers normally do not affect the median.

If committee members need help determining their individual λs, the λs can be determined implicitly through revealed preference experiments. For instance, suppose a committee member chooses the preferred combination of inflation and output-gap projections among a few alternatives. This choice then reveals the range of implicit λs for which that choice is preferred. Suppose that committee members are presented with the three alternative combinations of inflation gap and output-gap projections shown in figure 1 (where the inflation gap is the deviation from a fixed inflation target) and asked to choose the alternative they prefer. This choice would narrow the range of λs consistent with their choice.[12]

11. I use *monetary policy committee* as the generic term for the monetary policy decisionmaking body of the central bank, including when the bank has a single decisionmaker.

12. The figures are plotted for the Rudebusch-Svensson model in Svensson (2005b), with the same initial situation of a steady zero output gap, a steady 0.5 percentage point inflation gap, and three different values of λ. For two given policy alternatives, (π^{t1}, x^{t1}) and (π^{t2}, x^{t2}), if the monetary policy committee prefers one alternative, one can determine the range of λs for which that alternative gives lower intertemporal loss.

Figure 1. Projected Inflation and Output Gaps Given Alternative Weights on Output-Gap Stabilization



Source: Svensson (2005b).
Note: The solid line shows the inflation gap ($\pi - \pi^*$). The dashed line shows the output gap (x).

The λ can also be determined implicitly over time, revealed by the policy decisions the committee makes. To many committee members, this may be the most natural way to determine λ. If the central bank staff present the monetary policy committee with a few policy alternatives at each decision point (where each policy alternative consists of an inflation path, an output-gap path, and an interest rate path), the selected policy alternatives will over time narrow the range of λs consistent with the committee's decisions. It will also reveal whether the λs seem to be constant over time or time varying.

If the central bank puts weight on instrument-rate smoothing or exchange rate smoothing, the parameters $\lambda_{\Delta i}$ and $\lambda_{\Delta s}$ also need to be determined. If the committee members do not agree that the discount factor δ is equal to unity, they can vote about the discount factor, too, in which case the resulting discount factor will be the median of their individual discount factors.

Using an explicit intertemporal loss function such as (4) has several advantages:

- An explicit intertemporal loss function clarifies what the target variables are and resolves in an unambiguous way the intra- and intertemporal substitution between them. One projection of inflation and the output gap may have a negative output gap in the near future and lower inflation in the more distant future, whereas another may have a less negative output gap in the near future and higher inflation in the more distant future. The intertemporal loss function provides a consistent ranking of the two projections. The loss function makes clear that the entire projection path of the target variables matters, not just the projections at some particular horizon. It thus avoids the tendency to put weight on a particular horizon, such as eight quarters (see Faust and Henderson, 2004 and Heikensten, 1999).
- A loss function clarifies the unnecessary and unhelpful distinction between a "dual" and a "hierarchical" mandate (see Meyer, 2004 and Svensson, 2004); removes any ambiguity about the degree of flexibility in inflation targeting (for instance, in the debate on inflation targeting for the Federal Reserve; Kohn, 2003), and clarifies the appropriate role of asset prices and concerns about bubbles in inflation targeting (Bean, 2003).
- The monetary policy committee has to make choices between different projection combinations in any case; using an intertemporal loss function avoids other inconsistent and ad hoc ways of making such choices.

- It is important to realize that a loss function does not require that projections be made with a model; the loss function can be used to rank purely judgmental projections.
- The loss function can be seen as a necessary operational interpretation of a legislative mandate or government instruction, which is usually too vague to provide precise guidance to consistent policy in particular policy situations. Such an operational interpretation is already needed for the inflation target in some countries (such as Sweden and countries in the euro zone), where the institutional arrangement for monetary policy leaves the central bank in charge of deciding on the number and index for the inflation target.
- The parameters of the loss function have clear intuitive meaning. The discount factor δ represents the substitution between period losses in different periods: the weight of a period loss in one period relative to the period loss one period earlier. The weight λ can be interpreted as the weight on variability of the output gap relative to variability of inflation, so $\lambda = 1$ implies that the monetary policy committee is equally concerned with the variability of the output gap as with the variability of inflation (see the appendix).
- The monetary policy committee can add any target variables that it is concerned about with corresponding weights. Thus, it can include instrument-rate and/or exchange-rate smoothing and/or stabilization; unemployment-gap stabilization; or output-growth gap stabilization. (Mentioning these possibilities does not imply that I endorse them.)
- The monetary policy committee can use a loss function of other forms than the quadratic if it believes another loss function better represents its objectives.[13] (However, the quadratic loss function has many advantages. It can be seen as a second-order approximation to a more general loss function, its symmetry seems natural in an era in which both inflation and deflation are undesirable, and it is easy to use in optimization exercises.)
- If the monetary policy committee would prefer not to specify a loss function for some time, the staff can still provide it with optimal projections for a reasonable set of alternative parameters of the loss function. This set of optimal projections for different parameters then forms the set of efficient feasible projections from

13. Bray and Goodhart (2002) and Svensson (2003b) discuss other functional forms. Ruge-Murcia (2003) discusses inflation targeting with asymmetric preferences.

which the monetary policy committee should choose its preferred alternative.

- The monetary policy committee can experiment with internal uses of alternative loss functions and go public about any loss function at a later stage, when it has decided which loss function to use and the approach has proved useful.
- Eventually going public about the loss function will increase the transparency of monetary policy, improve precision and consistency in the evaluation of monetary policy, and increase accountability. It may also bring better public understanding of the substitutions and tradeoffs involved.

Consequently, I believe that specifying operational objectives in terms of an explicit intertemporal loss function is an easy way to significantly improve inflation targeting.[14]

2. The Instrument-Rate Projection

Because of lags in the transmission mechanism between monetary policy actions and effects on the economy and the target variables, good monetary policy must be forward looking and rely on projections of the target variables. Before it makes its instrument-rate decision, the monetary policy committee is normally presented with a number of alternative projections of the target variables,

14. Mishkin (2004) summarizes his arguments against central banks announcing a loss function—and implicitly also against central banks using one. (My counterarguments in parentheses.) Argument: It may be difficult for monetary policy committee members to specify a loss function, let alone to agree on a loss function. (I have already mentioned simple procedures to specify and agree on a loss function.) Argument: It is far from clear who should decide on the loss function. (The loss function can always be seen as a necessary operationalization of the central bank's mandate.) Argument: It may be difficult to communicate a loss function to the public. (Even a very precise statement like "a weight on output gap stabilization equal to half the weight on inflation stabilization" does not seem incomprehensible for an educated general public.) Argument: Announcing a positive weight on output gap stabilization may lead to more aggressive private sector price and wage increases. (There is no evidence of such increases after Norges Bank became more explicit about output gap stability, and Norway has powerful trade unions!) Argument: Announcing a positive weight on output gap stabilization will require the central bank to publish estimates of the output gap and potential output, and a conceptually correct estimation of potential output is difficult. (True, but such estimation is necessary for good policy. Difficulty is not a good argument in this context. It is difficult to provide inflation forecasts. This is no longer—if it ever was—a valid argument against publishing them. Before the introduction of inflation targeting in New Zealand, I am sure almost every central banker thought that the current standard of transparency would be impossible to achieve, and many probably thought it would be potentially harmful even if it could be achieved.)

conditional on alternative assumptions about the state of the economy, the development of various exogenous variables, the transmission mechanism, and so forth. These projections are conditional on some assumption about the instrument-rate path.

The decision process results in a decision about the level of the instrument rate for the immediate future. Implicitly or explicitly, however, this decision is actually about an instrument-rate plan. The optimal instrument-rate plan is the plan that results in an optimal projection of the target variables, the projection that minimizes the intertemporal loss function. This projection is also the best forecast, in the sense of minimizing expected squared forecast errors.[15]

2.1 The Instrument-Rate Assumption Underlying Projections of the Target Variables

Traditionally, several inflation-targeting central banks have used projections based on an assumption of a constant instrument rate over the forecast horizon. If, everything else equal, the inflation projection is higher (lower) than the inflation target at some given horizon, usually about eight quarters, this has been interpreted as indicating that sooner or later the instrument rate needs to be raised (lowered).

There are numerous problems with the constant instrument-rate assumption.[16] These include:

- A constant instrument rate is often unrealistic. This implies that the resulting projection of inflation and the output gap is unrealistic and not the best forecast of future inflation and the output gap. This in turn makes it difficult and misleading to compare these

15. I use the following terminology: *Feasible projections* (or the set of feasible projections) are the (mean) projections of the instrument rate and the target variables that are consistent with the central bank's information, more specifically, its estimate of the state of the economy, view of the transmission mechanism, and forecast of exogenous variables. The *optimal projection* is the central bank's preferred feasible projection of the instrument rate and the target variables—that is, the feasible projection that best achieves the central bank's objective. More specifically, the optimal projection is the feasible projection that minimizes the central bank's intertemporal loss function. The best forecast is the projection that best predicts the actual future path of the variables in question, more precisely, the projection that minimizes expected squared forecast errors. A *conditional forecast* is a projection that minimizes expected squared forecast errors subject to some particular assumption, such as a particular path of the instrument rate. The *unconditional forecast* is the best projection given available information, including information about monetary policy. The unconditional forecast is the best forecast.

16. See Archer (2004, 2005); Bean (2004); Goodhart (2001); Heikensten (2005); Honkapohja and Mitra (2005); Leitemo (2003); Lomax (2005); Svensson (2003a); and Woodford (2005) for discussions of these problems.

projections to those of other forecasters, which normally assume more realistic underlying instrument-rate paths. It also makes it difficult and misleading to compare the projections to actual outcomes and in this way to assess the forecast performance of the central bank.

- A constant instrument rate often differs from market expectations of future interest rates. Current asset prices (exchange rates, stock market prices, bond prices, housing prices, and so forth) depend on these market expectations. Typically, the current market prices of these assets are used as inputs in central bank projections rather than the hypothetical asset prices that would result if market participants actually expected a constant instrument rate. Hence the central bank projections end up using many inputs that are inconsistent with the constant instrument rate, making the projections inherently inconsistent and misleading. Put differently, they are not consistent constant instrument-rate projections but a mixture of projections based partly on the constant instrument rate, partly on market expectations of future interest rates.
- When market expectations of future interest rates differ from the constant instrument rate, central banks typically would not like market expectations of future interest rates to adjust toward the constant instrument rate. If that happens, it may result in drastic and unwelcome changes in asset prices. Hence central banks using constant instrument-rate projections would normally not like the private sector to take the constant instrument-rate assumption seriously.
- For a constant instrument rate, most projection models are unstable, and the inflation and output-gap projections tend to increase or decrease at an increasing rate with a longer horizon, making longer-term projections more or less useless. This has induced central banks to avoid plotting such projections for longer horizons, in order not to display the problems with constant instrument-rate projections too openly. Projection models with forward-looking variables are normally not even determinate for a constant instrument rate. Determinacy is restored by the assumed shift to some endogenous instrument setting in the form of an ad hoc reaction function beyond the forecast horizon. That shift is often associated with a drastic and awkward jump in the instrument rate, and the projection for shorter horizons depends on the assumed future endogenous policy. Alternatively, the projection model assumes that the instrument rate follows some determinacy-

inducing ad hoc reaction function, but unanticipated shocks to the instrument rate make it constant for many quarters.[17]

For these reasons the constant instrument-rate assumption for projections is inherently problematic and confusing. Since there are better alternatives, it should be abandoned sooner rather than later. Several central banks, including Norges Bank, the Bank of England, Sveriges Riksbank, and the European Central Bank, have abandoned the constant instrument-rate assumption. The Reserve Bank of New Zealand has used projections based on a time-varying instrument rate since 1997.

A first alternative to a constant instrument rate is market expectations of future instrument rates, normally identified with forward interest rates implied by the yield curve. The Bank of England, the Riksbank, and the European Central Bank use market expectations of future interest rates for their projections. Market expectations of future interest rates are usually more realistic than the constant instrument rate, depending on the market's understanding and prediction of future instrument-rate decisions. This makes projections based on them better forecasts of future instrument-rate decisions than constant instrument-rate projections. Moreover, since current asset prices are conditional on market expectations of future interest rates, using current asset prices as inputs in the projections does not cause any apparent inconsistency, in contrast to the case for constant instrument-rate projections.

Using market expectations of future interest rates may be problematic, however, if these expectations are peculiar in some way or deviate substantially from the central bank's preferred instrument plan—a situation that would indicate either a credibility problem or differences between the private sector's and the central bank's views of the state of the economy or the transmission mechanism. In such situations the central bank may want to use ad hoc adjustments of the instrument-rate projection implied by market expectations of future interest rates. Furthermore, market expectations of future interest rates would not normally be identical to the central bank's explicit or implicit instrument plan; the projections based on them would therefore normally not be the best forecast, the forecast that minimizes

17. See Leeper and Zha (forthcoming) for a formalization of this idea with an estimated reaction function. In practice the shocks are assumed to be unanticipated and not to affect market expectations, although they will be serially correlated for many quarters.

expected squared forecast errors.[18] Woodford (2005) provides more detailed criticism of market expectations of future interest rates.[19]

A second alternative for the instrument-rate assumption is an ad hoc reaction function for the instrument rate, such as a Taylor-type rule. Such an assumption results in projections in which inflation eventually approaches the inflation target and the output gap eventually approaches zero. The resulting instrument-rate projections will generally differ from market expectations of future interest rates. (To the extent that the projections are published and interpreted by the private sector as good forecasts of future instrument rates, they may bring market expectations of future interest rates closer to that instrument-rate projection.) The resulting projections of the target variables will generally not minimize an intertemporal loss function, and there is no reason why the instrument-rate projections will be good forecasts of the central bank's actual instrument-rate setting. The resulting projections are to some extent arbitrary.[20] However, if the reaction function used is an estimate of previous policy by the central bank, the resulting projections can be interpreted as those

18. Although private sector expectations are a natural and important input in central bank projections, it is important that they be only one set of inputs among many and that the central bank does not respond mechanically to private sector expectations that in turn depend on the central bank's response. As Woodford (1994) and Bernanke and Woodford (1997) show, a mindless and mechanical response to private sector expectations may lead to indeterminacy and a loss of the nominal anchor.

19. One particular problem emphasized by Woodford (1994) is that an exogenous instrument-rate path—whether it is constant, given by market expectations, or the optimal path—may imply multiple or unstable equilibria in models with forward-looking variables. The technical reason for such a problem is that the set of reduced-form eigenvalues violates the so-called saddlepoint property, namely that the set of eigenvalues with modulus above unity must be exactly equal to the number of nonpredetermined variables. The usual solution to this problem is to specify a reduced-form reaction function in which the instrument rate responds to endogenous variables and the corresponding reduced-form eigenvalues satisfy the saddlepoint property. However, as Svensson and Woodford (2005) show, any such exogenous instrument-rate path can be combined with a commitment to a specific "out-of-equilibrium" response by the central bank to restore a unique and stable equilibrium. For instance, if inflation deviates ex post from and exceeds the equilibrium value consistent with the instrument-rate projection, the instrument rate would be increased more than one-to-one with inflation. More generally, these out-of-equilibrium commitments can be constructed in the form of an instrument-rate response to violations of the first-order condition for optimal policy, the optimal targeting rule. This can be done so that the right reduced-form eigenvalue configuration is created. In this case, in equilibrium no out-of-equilibrium response will be observed, and the instrument rate and the equilibrium will be consistent with the exogenous instrument-rate path.

20. See Svensson (2003a) for a more general critique of simple instrument rules such as Taylor rules.

resulting from “policy as usual” (Berg, Jansson, and Vredin, 2004; Jansson and Vredin, 2003). Essentially, the projections would be analogous to vector autoregression forecasts.[21] The Reserve Bank of New Zealand uses an ad hoc reaction function in its forecast and policy system (discussed in Archer, 2004, 2005; Svensson, 2001a). However, the resulting instrument-rate path is subject to considerable adjustment that reflects judgment and policy preferences and makes it for practical purposes similar to an optimal instrument-rate plan (Archer, 2005).[22]

A third alternative is to use optimal instrument-rate projections, that is, instrument-rate projections for which the resulting projections of the target variables minimize an intertemporal loss function. The staff can present optimal projections of target variables and the instrument rate for alternative parameter values of the loss function and alternative scenarios. This can be done in several ways, incorporating judgment, as discussed in Svensson (2005b). Svensson and Tetlow (2005) describe the method of optimal policy projections, a variant of which is being used by the Federal Reserve Board.[23] If the monetary policy committee agrees on an intertemporal loss function, the staff can present it with optimal projections for that loss function for different scenarios (different assumptions about the state of the economy, forecasts of exogenous variables, and the transmission mechanism, for instance). If the monetary policy committee does not agree on a loss function or does not use a particular loss function, the staff can still present the relevant tradeoffs for different policy choices—the set of efficient feasible projections—by presenting projections for a few different parameters of the loss function. If the monetary policy committee chooses policy in line with this, the resulting projection will be the best forecast, in the sense of minimizing expected squared forecast errors.

As mentioned, since 1997 the Reserve Bank of New Zealand has relied on a time-varying instrument-rate projection that can be interpreted as an optimal instrument-rate projection. Norges Bank first published a time-varying instrument-rate projection that can be interpreted as an optimal instrument-rate path in March 2005. The

21. Blinder (2006) suggests using an empirical reaction function.

22. The particular reaction function used before any judgmental and policy adjustments, a variant of a so-called forecast-based Taylor rule originating with Bank of Canada’s quarterly projection model, has some particular problems, discussed in Svensson (2001c).

23. By central bank judgment, I mean information, knowledge, and views beyond the scope of a particular model.

presentation of optimal projections of inflation, the output gap, the exchange rate, and the interest rate has been refined, with fan charts, extensive discussion, and cross-checking, in consecutive inflation reports (see Qvigstad, 2005 and Svensson, 2005a for a discussion of the Norwegian example).

2.2 The Instrument-Rate Decision

The assumption about the current instrument rate matters very little for the central bank's projections. What matters is the assumption about the entire future instrument-rate path. Similarly, the current instrument rate matters very little for private sector economic decisions. What matters is the private sector expectations about future instrument rates. These expectations feed into the yield curve and affect longer-term interest rates and asset prices, which do affect private sector decisions.

The current instrument rate and central bank announcement have an effect on the economy essentially only through the private sector expectations they give rise to about future instrument rates and future inflation and output. Indeed, it is paradoxical that so much attention and discussion is focused on current instrument-rate settings and levels, when what matter are the related plans and expectations about future instrument rates. As is becoming increasingly well known, and as Woodford (2004) and Svensson and Woodford (2005) emphasize, modern monetary policy is essentially the management of private sector expectations.

Since the current instrument rate has very little importance and it is the entire future instrument-rate path that matters, explicitly or implicitly the central bank instrument decision is really a decision about the future path of the instrument rate, about an instrument-rate plan. To some extent this is becoming increasingly recognized. A good example is the increased attention paid to some key words in Federal Open Market Committee statements (www.federalreserve.gov/fomc/) indicating future instrument-rate setting: "policy accommodation can be maintained for a *considerable period*," "[the Committee] can be *patient* in removing its policy accommodation," and "policy accommodation can be removed at a *pace that is likely to be measured*"(italics added).[24]

24. Imagine how much more transparent this communication would have been if the Federal Open Market Committee instead had plotted an instrument-rate projection, as the Reserve Bank of New Zealand and Norges Bank are already doing.

My conclusion from this is that central banks should be more specific, systematic, and transparent about instrument-rate paths and plans. Since the decision about the instrument rate is in effect a decision about the instrument-rate path, it is better that this be explicitly acknowledged. Maintaining that the decision is one about the current instrument-rate levels alone is both misdirected and misleading. Indeed, throughout the decision process, it should be natural to think in terms of alternative instrument-rate paths and plans, not about the instrument rate during the next month or two. Similarly, it should be natural to think in terms of entire projection paths of future target variables, not just the current level, the target variables, or the projection at some particular horizon, such as eight quarters. Furthermore, the discussion of the intertemporal loss function above makes clear that the loss function induces a ranking of entire projection paths, not projections at particular horizons. Indeed, the monetary policy transmission mechanism should be seen as a mapping from an instrument-rate path to target variable paths, not as a mapping from an instrument-rate level to a level of the target variables at some particular horizon.

Goodhart (2001, 2005) and Mishkin (2004) argue that it is too difficult for a monetary policy committee to agree on a path (a sequence of numbers) rather than a current instrument-rate decision (a single number). I argue that doing so is neither necessary nor too difficult and that it is already being done. Monetary policy committees all over the globe decide on projections of inflation and output all the time. Projections are paths, sequences of numbers. Why would there be a big difference between agreeing on an instrument-rate path and an inflation path? Moreover, some central banks, such as the Reserve Bank of New Zealand and Norges Bank, are already explicitly deciding on instrument-rate paths.[25]

In particular, majority voting about paths is completely feasible. One possibility is that the staff prepare two or three alternative sets of projections, each with a particular instrument-rate path and corresponding projections of the inflation and the output gap (perhaps

25. At the Reserve Bank of New Zealand, the governor is the single decisionmaker and is advised by an internal monetary policy committee. The single decisionmaker is sometimes said to simplify the decision about the interest rate path (Goodhart 2001, 2005). My information about monetary policy committee meetings, gained especially during my review of monetary policy in New Zealand (Svensson 2001a), indicates that decisions are normally made in a very collegial manner, similar to a majority voting monetary policy committee. Archer (2005) provides more specific and recent information supporting this impression. Norges Bank has a seven-member board that makes monetary policy decisions. Two members (the governor and deputy governor) are from the bank, and five are external.

but not necessarily minimizing a loss function for alternative λs). The instrument-rate paths might, for instance, differ in the speed at which they return to a common normal level. The monetary policy committee could then vote on these two or three alternative sets of projections, in the same way that it would vote on two or three alternative current instrument-rate settings (if there are three alternatives, perhaps by first eliminating one alternative as least preferred and then voting between the remaining two).

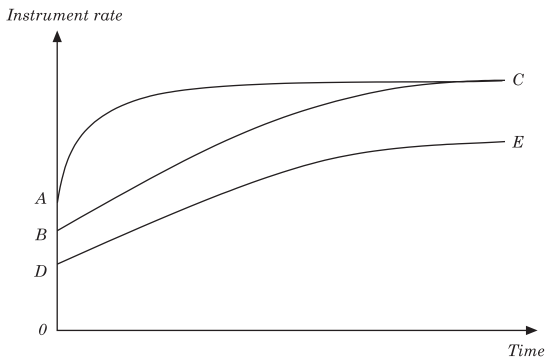
I have suggested a somewhat more general procedure (Svensson 2003a). Suppose that each monetary policy committee member has a preferred instrument-rate plan for the current and future instrument rate in the form of a path. All of these paths could be plotted in a graph with time on the horizontal axis and the instrument rate on the vertical axis. For each future date on the horizontal axis, the committee would pick the median instrument-rate level. Recall the Median-Voter Theorem: The outcome of majority voting about a single variable is the level preferred by the median voter. This is the median-voter theorem applied to a path, as if the monetary policy committee members were simultaneously voting about the instrument rate at the current and future dates. The procedure results in the median instrument-rate plan. This median instrument-rate plan could serve as the starting point for a new round of voting, with each monetary policy committee member suggesting some modification of the median instrument-rate plan. The median of these suggestions, corresponding to majority voting about the modifications, would be chosen as the instrument-rate plan. I would be very surprised if this procedure did not converge to a reasonably consistent compromise within a couple of rounds.[26]

Figure 2 illustrates a situation with three monetary policy committee members. One member prefers instrument-rate plan AC, where A corresponds to the preferred current instrument-rate setting. A second member prefers instrument-rate plan BC. The two members agree on the instrument rate far into the future but disagree on the time to get to that level and on the current instrument-rate level. A third member prefers instrument-rate plan DE, with a lower current level and a lower future level than the other two. The median instrument rate for each date is the instrument rate BC. For

26. Relying on the median instrument-rate plan also has the attractive property that outliers are disregarded: extreme monetary policy committee members will have little or no influence on the resulting instrument-rate plan.

this simple configuration of individual instrument-rate plans, the procedure converges in one step.[27]

Figure 2. Voting on Instrument-Rate Plans



Source: Author.

3. Transparency and Communication Issues

The internal forecast/decision process and the bank's announcement and communication process are distinct, although the appropriate announcement and communication is an important part of managing private sector expectations and thereby implementing monetary policy. From a transparency and accountability point of view, it is desirable that the central bank's reporting be a correct representation of the internal forecast/decision process and its results. However, I see no problem with the bank trying out different internal procedures for some time and announcing them later, once the bank has decided which procedures to follow.

Since monetary policy has an impact on the economy via the private sector expectations of inflation, output, and instrument rates it gives rise to, announcing the optimal projection—including the instrument-rate projection—and the analysis behind it would

27. For a monetary policy committee with an even number of members, the median curve can be defined as the average of the two middle curves. If one member (the governor) has the decisive vote in case of a tie, the governor's vote would decide which of the two middle curves is the median. If the committee members' individual instrument-rate plans intersect, the median curve may consist of segments of different members' plans. In this case a few rounds may be required before a reasonably smooth and consistent median plan is chosen.

have the greatest impact on private sector expectations and be the most effective way to implement monetary policy. Since the optimal projection is the best projection, in the sense of minimizing expected squared forecast errors, it also provides the private sector with the best aggregate information for making individual decisions. Announcing the optimal projections also allows for the most precise and sophisticated external evaluation of the monetary policy framework and decisions.

Morris and Shin (2002) present a result indicating that more public information may reduce social welfare. This result has received considerable attention and been interpreted as arguing against transparency (Amato, Morris, and Shin, 2002; Amato and Shin, 2003; Economist, 2004). However, Svensson (2006) shows that some scrutiny of the result reveals that it has been misinterpreted and is actually pro transparency: except in very special circumstances (when the precisions of private information is more than eight times higher than that of public information), more public information increases social welfare. In particular, for a conservative benchmark of equal precision in public and private information, social welfare is higher than it is without public information.[28]

The announcement of the optimal instrument-rate projection could include fan charts to emphasize that the projection is a probability distribution conditional on current information and judgment and that only with probability zero would future decisions be exactly equal to the central projection. Goodhart (2005) and Mishkin (2004) have warned that the instrument-rate projection might be interpreted as an unconditional commitment. Some special explanation may indeed be required to emphasize that the instrument-rate projection is not a commitment but only the best forecast, the best plan, conditional on current information and judgment and that future decisions and future projections would normally change to reflect new information and judgment. Experience from New Zealand indicates that the market and private sector have no problem understanding that projections are conditioned on current information and will change with new information (Archer, 2004, 2005; Svensson, 2001a). Furthermore, educating the market and the general public about monetary policy is a natural part of successful inflation targeting.

28. Woodford (2005) shows that a slight change in the social welfare measure, such that it is proportional to individual welfare, makes social welfare always increasing in transparency.

This discussion concerns conveying the bank's optimal projection of inflation, the output gap, and the instrument rate to the private sector. It does not attempt to convey the bank's reaction function, that is, how current instrument setting depends on current information and judgment. This reaction function is, in my view, too complex to ever be explicitly expressed, even within the bank. The optimal instrument-rate decision depends in a complex way on all the information and judgment used in the forecasting process. The reaction function is, in my view, best left implicit. (For more detail on this issue, see Svensson 2003c, 2005b.) Fortunately, the decision process proposed above does not require that central bank's reaction function be explicit.[29]

In short, I believe that the best instrument-rate decisions, the most effective implementation of monetary policy, and the most satisfactory degree of transparency and accountability can be achieved with the moderately formal framework discussed above. Let me now discuss a few additional points.

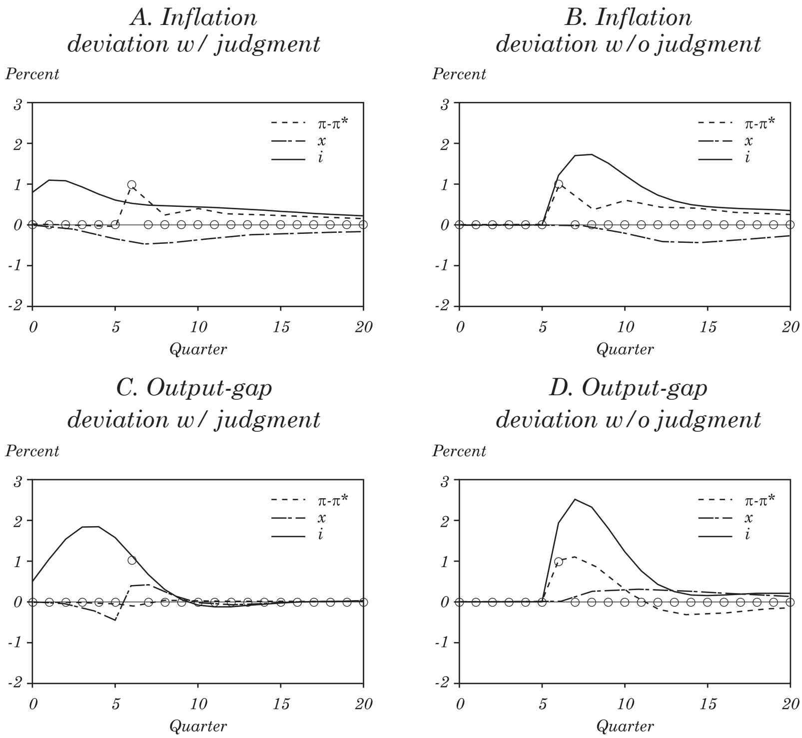
4. Incorporating Judgment

The framework proposed above can be used with projections that are largely judgmental, with projections that are largely model based, or any combination of the two. Svensson (2005b) discusses in greater detail how central bank judgment—information, knowledge, and views beyond the scope of a particular model—can be incorporated into optimal projections in a consistent way. Svensson and Tetlow (2005) describe a practical way of doing so, the method of optimal policy projections, which is in use at the Federal Reserve Board.

My view is that models are very useful in practical monetary policy, but a substantial amount of judgment always needs to be applied. I doubt that good monetary policy can ever be conducted without a substantial amount of judgment. Any model is always a drastic simplification of a complex economy; judgment, in the form of information, knowledge, and views outside the scope of a particular model, will always be necessary. The challenge is to apply good judgment in a disciplined and systematic way rather than in a completely discretionary and ad hoc way.

29. Although it is in principle true that inflation targeting can be described as an ex ante inflation target and an optimal instrument-rate response to observable shocks, as King (1996) notes, in practice the number of potential shocks is so large that the optimal response to all possible observable shocks cannot be made explicit.

Figure 3. Monetary Policy with and without Central Bank Judgment



Source: Svensson (2005b).

Figure 3 shows a situation discussed in Svensson (2005b), based on the empirical model of the U.S. economy of Rudebusch and Svensson (1999).[30] The inflation and output gaps have been equal to their steady-state levels, zero, up to quarter 0. In panel a, the central bank receives new information in quarter 0 about a shock to inflation, the inflation deviation, in quarter 6 with a mean of 1 percentage point and possibly a large variance; the anticipated mean deviation of inflation equals zero for other future quarters. The central bank's judgment in quarter 0, the mean inflation deviations, is marked by circles with no connecting line.

30. Svensson (2005b) also provides an example with an empirical forward-looking model of the U.S. economy by Lindé (2002).

It is important to realize that this example of central bank judgment does not amount to the assumption that the central bank has perfect foresight about future shocks. On the contrary, judgment about future inflation deviations is in the form of probability means. Behind these means would normally be a perceived probability distribution of inflation deviations with considerable uncertainty. The variance of this distribution could be very large. However, under the assumptions made, it is only the mean of the distribution that matters for policy.

Panel a shows the optimal policy projection in quarter 0, $(\pi^0 - \pi^*, x^0, i^0)$, of the inflation gap, $\pi - \pi^*$ (the dashed line); the output gap, x (the dashed-dotted line); and the instrument rate, i (the solid line).[31] The panel shows that when the central bank expects a 1 percentage point inflation deviation in quarter 6, it chooses an optimal instrument-rate projection such that the instrument rate is raised to about 1 percentage point during the first few quarters and then gradually lowered back to its steady-state level. As a result, the projected output gap gradually falls to about -0.5 percentage points in quarter 7 and then very gradually rises back toward zero. The inflation projection shows inflation falling slightly before it is hit by the inflation deviation in quarter 6, then rising to almost 1 percentage point before finally falling back toward its steady-state level after quarter 6. Thus the optimal policy projection is a clear example of preemptive monetary policy: the instrument rate is raised and the output gap reduced well before the expected inflation deviation shock, in order to efficiently control inflation and bring it back to target after the shock. The optimal policy projection in quarter 0 results in an expected intertemporal loss of 4.2 units.[32]

Panel b shows the projection of the same variables for the same expected inflation deviation. However, in this panel the central bank disregards judgment in each quarter while still responding optimally to the predetermined variables (current and past inflation and output gaps). The central bank responds in the same way to the predetermined variables as in the optimal policy, but it does not respond to any expected future deviation. It behaves as if it believes that the deviation

31. The optimal projection is calculated for a period loss function defined over projections as $L_{t+\tau,t} = (\pi_{t+\tau,t} - \pi^*)^2 + \lambda x^2_{t+\tau,t} + \nu (i_{t+\tau,t} - i_{t+\tau-1,t})^2$, with $\lambda = 1$, $\upsilon = 0.2$, and a discount factor $\delta = 1$.

32. Given how the target variables are measured, with the given loss function and $\delta = 1$, an expected difference of inflation from target of one (two) annualized percentage point(s) for a single quarter gives rise to an intertemporal loss of one (four) units.

is a serially uncorrelated zero-mean process, so its expected future deviations are zero. The central bank then keeps the instrument rate at its steady-state level through quarter 5. Accordingly, inflation and the output gap remain at the steady-state levels through quarter 5. In quarter 6 the inflation shock hits and inflation jumps to 1 percentage point, while the predetermined output gap remains at zero. In this situation, once the inflation shock has hit, the optimal monetary policy response is to raise the instrument rate substantially, to more than 1.5 percentage points above the steady-state level during the following few quarters. This reduces the output gap to almost -0.5 percentage points during the next eight to nine quarters. The instrument rate is gradually lowered back to the steady-state level, and inflation and the output gap return to their steady-state levels very slowly. The absence of any preemption requires a larger instrument-rate response when the shock occurs; the output gap is nevertheless reduced, with a considerable lag, and inflation stays above target for a long time. The resulting intertemporal loss is 6.3 units—2.1 units higher than when monetary policy relies on judgment. (Panels c and d illustrate analogous experiments for an expected output deviation in quarter 6; for more detail, see Svensson, 2005b.)

This example shows a substantial difference between monetary policy with and without judgment, with significant differences in the development of the target variables and corresponding intertemporal losses. It indicates the importance of taking central bank judgment into account.

5. Uncertainty, "Mean" Forecast Targeting, and "Distribution" Forecast Targeting

Monetary policy is always conducted under substantial uncertainty. The projections discussed above can be interpreted as mean projections of future random variables, and the procedures discussed above can be called *mean forecast targeting*. Strictly speaking, mean projections are sufficient for optimal policy only under certainty equivalence, which requires a known linear model and a quadratic loss function and only additive uncertain shocks.

When certainty equivalence is violated—because uncertainty is multiplicative and not just additive, for instance—mean projections are not sufficient for optimal policy. In this case, the entire distribution of future random target variables matters.

Svensson and Williams (2005) develop a flexible and powerful but still tractable framework for optimal monetary policy under model uncertainty. Their framework extends the so-called Markov jump linear-quadratic framework to include forward-looking variables.[33] In principle, the forecast targeting procedure discussed here can be carried out using projections of probability distributions—distribution projections—rather than mean projections. In this case the procedures can be called *distribution forecast targeting*. It is too early to tell whether in most situations for monetary policy the difference between mean forecast targeting and distribution forecast targeting is large enough to matter for policy.

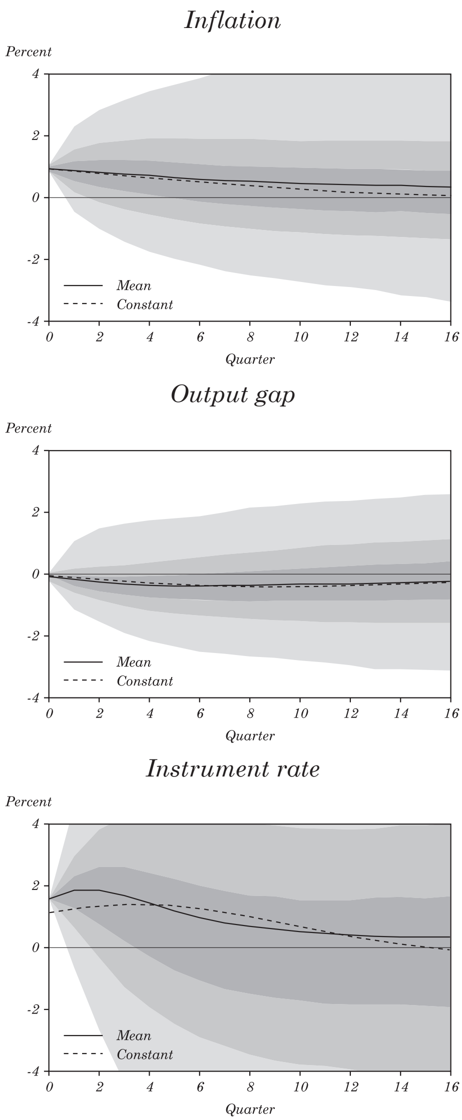
In both mean and distribution forecast targeting, the uncertainty of the projections can conveniently be illustrated with fan charts. The methods of Svensson and Williams (2005) allow the convenient construction and plotting of theoretically and empirically consistent fan charts under both certainty equivalence and certainty nonequivalence.

Figure 4 shows the probability distribution of an optimal projection of inflation, the output gap, and the instrument rate for a three-mode version of the Lindé (2002) empirical neo-Keynesian model of the U.S. economy. This model is used as one example in Svensson and Williams (2005) (another example used there is a three-mode version of the Rudebusch and Svensson, 1999 model). Model uncertainty is modeled as a Markov process that jumps among three alternative modes, with each mode having a different set of model coefficients (that is, a three-mode regime-switching model). The modes are not directly observed by the central bank. The central bank then conducts optimal policy conditional on its subjective probability distribution of the modes—in this case, the stationary distribution of the modes. Svensson and Williams (2005) provide details of the Bayesian method used to estimate the mode-dependent model parameters, the transition probabilities of the modes, and the variance of the mode-dependent additive shocks.

The figure shows the optimal projection of inflation (measured as the difference from the inflation target), the output gap, and the instrument rate starting from an initial situation in quarter 0, when inflation exceeded the inflation target by 1 percentage point and the instrument rate was equal to 1 percentage point the previous quarter, quarter -1. From quarter 0, the economy is subject to unobserved jumps between model modes with estimated transition probabilities, as well

33. Zampolli (2005) uses a Markov jump linear-quadratic framework to examine optimal policy with switching exchange rate dynamics.

Figure 4. Optimal Projection of Inflation, the Output Gap, and the Instrument Rate with Model Uncertainty and Additive Shocks



Source: Svensson and Williams (2005)
Note: Solid lines show the mean projection. Dashed lines show the optimal mean projection for constant coefficients. The dark shading shows the 30 percent probability band. The medium shading shows the 60 percent probability band. The light shading shows the 90 percent probability band.

as additive shocks with estimated mode-dependent variance. Thus, the simulation takes into account both additive and multiplicative uncertainty, with empirical distributions for both kinds of uncertainty. The probability distribution was simulated with 10,000 realizations of the Markov chain.

The light gray bands (90 percent probability) show that the projection's probability distribution has relatively wide tails; the medium (60 percent probability) and dark gray (30 percent probability) shades show that most of the probability mass is relatively concentrated for the inflation and output-gap projection. The probability distribution for the instrument-rate projection is wider than for inflation and the output gap. It is also somewhat asymmetric. This is apparent since the median projection, which will be within the dark gray band, differs from the mean projection, shown by the solid line. The probability distribution seems to converge to a stationary distribution after about 12 quarters.

The Markov jump linear-quadratic framework approach to model uncertainty can be combined with the "additive" central bank judgment discussed in Svensson (2005b). Furthermore, it allows the introduction of "multiplicative" central bank judgment, such as the judgment that model uncertainty is temporarily "high," "normal," or "low." Optimal policy projections can then be computed for these alternative levels of perceived model uncertainty. Svensson and Williams (2005) provide further discussion of these and other extensions.

6. Optimization under Commitment, the Timeless Perspective, and Discretion

When forward-looking private sector expectations are important, optimization under commitment differs from optimization under discretion. The behavior of some central banks is probably better described as optimization under discretion, where each new decision is made from scratch, regardless of previous promises and statements. Indeed, some observers who are opposed to the idea of publishing instrument-rate projections have referred to the undesirability of such projections, because they might be interpreted by the private sector as commitments and thereby restrict the bank's freedom to act (Mishkin, 2004).

From a normative point of view, and when policy advice is given, optimization under commitment is the obvious standard, since policy under commitment, when commitment is possible, results in better outcomes. Furthermore, the issue of consistent reoptimization under commitment can be handled with optimization under commitment in the timeless perspective (Woodford, 2003; Svensson and Woodford, 2005). Svensson (2005b) provides details under certainty equivalence; Svensson and Williams (2005) examine the case of noncertainty equivalence.

7. The Output Gap, Potential Output, the Interest-Rate Gap, and the Neutral Interest Rate

The output gap—the difference between output and potential output—has been used as a generic variable indicating the state of the business cycle. However, in modern views of the transmission mechanism, the output gap is an import variable and far from arbitrary. In this regard, the theoretically most satisfactory concept of potential output is the hypothetical output level that would result in the economy if all prices and wages were completely flexible. This means that potential output is time varying, shock dependent, and not a simple trend.

Because the output gap and potential output gap are crucial variables in the transmission mechanism, it makes sense for central banks to devote a fair amount of resources to estimating potential output, constructing projections of potential output and the output gap, and publishing those estimates and projections, especially if the output gap is an implicit or explicit target variable. The fact that estimates and projections of potential output and the output gap are quite uncertain does not diminish their importance and is not a reason not to publish them (contrary to what Mishkin, 2004 argues). Generally, a simple principle for transparency is that the central bank should publish projections of all its target variables. If a central bank sets the employment or unemployment gap (defined as the difference between employment [unemployment] and "potential" employment [unemployment]), as a target variable, it should publish estimates and projections of these measures as well. (The theoretically most satisfactory definition of "potential" is the hypothetical level in an economy with completely flexible prices and wages.)

In modern views of the transmission mechanism, the most appropriate measure of monetary policy stance is the projection of the current and future interest-rate gap—the difference between the real instrument rate and the neutral real interest rate. The neutral real interest rate (the Wicksellian natural real interest rate) is the hypothetical real short-term interest rate that would result in the economy if prices and wages were completely flexible. It is time varying, shock dependent, and not a simple average of past real interest rates. The neutral real interest rate and potential output are related. In the simplest case, the neutral real interest rate is the sum of the rate of time preference and a term equal to expected growth of potential output divided by the intertemporal elasticity of consumption. The most appropriate measure of monetary policy stance is then given by the projection of the current and future interest-rate gap (see appendix). Given the importance of this concept in modern views of the transmission mechanism, it makes sense that central banks estimate, use, and publish estimates of it.

8. Conclusions

Inflation-targeting central banks can improve their targeting by being more specific, systematic, and transparent about their operational objectives (by using an explicit intertemporal loss function), their forecasts (by deciding on optimal projections of the instrument rate and the target variables), and their communication (by announcing optimal projections of the instrument rate and target variables). Progress can also be made by incorporating central bank judgment and model uncertainty in a systematic way in the forecasting and decisionmaking process. In particular, incorporating model uncertainty allows the central bank to target based on more general distribution forecast rather than on the more restrictive mean forecasts under the assumption of approximate certainty equivalence.

APPENDIX

The Loss Function and the Interest-Rate Gap

A. The Loss Function

Let the period loss function be as shown in expression (1). Assume that δ is arbitrary close to unity. Note that the limit of the intertemporal loss when δ approaches unity satisfies

$$\begin{aligned} &\lim_{\delta \to 1}(1-\delta)\mathrm{E}_t \sum_{\tau=0}^{\infty} \delta^{\tau} L_{t+\tau} = \mathrm{E}\left[L_t\right] \\ &= \left(\mathrm{E}\left[\pi_t\right] - \pi^*\right)^2 + \mathrm{Var}\left[\pi_t\right]^2 + \lambda\left(\mathrm{E}\left[x_t\right]^2 + \mathrm{Var}\left[x_t\right]\right) \\ &= \left(\mathrm{E}\left[x_t\right] - \pi^*\right)^2 + \mathrm{Var}\left[\pi_t\right] + \lambda \mathrm{Var}\left[x_t\right], \end{aligned} \tag{A.1}$$

under the assumption that $\mathrm{E}\left[x_t\right] = 0$. Then the intertemporal loss is given by the sum of three terms. The first is the squared deviation from the inflation target of the unconditional (that is, long-run) mean of inflation. The second is the unconditional variance of inflation. The third is the product of λ and the long-run variance of the output gap. Hence λ can be interpreted as the weight on variance of the output gap relative to the weight on variance of inflation (or squared long-run deviations of inflation from the inflation target).

B. The Interest-Rate Gap

That the projection of the current and future interest-rate gap is an appropriate indicator of the monetary policy stance can most easily be demonstrated in a simple neo-Keynesian model of aggregate demand. Let aggregate demand be given by

$$y_t = y_{t+1|t} - \sigma(r_t - \rho_t), \tag{A.2}$$

where y_t denotes (log) output in period t, $z_{t+\tau|t}$ denotes $\mathrm{E}_t z_{t+\tau}$ (the rational expectation in period t of the realization of variable $z_{t+\tau}$ in period $t+\tau$), $\sigma > 0$ denotes the intertemporal elasticity of substitution, r_t denotes a short-term (one-period) real interest rate, and ρ_t denotes the rate of time preference between period t and period $t+1$ and is an exogenous stochastic process. The short-term real interest rate is defined by

$$r_t \equiv i_t - \pi_{t+1|t}, \tag{A.3}$$

where i_t is a short-term (one-period) nominal interest rate and $\pi_{t+1|t}$ denotes the rational expectation in period t of inflation between period t and period $t + 1$. Equation (A.2) follows from a first-order condition for optimal intertemporal consumption choice with an additively separable utility function for a representative consumer with constant elasticity of intertemporal substitution σ and a stochastic subjective discount factor whose logarithm is ρ_t.

Let $\bar{y}_t$ denote (log) potential output, and assume that it is an exogenous stochastic process. Define the neutral real interest rate, $\bar{r}_t$, as the real interest rate for which output in (A.2) equals potential output. This gives

$$\bar{r}_t \equiv \rho_t + \frac{1}{\sigma}\left(\bar{y}_{t+1|t} - \bar{y}_t\right), \tag{A.4}$$

so the neutral interest rate equals the sum of the rate of time preference and expected potential output growth divided by the intertemporal elasticity of substitution.

Define the output gap as the difference between (log) output and (log) potential output,

$$x_t = y_t - \bar{y}_t. \tag{A.5}$$

Using expressions (A.4) and (A.5) in (A.2) results in

$$x_t = x_{t+1|t} - \sigma(r_t - \bar{r}_t). \tag{A.6}$$

The output gap in period t depends on the expected output gap in period $t + 1$ and the current interest-rate gap, $r_t - \bar{r}_t$. (The nominal and the real interest-rate gaps are the same, if we identify $\bar{r}_t + \pi_{t+1|t}$ with the nominal neutral interest rate, since $r_t - \bar{r}_t = r_t + \pi_{t+1|t} - \bar{r}_t - \pi_{t+1|t} = i_t - (\bar{r}_t + \pi_{t+1|t})$).

Solving (A.6) forward T periods gives

$$x_t = x_{t+T|t} - \sigma\sum_{\tau=0}^{t-1}\left(r_{t+\tau|t} - \bar{r}_{t+\tau|t}\right). \tag{A.7}$$

Assume that the expected output gap far into the future approaches zero ($x_{t+T|t} \to 0$ when $T \to \infty$), and assume that the sum in (A.7) converges when $T \to \infty$(that is, that $r_{t+T|t} - \bar{r}_{t+T|t} \to 0$ sufficiently fast when $T \to 0$). Then we can let $T \to 0$ in (A.7), yielding $x_t = -\sigma \sum_{\tau=0}^{\infty} \left(r_{t+\tau|t} - \bar{r}_{t+T|t} \right)$.

The output gap depends on the accumulated projected current and future interest-rate gaps, $\sum_{\tau=0}^{T-1} \left(r_{t+\tau|t} - \bar{r}_{t+\tau|t} \right)$. The projection of the current and future interest-rate gap, $r^t - \bar{r}^t = \left(r_t - \bar{r}_t, r_{t+1|t} - \bar{r}_{t+1|t}, \ldots \right)$, contains all the information about the monetary policy stance.

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