VI. INFLATION-FORECAST TARGETING AND THE ROLE OF MACROECONOMIC MODELS

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Several central banks have turned to inflation-forecast targeting as a framework for guiding monetary policy, but the degree of transparency about how the forecast is constructed varies considerably across countries. Over the last several years the Reserve Bank of New Zealand, which pioneered inflation targeting, has expended considerable effort to develop a consistent forecasting and policy system. To date, New Zealand is the only inflation-targeting country that releases a complete medium-term macroeconomic forecast as well as the modeling and policy assumptions that are used to construct it. This chapter argues that there may be significant potential benefits from using a consistent model-based projection process to inform policymakers even if considerable judgmental input is required to implement it. The chapter discusses the potential role of modern macroeconomic models in central banks as well as the pitfalls associated with using different classes of models to analyze the effectiveness of policy rules. It then uses a small macro model, calibrated to the Czech economy to illustrate how such models can be used to support inflation targeting. The chapter also argues that while it is useful to adopt one model as a basic paradigm to organize the projection process, it is important to consider insights from a range of plausible models in order to quantify the potential uncertainties surrounding the forecast.

A. Introduction

Several central banks have turned to inflation-forecast targeting as a framework for guiding monetary policy, but the degree of transparency about how the forecast is constructed varies considerably across countries. Over the last several years, the Reserve Bank of New Zealand, which pioneered inflation targeting, has expended considerable effort to develop a consistent forecasting and policy system. To date, New Zealand is the only inflation-targeting country that releases a complete medium-term macroeconomic forecast as well as the modeling and policy assumptions that are used to construct it. This chapter argues that there may be significant potential benefits from using a consistent model-based projection process to inform policymakers even if considerable judgmental input is required to implement it. The chapter discusses the potential role of modern macroeconomic models in central banks as well as the pitfalls associated with using different classes of models to analyze the effectiveness of policy rules. A small macro model, calibrated for Czech economy, is used to illustrate the way such models can provide guidance for inflation targeting. The chapter also argues that while it is useful to adopt one model as a basic paradigm to organize the projection process, it is important to consider insights from a range of plausible models in order to quantify the potential uncertainties surrounding the forecast.

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The remainder of the paper is organized in the following way. Section II discusses some key strategic issues related to implementing an inflation-forecast-based targeting framework. The section argues that the main benefit of a transparent inflation targeting framework is that it will result in internally consistent policy analysis, improved policy credibility, and a more effective anchor for inflation expectations. This in turn should result in greater macroeconomic stability and higher levels of welfare. Section III discusses the monetary transmission mechanism and the role of monetary policy and then presents a paradigm for implementing an inflation-forecast-based targeting framework. Section IV discusses the implications of model uncertainty and provides a critique of recent research that has focused on analyzing the performance of policy rules in models where monetary policy errors only have second-order welfare implications. The basic argument of this section is that it may be dangerous to base monetary policy decisions solely on the insights obtained from one particular model. Instead, it argues that model uncertainty implies that several types of models should be used to assess the potential risks for monetary policy. That being said, Section V focuses on a specific small open economy model for purposes of illustrating how such models can be used to support inflation targeting. Section VI provides some concluding remarks.

B. Some Key Strategic Issues Related to Inflation Targeting

Over the last decade a number of countries which have had difficult historical experiences with inflation control have turned to inflation targeting as a framework for governing monetary policy—see Bernanke and others(1999) for a review of the experiences to date of the countries that have employed inflation targeting. While there are significant differences in the specific institutional arrangements that have been adopted in these countries, they usually embrace the following five basic principles.

Five basic principles

1. The primary role of monetary policy is to provide a nominal anchor for the economy; placing a weight on other objectives, such as unemployment, must not be inconsistent with this primary objective of providing an anchor for inflation and inflation expectations.

2. Given the possibility of a conflict between inflation targets and other objectives, central bankers must have reasonably clear goals and sufficient independence from the political process to achieve them.

3. Because of lags in the monetary transmission process, it is impossible to keep inflation exactly on target period-by-period; in practice, inflation targeting effectively boils down to inflation-forecast targeting where the monetary authorities set interest rates to

eliminate deviations of their expected future inflation rates (inflation forecasts) from the target—see Svensson (1997a, 1997b).

4. There must be effective monitoring and accountability mechanisms to ensure that central bankers are behaving in a manner that is consistent with the announced underlying objectives and that monetary policy decisions are being based on the best available models and forecasts of the economy.

5. An effective inflation targeting framework should have beneficial first-order effects on welfare because such a framework will result in less uncertainty, higher levels of confidence in the monetary authorities' abilities to provide an anchor for inflation expectations, and a reduction in the incidence and severity of boom and bust cycles.

As mentioned above, while there seems to be general agreement on these basic principles, most countries that have adopted inflation targeting frameworks have significant differences in views about what the explicit objectives should be, what institutional arrangements are best to achieve them, and how transparent and accountable central bankers should be.

Instrument independence

A minimum necessary prerequisite is that the central bank must be assigned instrument independence. In principle, the government may also assign goal independence to the central bank, but what is important in practice is that the government provide a strong commitment that—unless there are extenuating circumstances—it will not override the central bank once the goals have been determined. Furthermore, in such circumstances where an override is judged to be necessary, it has to be made clear to the public and market participants that the central bank is being overridden. This is intended to provide a punishment mechanism in order to prevent overrides that may be motivated by short-term political gain and are not in society's long-term interests.

Transparency

Given the enormous difficulties and complexities associated with forecasting the economy and assessing the pervasive uncertainty inherent in any particular forecast, it is not surprising that many countries have been reluctant to implement a completely transparent inflation-forecast targeting framework. Even though some countries may implicitly be targeting an inflation forecast, their central banks may fear that releasing detailed information about the uncertainty in their forecasts and models not only might result in personal embarrassment, but also might undermine the public's confidence in their abilities to provide a stable anchor for inflation expectations. That being said, most of the countries that have announced inflation targeting have taken significant strides to ensure that the public understands the basic objectives and arguments behind their particular policy settings. This communication with the public has been done through regular inflation reports, minutes of various meetings, press conferences, public speeches, and conferences that are designed to illuminate the central bank's paradigm and to promote interest in improving it.

The primary motivation for these initiatives in the area of openness and transparency has not been the desire to achieve significant short-term credibility gains, but rather the view that there will be benefits over time if it becomes easier for the public and market participants to understand and assess the systematic component of monetary policy—see Longworth (1999).

The Reserve Bank of New Zealand (RBNZ), which pioneered inflation targeting, is clearly on the cutting edge in terms of openness, transparency and accountability. Not only does the RBNZ set precise targets and spend an enormous amount of time explaining its policies to the public, it is the only inflation-targeting country that releases a detailed medium-term forecast that includes information about its future policy assumptions as well as other key macroeconomic assumptions.

The RBNZ has also designed a model and projection system explicitly for implementing inflation-forecast-based targeting, and it makes its core policy projection model available to the public—see Black and others (1997) for a description of the forecasting and policy analysis system employed at the Reserve Bank of New Zealand. The interest rate reaction function in the model is an inflation-forecast-based (IFB) rule where the slope of the term structure depends on the forecast of future inflation.

Uncertainty, openness, and learning from past errors

To develop and maintain credibility, central banks that adopt a strategy of inflation-forecast-based targeting should strive to learn lessons from past mistakes and then attempt to prevent these errors from occurring in the future. One of the problems with central banks in the past is that they have been very reluctant to admit policy errors in a timely manner—a stance that has significantly slowed down the learning process. For example, far too much ink has been spilled in academia and policymaking institutions debating issues that could have been easily resolved if monetary policy committees had been more open about the assumptions and projections on which their policy decisions were based.

One important benefit from transparency and openness is that the likelihood of large policy errors may be substantially reduced by involving a greater number of people outside central banks in the debate. As Buiter (1999) has emphasized, the process of fact finding and searching for truth is not served well by a highly secretive policymaking process. Moreover, failure to release detailed information behind policy setting results in an unproductive use of resources, both inside and outside central banks, in attempts to infer what policymakers might be thinking. For an inflation-forecast-targeting framework to be effective and credible, central bankers must be open and willing to change policies on the basis of past errors.

The New Zealand experience provides a great example of how an inflation-forecast-based system can be improved over time. In hindsight, it is clear that in its early stages, the policy process in New Zealand was excessively preoccupied with hitting near-term inflation objectives over a 6–12 month horizon at the expense of other objectives. However, with experience and firmer empirical evidence, it was recognized that such a policy could be destabilizing to activity and inflation in the medium term and the policy horizon was lengthened—see Svensson (1997b, 1998).

Several important lessons from the New Zealand experience with inflation targeting may be applicable to other countries. One lesson is that it can be counterproductive to overuse the direct exchange rate channel to hit a near-term inflation objective if it results in a loss in the public's confidence that the central bank is behaving in a manner that is consistent with the interests of society. Second, the policy process should not be focused exclusively on computing interest rate paths for hitting near-term targets without understanding the potential medium-term implications of these policy settings. Third, policies designed to win credibility too quickly by being too rigid may actually backfire when the public and market participants recognize that there is a good chance that the system will be reformed in the future. In order to minimize the number of adjustments to key parameters in the framework, policymakers need to better understand the risks before committing to a particular inflation-based-forecasting strategy. Indeed, policies that destabilize the business cycle can have first-order welfare consequences and will and should be changed.

Flexible bands versus precise inflation-forecast targeting

In most cases it is generally recognized that the central bank has an important role to play in terms of stabilizing the business cycle, and that it should attempt to do this as long as achieving this objective does not conflict with its primary responsibility of providing an anchor for inflation and inflation expectations. However, the tradeoffs, or potential conflicts, pose a fundamental problem for the monetary authorities because uncertainty implies that it is impossible to commit in advance to how monetary policy should respond in the face of all shocks.

One strategy has been to retain flexibility by being somewhat vague about specific goals and by expressing inflation objectives as simply a desired range over the medium term. However, the main disadvantage of this approach is that it provides less information to the public about the future intentions of the monetary authorities in the face of shocks compared to a regime where the monetary authorities have a very precise target and attempt to achieve this target over a particular horizon. Indeed, proponents of precise and symmetric targets argue that these can be essential in order to anchor inflation expectations. For example, in reviewing the U.K. experience Haldane (2000) argues that the problem with the initial inflation target range of 1–4 percent between 1992 and 1995 was that it gave rise to positive "range bias" because it was interpreted as range of indifference. Haldane (2000) and Isard and Laxton (2000) report some data on long-term inflation expectations for the United Kingdom and show that the move to an independent central bank with a well-defined and symmetric target has resulted in a significant reduction in long-term inflation expectations and an improvement in policy credibility.

The adoption of a framework that has precise and symmetric targets also requires significantly greater transparency about how the monetary authorities will attempt to achieve their targets. In order to aid in the communication process some central banks have been releasing information about their own forecasts for inflation in order to provide some guidance to the public about the horizon over which they will attempt to achieve the target.[2] However, in some cases these forecasts are based on a constant interest rate assumption that is not perceived to be credible by bond market participants—see Isard and Laxton (2000) for a discussion of the problems with basing monetary policy decisions on an assumption of constant interest rates. As Flemming (1999) has argued, in order for the central bank's policy process to be forward-looking and internally consistent, it must be based on realistic assumptions about how monetary policy is likely to react to new information in the future. In other words, for a forward-looking monetary policy process to be internally consistent and transparent, the monetary authorities must provide an effective action plan, or strategy, that explains how exactly they plan to achieve these targets. In some central banks that have adopted an inflation targeting framework, this has resulted in the development of "working assumptions" about how the policy rate will respond to the central bank's forecast; and in the case of New Zealand this information is made available to market participants.[3] These assumptions for monetary policy that are used inside central banks are sometimes referred to as working assumptions to emphasize that policy makers would never follow a rule blindly and that it is necessary to add judgment to the policy rule just as judgment is added to all of the other equations in the core projection model that is used to organize the projection process. For this chapter, we will assume that this is well understood and for this reason we will refer to the central bank's reaction function as a "policy rule" and consider the two types of forward-looking policy rules that have been suggested in the literature.

Targeting rules versus instrument rules

Svensson (1999) distinguishes between targeting rules and instrument rules. The latter amount to formulas or reaction functions that link the policy instrument to the observed (or forecast) outcomes for a set of macroeconomic variables. The former, which Svensson regards as more fruitful and realistic formalizations of real-world monetary policy, involve a commitment to

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[2] The reason for providing a forecast is that it will not generally be optimal (or even feasible) to have a fixed horizon to set the forecast of inflation equal to the target. For most countries, what is important is that the monetary authorities' reactions be successful in steering inflation back towards the target over a reasonable horizon depending, inter alia, on the lags in the monetary transmission mechanism and the degree of serial correlation in the underlying shocks.

[3] Central bankers have been very reluctant to release the modeling and policy assumptions behind their forecasts, fearing that market participants may not completely understand the uncertainties in the forecast; at this point in time only the Reserve Bank of New Zealand publishes these assumptions. Section V of this paper shows that one of the advantages of developing an internally consistent modeling framework is that it is then possible to use that framework to develop confidence bands for the policy rate and a host of other macroeconomic variables.

minimize a given loss function or to fulfill some optimality condition for (forecasts of) the target variables, but allow the optimization to be done under discretion.[4]

There are several potential problems with targeting rules from a normative perspective. First, as demonstrated by Woodford (1999) and McCallum and Nelson (2000), targeting rules may be suboptimal because they are based on optimization under discretion. Second, as argued by Isard and Laxton (2000), because targeting rules are not time consistent, they are unlikely to be regarded as credible by forward-looking bond market participants, and consequently they may fail to provide valuable guidance to market participants about the systematic component of monetary policy. Third, as argued in Isard and Laxton (2000), the use of targeting rules can be counterproductive if it implies that the authorities limit themselves by basing policy either on relatively simple macroeconomic models for which they are able to derive first-order conditions for their policy instrument, or on a limited set of candidate paths for the policy instrument, such as paths that hold the policy instrument constant over the forecast horizon.[5]

Much of the recent literature on instrument rules has addressed the stabilization properties of Taylor rules and inflation forecast-based (IFB) rules. This research has suggested that IFB rules may be more robust to a larger variety of shocks than backward-looking Taylor type rules, because under unconstrained IFB rules, interest rates are free to jump to find a path for real monetary conditions that is consistent with both inflation control and stabilization objectives—see Isard, Laxton, and Eliasson (1999).[6]

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[4] McCallum and Nelson (2000) dispute Svensson's claim that targeting rules provide a better characterization of the decision making process in central banks that have adopted inflation targeting and argue that no central bank relies upon an explicit objective function.

[5] When Svensson introduced the concept of targeting rules he did so in a very simple model where only past changes in the policy rate affected aggregate demand and inflation with no effects on aggregate demand and inflation from expectations of future movements in the policy rate. The resulting policy implications from these models should be interpreted with caution. First, even though the model was extremely simple, it may have given the impression that it would be optimal to choose a fixed horizon to set the forecast of inflation equal to the target. This generally will not be true in macroeconomic models with more realistic macroeconomic dynamics. Second, because of the extremely simple control lags in the model, it may have given the impression that it made sense to characterize an unchanged monetary policy assumption with an unchanged policy rate over the policy horizon. This will obviously not be true in models where expectations of future policy rates affect aggregate demand and inflation expectations and where attempting to follow a constant-interest-rate rule can produce very undesirable consequences—see Isard and Laxton (2000).

[6] Section V provides an example of how an IFB rule can be optimally calibrated for a small, simple, macro model of the Czech Republic. The model is "complete" in the important sense of having a well-specified role for the monetary authorities to provide an anchor for inflation expectations and to prevent large boom and bust cycles from occurring. The model is incomplete in the sense that it ignores many issues about real world macroeconomic dynamics but, as Longworth (1999) has argued, such simple models may be a useful starting point to organize the

For an inflation-forecast-based rule to be credible, the rule must be reasonably robust and the central bank must be able to present a clear paradigm about how it thinks about the economy when setting interest rates. Central banks, which are currently following an inflation-forecast-based regime, or may be considering doing this so, will be well served by strengthening their analytical frameworks and projection paradigm along the lines that New Zealand has.

C. A Paradigm for Implementing Inflation-Forecast Targeting

This section discusses an appropriate paradigm for organizing and implementing an inflation-forecast targeting framework. We would emphasize at the outset that monetary policy necessarily involves a large element of discretion, but that formal models can be very useful in promoting the consistency of policy analysis and in helping the authorities communicate the rationale for policy actions. The views in this section reflect some personal experiences at the Bank of Canada as well as our observations about how inflation-forecast targeting is organized—or not organized—at other central banks. Box 1 provides some summary points about the key aspects of a basic paradigm. The remainder of this section and the other sections will attempt to elaborate on these points.

"thinking process" inside central banks and the models can become more elaborate and sophisticated as more data and expertise becomes available.

Box 1: Inflation-Forecast-Based Targeting Paradigm

1. Develop a clear view of the monetary transmission mechanism and the fundamental role of the monetary authorities.

2. Build a core projection model that embodies the consensus views of policy makers about how the economy responds to standard shocks. Keep the model simple and easy to understand but be wary of highly simplistic rule-of-thumb models in which the timing of monetary policy decisions are unimportant and where monetary policy errors only have second-order implications for welfare.

3. If there are differences in views about what the properties of the core projection model should be, develop a broader taxonomy of models to represent these alternative views and use this taxonomy to help measure the uncertainty in the core projection model. Good examples of where well-informed policy makers could disagree, for example, would be on lags in the monetary transmission mechanism, the role of expectations, and the relative incidence of supply versus demand shocks.

4. Acknowledge that the core projection model is designed to only handle a well-specified set of standard shocks. Keep the structure of the models simple so that it is easy to embody insights from non-model based judgement, or other models that are designed to study the effects of non-standard shocks that appear too infrequently (or would excessively complicate the core projection model).

5. Encourage an active research agenda both within and outside the central bank to understand the implications of uncertainty. Don't forget that an important benefit of developing a transparent paradigm is that it provides more productive direction for paradigm busters to come up with concrete alternatives that can compete with the core projection model.

6. Document errors from previous paradigms and models to ensure that these errors are not forgotten and repeated in the future.

7. Be prepared to adjust the paradigm and core projection model in response to new experiences and empirical evidence. This process is much easier if the initial paradigm explicitly acknowledges uncertainty.

8. Recognize the low power of statistical tests and don't let the paradigm fall hostage to poor methodology.

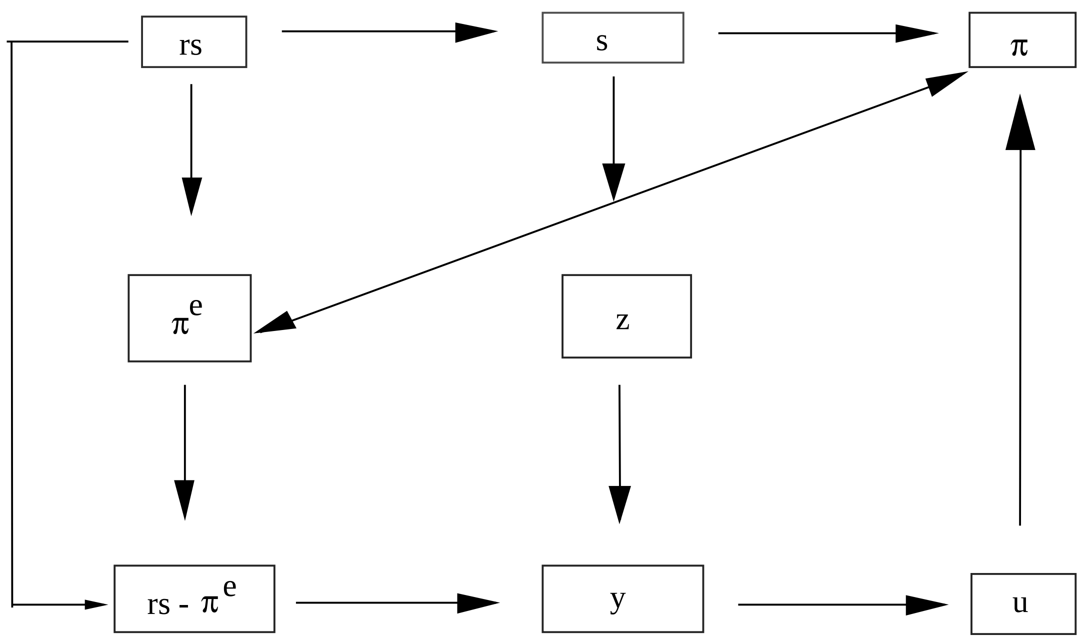
The monetary transmission mechanism and role of the monetary authorities

The first step is to develop a view of the monetary transmission mechanism and the role of the monetary authorities. These issues are considered in much more depth below and elsewhere, but a few summary points can be mentioned here.

A prerequisite for inflation-forecast-based targeting is that there must be a reasonably clear view about the monetary transmission mechanism as well as the major shocks that influence the economy and inflation.[7] The analytical frameworks that have been developed for addressing monetary policy issues for an open economy traditionally exhibit the monetary policy transmission mechanism depicted in Figure 1. The authorities control a short-term interest rate (rs) with the objective of influencing the rates of inflation (π) and unemployment (u). As shown by the arrows, changes in the policy instrument are transmitted to the policy target variables through several channels. Adjustments in the nominal interest rate can trigger movements in the nominal exchange rate (s), which are transmitted fairly directly to tradable goods prices and inflation and indirectly to unemployment through their effects on the real exchange rate (z) and the gap (y) between actual and potential domestic output. Changes in the nominal interest rate also affect the real interest rate ($rs - \pi^e$), both directly and through the response of inflation expectations (π^e); changes in the real interest rate in turn influence unemployment through their effects on aggregate demand and the domestic output gap; and changes in the output gap and unemployment rate influence the inflation rate through channels summarized by the Phillips curve. In addition, important feedback mechanisms are at work over time, with inflation expectations responding to the history of inflation and inflation influenced in turn by changes in inflation expectations.

[7] Most central banks in inflation targeting countries have released information about how they view the monetary transmission mechanism—for examples, see Longworth (1999), Black and others (1997), and Bank of England (1991a, b).

Figure 1. The Monetary Policy Transmission Mechanism



rs : Nominal short-term interest
s : Nominal exchange
z : Real exchange
y : Output

π : Inflation
π^e: Inflation
u : Unemployment

Figure 1 does not show any feedback mechanisms from the policy target variables to the policy instruments. The task of identifying and implementing a feedback mechanism that is conducive to macroeconomic stability is the responsibility of the monetary authorities. In particular, the role of monetary policy is to react to observed and anticipated changes in unemployment, inflation, and other macroeconomic variables, taking account of the behavioral relationships among these variables.

In reality, the operation of monetary policy is greatly complicated by two types of uncertainties: imperfect information about the magnitudes of the various transmission effects shown in the diagram, and difficulties in identifying the effects on macroeconomic variables of various types of economic shocks. The operation of monetary policy is also complicated by the fact that policy credibility is imperfect and can vary with the effectiveness of the monetary authorities in achieving desirable outcomes for policy target variables. The endogenous behavior of policy credibility and its role in the monetary policy transmission mechanism has not yet been adequately incorporated into the models that have been used to analyze monetary policy issues.[8]

Countries that have adopted IFB targeting have generally embraced the principle that the fundamental role of the monetary authorities is to provide a nominal anchor for the economy. As mentioned above, one of the lessons derived from history is that it can be unproductive to ignore stabilization issues by placing too large a weight on manipulating near-term inflation forecasts. That being said, another important lesson from history is that it can be even more costly to place too high a weight on extremely uncertain measures of unemployment and output gaps—see Laxton and Tetlow (1992); and Orphanides (1998).[9]

Most policymakers believe that experience suggests that large policy errors can result in first-order welfare consequences, but the simple linear macro models that have been used extensively in policymaking institutions imply that there are only second-order welfare consequences associated with monetary policy errors. One place where standard linear models should and can easily be modified is to re-introduce convexity into the short-run Phillips curve, which can be done within the confines of the long-run natural rate hypothesis. The introduction of such convexity gives rise to much more realistic and interesting policy implications insofar as it

[8] See Isard, and Laxton (1999); and Isard, Laxton and Eliasson (1998) for some first steps in this direction. Amano, Coletti, and Macklem (1998), provide a recent analysis of monetary rules that explores the implications of changes in a credibility parameter, but without attempting to model the endogenous behavior of credibility.

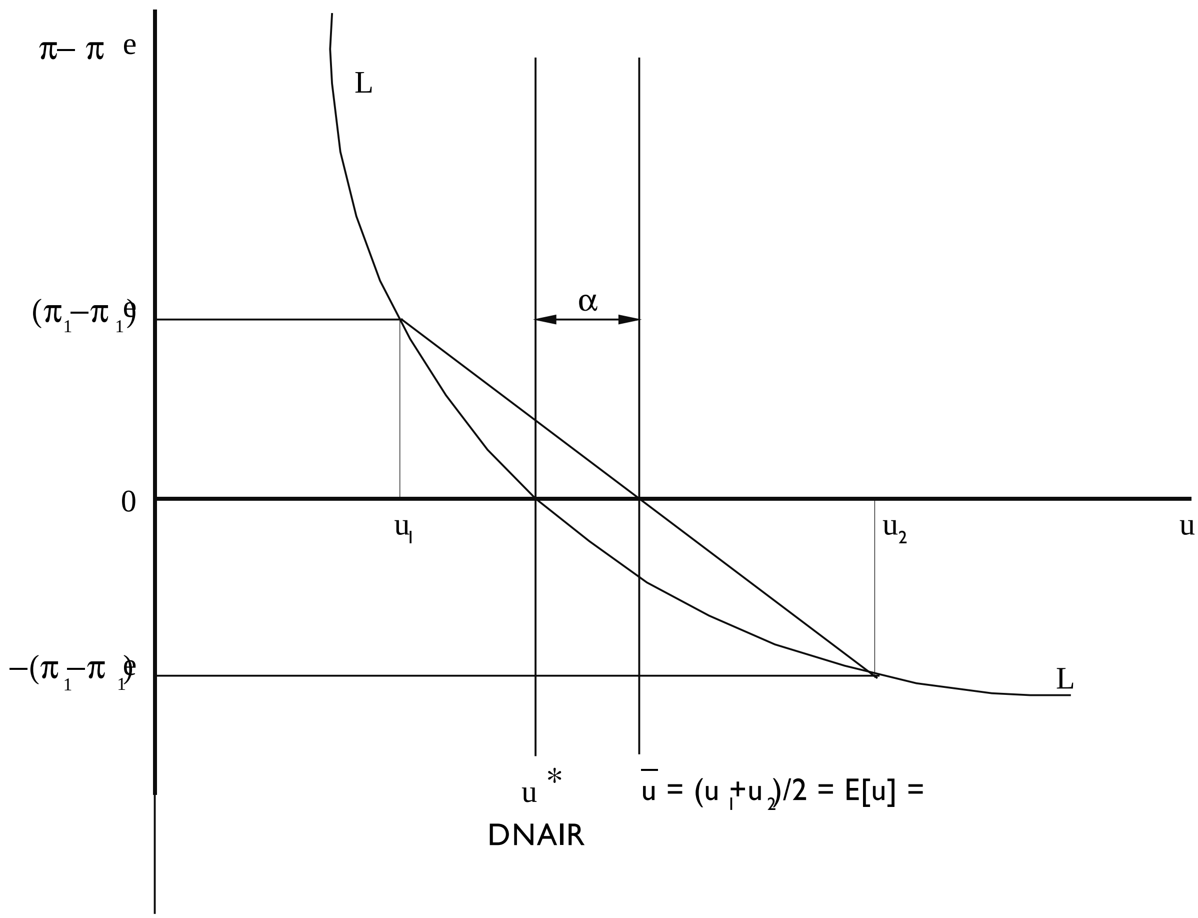
[9]Examples of where linear models have been used to study the implications of uncertainty in the NAIRU or output gap can be found in Wieland (1997), Smets (1999). Drew and Hunt (1999), Isard (1998) and Isard, Laxton and Eliasson (1998, 1999) employ nonlinear models and arrive at different conclusions regarding the potential risks of high degrees of interest rate smoothing that arises from uncertainty about the NAIRU and potential output.

explicitly recognizes that myopic policy rules can have significant effects on both the means and the variances of inflation and unemployment.

Convexity in the short-run Phillips curve implies that the tradition of decomposing unemployment into structural and cyclical components requires modification, as does the traditional discussion of the non-accelerating inflation rate of unemployment—the so-called NAIRU. To illustrate, Figure 2 shows a convex (to the origin) short-run Phillips curve, plotted as a relationship between expectations-augmented inflation (vertical axis) and the unemployment rate (horizontal axis), with expectations-augmented inflation corresponding to the difference between actual and (ex ante) expected inflation. The unemployment rate at which expectations-augmented inflation is zero—labeled u^* in Figure 2 and referred to as the DNAIRU or *deterministic* NAIRU—corresponds to the structural rate of unemployment that would prevail in a deterministic world. It is critical to recognize that the DNAIRU is not a feasible stable-inflation equilibrium in a *stochastic* economy with convexity. The average rate of unemployment that would be associated with non-accelerating inflation (and expectations equilibrium) in a stochastic world—labeled $\bar{u}$ in the figure and referred to as the NAIRU—must lie above the DNAIRU. This is because convexity in the short-run Phillips curve means that inflation rises faster when unemployment is below the DNAIRU than it falls when unemployment is commensurately above the DNAIRU.[10] If u were maintained equal to u^* on average, the asymmetry in the response of inflation to symmetric aggregate demand shocks would make it impossible to maintain a constant average inflation rate.

[10]This type of convexity was an important feature of the original curve introduced by Phillips (1958) and discussed by Lipsey (1960) and several others. Macklem (1996) and Clark and Laxton (1997) provide a brief history of convexity in the Phillips curve and explain why it was overshadowed by other issues.

Figure 2. A Convex Short-Run Phillips Curve



The convex short-run expectations-argumented Phillips curve combined with standard models of inflation expectations implies that stabilization policies that are successful in avoiding boom and bust cycles will reduce the average unemployment rate and raise the average level of output. This can be seen in Figure 2, which has been drawn under the assumption that the unemployment rate is symmetrically distributed around the NAIRU over the range between u_1 and u_2. The important point is that success in reducing the variability of unemployment will also lower its mean value. One can see this immediately from Figure 2 by imagining a tighter control on the dispersion of unemployment. The line LL would move down and to the left and the gap between $\bar{u}$ and u^* would shrink. The key lesson is that stabilization can matter in the sense that policies that either induce or allow extreme variability in the business cycle will also cause a permanently higher NAIRU.

If the degree of convexity in the *short-run* expectations-argumented Phillips curve is independent of the long-term inflation objective, then it will still be true that the *long-run* Phillips curve is vertical and the average unemployment rate will be independent of the target inflation rate. However, if convexity in the short-run Phillips curve becomes greater at very low expected inflation rates, as suggested by Akerlof, Dickens, and Perry (1996), then there may be a permanent trade-off between inflation and unemployment at low inflation rates.

With convex models of the Phillips curve, the analysis of unemployment behavior, in addition to identifying the cyclical variation of actual unemployment around its average rate, needs to recognize that the average rate of unemployment exceeds the structural rate of unemployment by an amount that generally reflects both the nature and the magnitude of economic shocks and the effectiveness of stabilization policies. With convexity in the short-run Phillips curve, stabilization policies can have permanent effects on unemployment and output.[11] When combined with more elaborate models of inflation expectations and imperfect policy credibility, the convex Phillips curve paradigm will hopefully provide a much a richer macroeconomic framework for assessing the effectiveness of alternative monetary policy rules and stabilization policies—see Isard and Laxton, and Eliasson (1998).

A core quarterly projection model

In order to formally implement an inflation-forecast-targeting framework, it is desirable to design and build a core projection model that embodies the consensus views of policymakers about how the economy responds to standard shocks. It is important that this model is easy to understand, but policymakers should be wary of over reliance on highly simplistic reduced-form rule-of-thumb models where there is no fundamental role for the monetary authorities. Relying upon such models may be acceptable when policy is always in the neighborhood of the optimum because, by definition, all policy errors are second order. However, the core projection model must to some extent embody the possibility that monetary policy reactions that do not respond

[11]See Mankiw (1988) and De Long and Summers (1988).

forcefully enough or quickly enough to shocks can lead to shifts in inflation expectations and potentially to first-order welfare losses.

It must also be easy to incorporate judgment into the core projection model by drawing insights either from other types of models or from non-model based monitoring and forecasting of individual sectors. Experience at some central banks suggests that non-model based forecasting is more reliable for very near-term forecasting than pure model based forecasting—see Kohn (1995) and Longworth (1999). Consequently, economists should be prepared to fine-tune the first few quarters of the projection horizon for those variables where more accurate projections can be obtained, and use the judgment and intuition of sectoral specialists to incorporate non-model based information—see Black and others (1997) and Longworth (1999)

There are a number of advantages to having a core projection model. First, it will get people inside and outside central banks speaking the same language, and further improvements can be made by those people that choose to be paradigm builders and paradigm busters. Without a clear core model to serve as a standard of comparison, it is very difficult to judge whether or not good and bad outcomes of the policy process over time are being driven by good and bad luck or by good and bad monetary policy.

Classification of small models that encompass the core model

If there are differences in views about what the properties of the core projection model should be, it would be useful to develop a broader taxonomy of models to represent these alternative views and use this arrangement to help measure the uncertainty in the core projection model. Good examples of where well-informed policymakers could disagree, for example, would be on lags in the monetary transmission mechanism, the role of expectations, and the relative incidence of supply versus demand shocks. There has been a tendency in central banks not to analyze sufficiently the enormous risks associated with a given projection and policy setting.

With the advent of inflation-forecast-based targeting, transparency and openness has created a much better environment for studying and presenting risks. Indeed, although some current-generation inflation reports are far too descriptive and not sufficiently analytical insofar as they stop short of spelling out an acceptable formal macro paradigm, some significant progress has been made in illustrating the uncertainties in the forecast.

A simple model focused to address a well-defined set of issues

Acknowledge that the core projection model is designed to only handle a well-specified set of standard shocks. This is critical, because taking on too many issues with a model runs the risk of it becoming too large and too complicated. If the model becomes a black box, experience has shown that it will soon lose the confidence of policymakers. Again, the structure of the model should be kept simple so that it is easy to embody insights from non-model-based judgment, or from other models that are designed to study the effects of non-standard shocks that appear infrequently (or would excessively complicate the core projection model). The model should not hide weaknesses, nor should it ever fall hostage to methodology that is based either on pure empirics or on theoretical elegance alone.

For a model to be used by policymakers, they must have confidence that it has something useful to say. Given the low power of statistical tests, it is important that the model's parameters and structure be based on an assessment of Type I and Type II policy errors—see Laxton, Rose, and Tetlow (1993). Beware of pure empirics that place linear models on the pedestal and then use low-powered statistical tests to show that they cannot be rejected against models that have much more intuitive policy implications.

Laxton, Rose, and Tambakis (1999) show that recent statistical rejections of convexity in the Phillips curve have been uninformative because researchers have employed measures of business cycle gaps that are inconsistent with implications of convexity. Their paper also shows that identifying convexity in the Phillips curve will become even more difficult if policymakers are successful in avoiding large boom and bust cycles. To the extent that convexity in the Phillips curve is used as a rationale for establishing stabilization policies and for the importance of forward-looking monetary policy rules, their findings present an interesting conundrum, because successful policymakers will further weaken the empirical evidence on which such policies are based.

There are a host of econometric difficulties associated with building models for monetary policy analysis. In the end, it may be more productive and informative to simply calibrate certain parameters based on a more considered view about system properties rather than single equation diagnostic tests.

The implications of uncertainty

Encourage research to understand the implications of uncertainty. An active research agenda, both within and outside the central bank, should be encouraged so as to understand the implications of uncertainty. The Reserve Bank of New Zealand, the Bank of Canada and the European Central Bank have organized conferences to study the implications of uncertainty, and most central banks that have adopted inflation targeting have been prepared to invest significant resources to publish papers that document the structure and properties of their core models—see for example Drew and Hunt (1998), Black, Macklem, and Rose (1997) and Bank of England (1999a). An important benefit of developing a transparent paradigm is that it provides more productive direction for paradigm busters to come up with concrete alternatives that can compete with the core projection model; such a benefit should not be forgotten.

Document and publish errors

Document and publish errors and don't forget them. It is important to document errors from previous paradigms and models to ensure that these errors are not forgotten and repeated in the future.

Adjust the paradigm

Be prepared to adjust the paradigm and core projection model. It is equally important to be prepared to adjust the paradigm and core projection model in response to new experiences and empirical evidence. This process is much easier if the initial paradigm explicitly acknowledges uncertainty.

The low power of statistical tests

Recognize the low power of statistical tests, and don't let the paradigm fall hostage to poor methodology. Enough said.

E. Model Uncertainty and Recent Research on Monetary Policy Rules

The past few years have brought a flurry of papers devoted to studying the properties of simple monetary policy rules in which the short-term nominal interest rate responds directly to measures of both inflation and output gaps. John Taylor of Stanford University has been one of the leading advocates of these types of monetary policy rules, which are now commonly referred to as

Taylor rules. Taylor (1999a) has suggested that the poor performance of the U.S. economy during the late 1960s and 1970s could have been avoided if policymakers had relied upon the simple Taylor rule as a guideline for policy, provided that the rule was calibrated to respond to inflation and output about as aggressively as the interest rate was adjusted in the late 1980s and 1990s. Along similar lines, Levin, Wieland, and Williams (1999) have recently shown that simple rules linking the change in the interest rate to the variables that enter conventional Taylor rules have desirable properties in four different macro models of the U.S. economy. However, as Christiano and Gust (1999) argue, one of the shortcomings of most evaluations of monetary policy rules—including the work of Taylor and Levin, Wieland and Williams—is that the effectiveness and robustness of these rules has only been analyzed in a very small class of IS-LM models. Unlike Levin, Wieland, and Williams, Christiano and Gust conclude that these simple interest rate rules are not robust to model uncertainty. In fact, they argue that it would be very dangerous for policymakers to follow such rules in practice because it would risk a repeat of the great inflation of the 1970s.

Too simple—the conventional Taylor Rule?

Is the Taylor rule too simple to be taken seriously? Yes. The reason that the conventional Taylor rule is too simple, and would be dangerous to adhere closely to in practice, reflects the following considerations.

First, as a general point, the effectiveness of any rule for the nominal interest rate depends critically on its success in preventing significant and prolonged deviations of unemployment from the NAIRU, and in thereby preventing an acceleration of inflation. Adjustments in nominal interest rates influence unemployment largely through their effects on aggregate demand, which are transmitted primarily through the real interest rate.

Second, under the Taylor rule, the level of the short-term nominal interest rate depends on the *current* level of inflation, which serves as both an indicator of inflation expectations and a variable that, in conjunction with either the unemployment gap or the output gap, tells the monetary authorities in which direction, and by how much, they should adjust the real interest rate.

Third, inflation expectations in reality have a significant rational and forward-looking component. By contrast, the Taylor rule is myopic and backward-looking insofar as it embodies the current level of inflation as a measure of inflation expectations.

Fourth, monetary policymakers confront considerable uncertainty about the behavior of the economy. Because estimates of the output gap and the equilibrium level of the real interest rate are imprecise, and because economists tend to make serially correlated errors in estimating the output gap, even the best informed policymakers occasionally come to the realization that they had been misgauging the strength of the economy in the recent past, and that their policy errors have led to a state of significant excess demand or significant excess supply.[12] States of significant excess demand or supply can also result from the economy being hit by large and unanticipated shocks, and from serially-correlated errors in policymakers' attempts to distinguish between the transitory and permanent components of shocks.[13]

Fifth, when an economy is experiencing a state of significant excess demand, the nominal interest rate adjustments that would be dictated by a backward-looking Taylor rule may be insufficient to raise the level of the real interest rate that is perceived by forward-looking market participants, and might therefore allow excess demand to continue to strengthen, accompanied by a continuing upward spiral in market participants' inflation expectations. As elaborated by Isard, Laxton, and Eliasson (1999) in evaluating the Taylor rule calibrations advocated by Taylor (1993, 1999a), in some plausible models it would take only a moderate level of excess demand to break loose the anchor for inflation expectations.

In our view, the conventional Taylor rule is too simple to be taken seriously because it would risk a repeat of the types of monetary policy errors that have been experienced in the past. As Kohn (1999) has emphasized, "certainly central banks would modify reaction functions if they sensed destabilizing behavior." Thus, for an economy that was experiencing significant excess demand, a myopic Taylor rule in a world of forward-looking agents would simply not be a credible guideline for monetary policy.

The role of monetary policy and lessons learned from historical policy errors

What is the role of monetary policy and what lessons have we learned from historical policy errors? What types of macroeconomic models should be admissible for evaluating the performances of monetary policy rules? In *linear* macro models that embody the long-run natural

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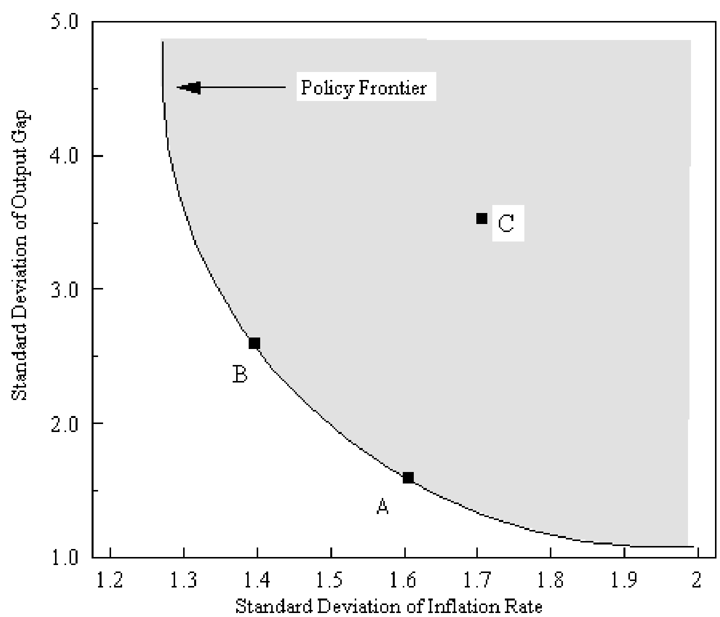
[12]For a discussion of the historical errors in estimating potential output and the NAIRU in Canada and the United States, see Laxton and Tetlow (1993) and Orphanides (1998, 1999).

[13]As elaborated below, in macro models that are globally linear, states of significant excess demand or supply do not pose risks of large and undesirable consequences (i.e., overheating or deflation). In such linear models, Taylor rules—which are linear functions of the current level of the inflation rate and the output gap (or unemployment gap)—typically embody all the information that is required to forecast inflation and stabilize the business cycle; hence, Taylor rules tend to work very well in linear models. For nonlinear models, by contrast, a rule that depends on current (or past) inflation and output gaps generally must be a nonlinear function of these variables to work well in maintaining macroeconomic stability (see Schaling, 1998, and Clark, Laxton, and Rose, 2000), although linear functions of (model-consistent) inflation forecasts and output gaps can work well as policy rules in some nonlinear models (see Isard, Laxton, and Eliasson, 1999).

rate hypothesis, monetary policy does not affect the average level of output, but it does influence the variances of the output gap (i.e., the gap between actual output and potential output) and the inflation rate. Accordingly, the role of monetary policy is often described in terms of a simple chart like Figure 3, popularized by Taylor, which shows the minimum standard deviation of the output gap that is feasible for any standard deviation of the inflation rate.[14] In terms of Figure 3, the role of monetary policy can be characterized as the task of insuring that the economy reaches some point on (or acceptably close to) this policy frontier, where the optimal point on the frontier depends on society's preferences. This role is equivalent to, and is sometimes described more formally as, minimizing a quadratic loss function that is separably additive in the squared output gap and the squared deviation of inflation from target.[15]

Figure 3: Policy Frontier Derived From the Federal Reserve Board of Governors' Econometric Model of the U.S. Economy



Source: Reifschneider, David, Robert Tetlow, and John Williams, 1999, "Aggregate Disturbances, Monetary Policy, and the Macroeconomy: The FRB/US Perspective," Federal Reserve Bulletin, January, pp. 1-19.

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[14]The policy frontier in Figure 3, which has been taken from Reifschneider, Tetlow, and Williams (1999), was derived for the Federal Reserve Board's FRB/U.S. model of the U.S. economy.

[15]Within the four of models considered by Levin, Wieland, and Williams (1999) the optimal calibrations of simple interest rate rules for one model also tend to perform relatively well in the other models in the sense that they generate standard deviations (of inflation and the output gap) that are relatively close to the policy frontiers for the other models.

This view of the role of monetary policy, along with the underlying macro models that support such a characterization, fail to focus on the “possibility” that monetary policy in reality can have substantial and prolonged effects on the average levels of inflation and output gaps. Most central bankers and economic historians would assert that such effects are a clear reality, not simply a possibility. Linear macro models that do not reflect this possibility risk seducing policymakers into a repeat of the large monetary policy errors of the past and should not be admissible for evaluating the performances of monetary policy rules.[16]

Several types of nonlinearities seem relevant in efforts to develop admissible models for monetary policy evaluation. One potentially important element of nonlinearity is the Phillips curve—see, for example, Debelle and Laxton (1997), Laxton, Rose, and Tambakis (1999), and Clark, Laxton, and Rose (2000). A second potentially important element of nonlinearity is the endogenous nature of monetary policy credibility and the apparent asymmetry in the speeds with which the gap between expected inflation and actual inflation responds to the track record of the monetary authorities; see Isard and Laxton (1998) and Isard, Laxton, and Eliasson (1998). Still another important source of nonlinearity, sometimes alluded to as a “liquidity trap,” is the fact that monetary policy cannot push nominal interest rates below a floor of zero; see Laxton and Prasad (1997, 1999) and Sims (1999).

One of the key lessons from history, which reflects both *lags* in the transmission of monetary policy to output and inflation and *nonlinearities* in the output-inflation process, is that it is important for monetary policy to be forward-looking, and to try to take account of all available information that has a significant bearing on the future paths of inflation and output; see Mussa (1994) and Clark, Laxton and Rose (2000). Myopic policy responses to available information can have potentially large costs in terms of output and inflation.

A second key lesson from history is that uncertainty is important. Failing to account adequately for uncertainty about the level of potential output, or about the level of the NAIRU, can lead the monetary authorities to adjust interest rates too aggressively in response to estimated output or unemployment gaps, and would risk a repeat of the policy errors of the 1970s, when many central banks provided excessive monetary accommodation in response to inaccurate estimates of the NAIRU and potential output; see Laxton and Tetlow (1992) and Freedman (1996).

A third lesson is that, in evaluating monetary policy strategies, it is important to distinguish between ex ante policy mistakes and ex post policy mistakes. For example, while some may regard the Federal Reserve Board’s “pre-emptive strikes” to raise U.S. interest rates in the Fall and Winter of 1994–95 as, in retrospect, unnecessary or excessive, it would not be appropriate to characterize those policy actions as ex ante mistakes, given the information that the Federal

[16]For critiques of policy analysis based on models with linear Phillips curves, see Summers (1988), DeLong and Summers (1988), and Laxton, Rose, and Tambakis (1999). While models that presume global linearity may be useful for short-term forecasting, models designed for policy analysis must allow for the possibility that poorly conceived policies can result in deficient outcomes.

Reserve was acting upon at the time. Ex post, the case for those actions has been weakened by the combination of downward reductions in estimates of the NAIRU and the greater-than-expected slowdown in U.S. economic activity during the first half of 1995 (partly reflecting spillovers from the economic crisis in Mexico). But ex ante, the case for such pre-emptive strikes can be argued on the basis of a combination of NAIRU uncertainty, asymmetries in the unemployment-inflation process, and significant lags in the monetary transmission mechanism (Isard and Laxton, 1998).[17]

The robustness issue

Has the robustness issue been explored adequately? No. As Christiano and Gust (1999) argue, the four models that Levin, Wieland, and Williams (1999) have explored are all quite similar insofar as they all belong to the class of sticky-price IS-LM models. Moreover, as noted above, most evaluations of monetary policy rules have relied on linear macro models. We have shown that small extensions to the structures of the models studied by Levin, Wieland, and Williams (1999) to account for nonlinearities in the unemployment inflation process and uncertainty in the NAIRU can give rise—under either the conventional Taylor rule or the rule advocated by Levin, Wieland, and Williams—to large boom and bust cycles, or to extreme instabilities in inflation expectations; see Isard, Laxton, and Eliasson (1998).

Problems with the optimal policy rules

What are the specific problems with the optimal policy rules derived from simple linear IS-LM Rational Expectations Models? A considerable amount of time has been devoted to studying the effectiveness and robustness of simple interest rate rules in a class of simple linear IS-LM Rational Expectations models. As noted above, one important lesson from history is that it is important for monetary policy to be forward-looking in order to prevent large boom and bust cycles. The optimal reaction functions derived from these simple linear IS-LM Rational Expectations models are extremely myopic, and we agree with Christiano and Gust that blindly following such rules would risk a repeat of the types of monetary policy errors that have been experienced in the past.

The types of models that have been used by Levin, Wieland, and Williams (1999) and several others have two basic problems that make them ill-equipped for studying alternative policy rules.

[17]In Congressional testimony explaining the 1994–95 interest rate actions, Federal Reserve Chairman Greenspan (1995) professed that it could be potentially costly to delay an interest rate hike: "In modern economies output levels may not be so rigidly constrained in the short run as they used to be when large segments of output were governed by facilities such as the old hearth steel furnaces that had rated capacities that could not be exceeded for long without breakdown. Rather, the appropriate analogy is a flexible ceiling that can be stretched when pressed, but as the degree of pressure increases, the extent of flexibility diminishes." These arguments apply to guarding not only against overheating but also against serious overcooling where economies are more sensitive to the risks of deflationary shocks; see Laxton, and Prasad (1997).

First, the models presume that the monetary policy rule is always perceived to be fully credible by the public, even when the monetary authorities respond myopically to inflation developments or place a very large relative weight on real objectives. Second, in this class of models, myopic policy rules only have second-order welfare implications. In our view, any serious model of the economy advanced for studying alternative monetary policy rules must embody the notions that the timing of monetary policy is essential, and that myopic policy responses can, in practice, have significant first-order welfare implications for the economy.[18] We agree with Christiano and Gust (1999) that research should be directed away from fine-tuning optimal policy reaction functions in models where there is no real role for monetary policy to focus on a much broader set of models in order to develop strategies for attempting to avoid large policy errors that can result in first-order welfare losses.

In the spirit of Christiano and Gust (1999), we illustrate the problems with optimal policy rules derived from simple IS-LM Rational Expectations models, by reporting the Blanchard-Kahn (1980) saddle-point stability conditions for two classes of interest rate rules in the context of one of the linear forward-looking models that Levin, Wieland, Williams (1999) used to investigate the robustness properties of such rules.[19] We show that both classes of rules produce saddle-point stability over an enormous range of parameter values.

Rule 1: Conventional Taylor Rule Generalized for Interest Rate Smoothing

Figure 4 reports the combinations of parameter settings that lead to unique, explosive, and indeterminate solution paths in the Fuhrer-Moore (1995b) model under a conventional Taylor rule that has been generalized to allow for interest rate smoothing.

This rule can be written as:

$$rs_t = \rho\, rs_{t-1} + (1-\rho)[w_\pi(\pi 4_t) + w_y(y_t)] \tag{1}$$

where rs_t is the nominal interest rate setting at time t; $\pi 4_t$ which is the average inflation rate over the previous four quarters; y_t represents the output gap in the Fuhrer-Moore model; and ρ, w_π, w_y

[18]For example, in nonlinear models of the unemployment-inflation process, a failure to prevent large boom and bust cycles will result in a permanently higher level of unemployment; see Mankiw (1988).

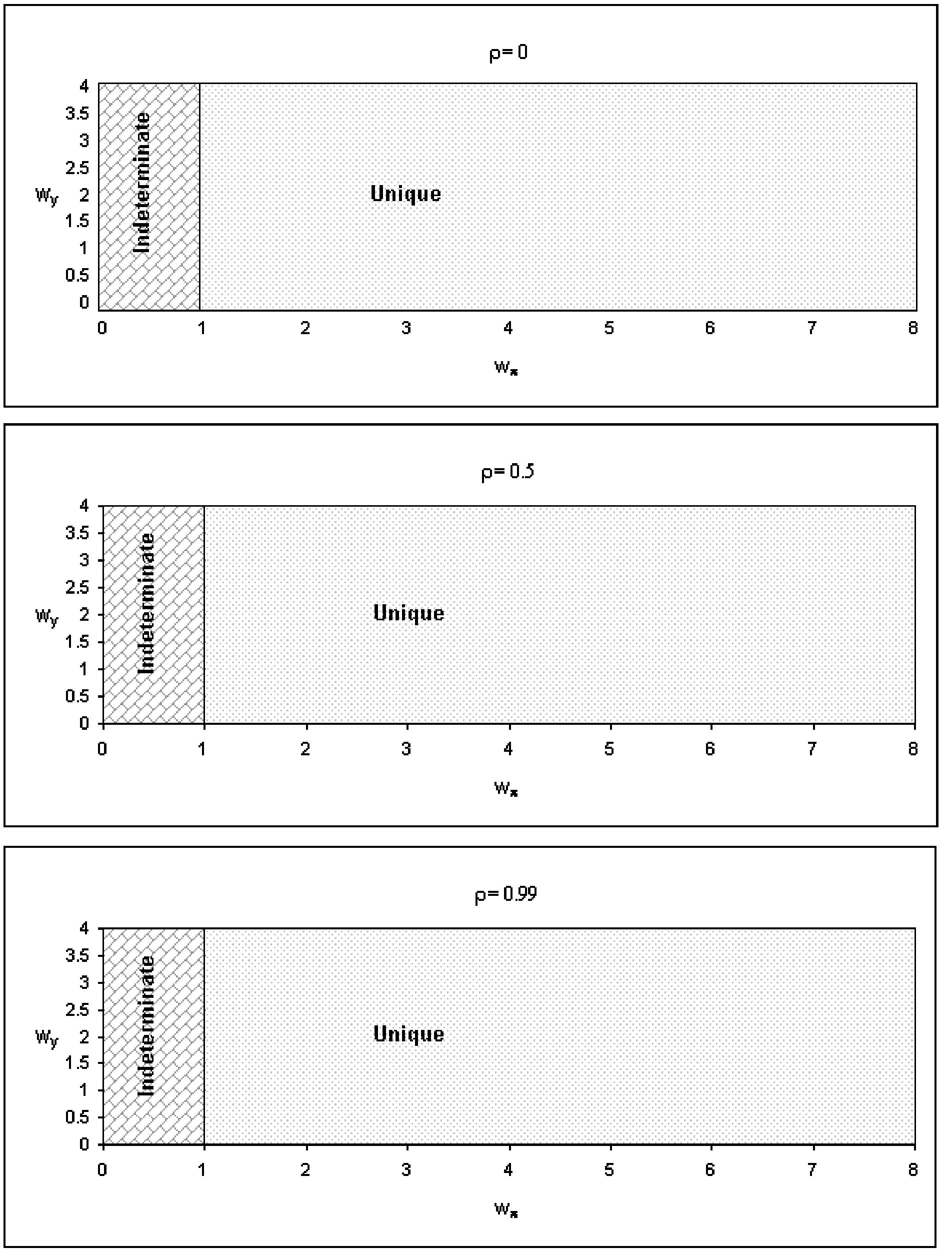
[19]The specific model was developed by Fuhrer and Moore (1995a, 1995b). We chose this model because it was more easily accessible than the other models considered by Levin, Wieland, and Williams (1999). We are indebted to Jeffrey Fuhrer for taking the time to help us replicate some of his earlier results. The results reported in this paper have been derived from the parameter estimates reported in Fuhrer and Moore (1995b).

are parameters.[20] Note that the interest rate reaction function has been coded so that the parameters w_π and w_y represent asymptotic long-run responses of the interest rates to the year-over-year inflation rate and the output gap.[21]

[20]It is convenient here to follow Taylor (1993) in defining the rule in terms of the output gap rather than the unemployment gap. For notational convenience we have dropped the constant term in the equation by assuming that the equilibrium real interest rate and long-run inflation target are zero.

[21]For example, the long-run effects of a permanent unitary change in the output gap is equal to the short-run effect, $(1-\rho)w_y$, divided by $(1-\rho)$.

Figure 4: Regions of Uniqueness, Explosiveness and Indeterminacy
(Generalized Taylor Rule in Fuhrer and Moore (1995) Model)
Policy Reaction Function: $rs_t = \rho rs_{t-1} + (1-\rho)[w_\pi(\pi 4_t) + w_y(y_t)]$



A striking feature of Figure 4 is that for a very wide range of parameter values—and independently of the speed with which monetary policy reacts to inflation and output gaps (i.e., independently of ρ)—the model has a stable and unique solution. Indeed, the stability properties of the generalized Taylor rule in this linear rational expectations IS-LM model are extremely simple. The only condition necessary for stability and uniqueness is that the long-run response of the interest rate to year-over-year inflation must be greater than one. Provided this condition is met, even a Taylor rule that reacts much more aggressively to output than to inflation and allows inflation to drift persistently above the target will provide an anchor for inflation expectations in the Fuhrer-Moore model.

What is it that explains the "excessive stability" generated by conventional Taylor rules in these sticky-price linear rational expectations models? What gives rise to stable macroeconomic behavior even when the monetary authorities respond in a very myopic way to inflation developments, or place an extremely high weight on real objectives relative to inflation objectives? Two assumptions appear to be critical here. The first is the assumption that the economy can be characterized by a Phillips curve that imposes global linearity.[22] The second is the premise—embodied in the simulation exercise—that no matter how myopic policy responses are in the short run, the private sector forms its expectations under the assumption that the monetary policy rule will be adhered to forever.

Isard, Laxton, and Eliasson (1998) study the implications of uncertainty about the NAIRU in a nonlinear Phillips curve model and show that following a Taylor rule blindly, not only would fail to prevent the policy errors of the 1970s but also would almost certainly ensure that they would occur again. For the nonlinear model considered in their paper, even moderately myopic policy rules like the conventional Taylor rule can result in explosive behavior if the economy is subjected to a significant degree of overheating. This reflects a combination of factors. First, even moderate convexity in the Phillips curve implies that at some point the short-run unemployment-inflation tradeoff must worsen considerably when unemployment falls significantly below the NAIRU, and beyond this point a further marginal easing of monetary policy results mainly in inflation with only a very small incremental reduction in unemployment.

Second, to the extent that policymakers tend to make serially correlated errors in estimating unemployment and output gaps, the probability of experiencing a significant degree of overheating is heightened.[23] Third, when inflation expectations have a model-consistent

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[22]Under the global linearity assumption, the estimated slope of the Phillips curve (based on post-war U.S. data) suggests that unemployment or output gaps have small effects on the inflation process. These small effects imply that it can be very costly, in the context of these models, to reduce inflation once high inflation expectations have become entrenched. It also means that for given inflation expectations, the marginal effect on inflation of an increase in excess demand is small, even when the level of excess demand is high.

[23]One important shortcoming with the analysis provided by Taylor (1999a), and Levin, Wieland, and Williams (1999) is that it reflects a strong inherent presumption that policymakers do not make large and persistent errors in estimating output gaps and unemployment gaps.

component and rational agents possess information about the policy rule and the nonlinear nature of the expansionary effects of monetary policy, attempting to adhere to a conventional Taylor rule with a high weight on imprecise measures of unemployment gaps relative to a backward-looking measure of inflation could be conducive to wide swings or explosiveness in inflation expectations.

As is evident in Figure 4, one of the striking features of the stability conditions for the Fuhrer-Moore model is that they appear to be independent of the degree of interest rate smoothing. This points to a general problem with linear models of the inflation process, which imply that slow monetary policy responses to information about future inflation developments only have second-order welfare consequences. Isard, Laxton, and Eliasson (1998) also show that these stability problems are exacerbated when interest rate smoothing is imposed on an already myopic policy rule.

Rule 2: Levin, Wieland, and Williams Interest-Rate-Change Rule

Figure 5 reports the regions of stability for the class of interest-rate-change rules suggested by Levin, Wieland, and Williams (1999). In this case, the general form of the reaction function is:

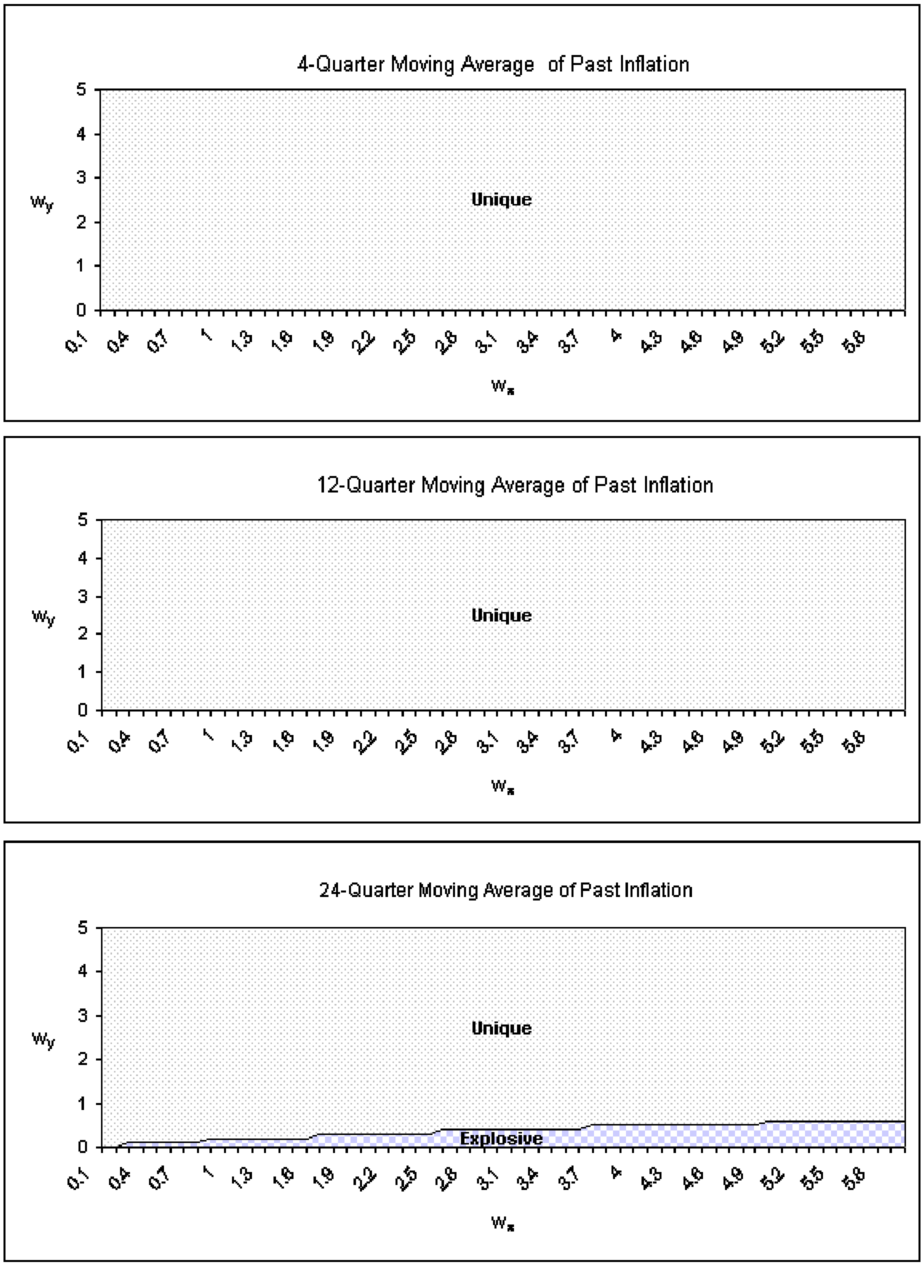
$$rs_t = rs_{t-1} + (w_\pi(\pi n_t) + w_y(y_t)) \tag{2}$$

where πn_t is an n-quarter moving average of inflation measured over the previous n quarters. The top and middle panels of Figure 5 consider the two optimal rule parameterizations reported by Levin, Wieland and Williams (1999), where n is equal to 4 quarters and 12 quarters; the longer lag structure on inflation was found to be optimal in a linearized version of the FRB-US model, while the shorter lag structure was found to be optimal in the other linear models that they included in their study. In this case again, even where there is extreme interest rate smoothing and monetary policy responds to very backward-looking measures of inflation, the linear model is stable for an incredibly wide range of weights on inflation and output. The lower panel of Figure 5 considers an even more extreme case of myopic reaction functions, where the reaction function now depends on a six-year moving average of past inflation. Here there is some evidence of instability in the model; but unlike the type of results found by Christiano and Gust (1999), in this case explosiveness can arise from setting too low a weight on output.

Figure 5: Regions of Uniqueness, Explosiveness and Indeterminacy

(LWW Rule in the Fuhrer and Moore Model)

Policy Reaction Function: $rs_t = rs_{t-1} + w_\pi(\pi 4_t) + w_y(y_t)$



In contrast to the impressive stabilization properties suggested by Figure 5, the interest rate change rule has extremely poor stabilizing properties in the nonlinear model developed studied by Isard, Laxton, and Eliasson (1999), for two reasons. First, the rule is so myopic and backward-looking that it fails to provide an anchor for inflation expectations. Second, even if one recalibrates the model to reduce the effects of overheating very substantially, an optimal "parameterization" of the Levin, Wieland and Williams (1999) rule still gives rise to significant boom and bust cycles.

It does not seem to be widely recognized that interest-rate-change rules such as equation 2 are exactly equivalent to targeting a trend change in the price level when w_y =0, and result in approximate price level targeting for small values of w_y. To see this, consider a simple case in which the interest rate change depends solely on the quarterly change in the logarithm of the price level (P) expressed at an annual rate:

$$rs_t = rs_{t-1} + w_\pi \pi_t \tag{3}$$

where $\pi_t = 4(P_t - P_{t-1})$. As initial conditions, assume that inflation is on target and the real interest rate is at its equilibrium value (i.e., in period 0, rs_0 = rs* and $\pi_0 = \pi^* = \pi^e$,where * denotes equilibrium).

Now assume that a demand or supply shock raises the inflation rate in period 1 to some arbitrary value π_1. It is interesting, and perhaps even surprising, that monetary policy governed by equation 3 would attempt to move the price level back to the original baseline path. This will be the case, for example, if long-run neutrality holds (as Levin, Wieland, and Williams claim for each of the models they consider), because long-run neutrality implies that the real interest rate must return back to its initial value. But if the real interest rate returns back to control, the nominal interest rate must also eventually return back to control in some period T since, by assumption, the rule is successful in moving inflation back to its initial level of π^*.

If we now sum equation 3 between periods 1 and T, we obtain:

$$rs_T - rs_0 = w_\pi \sum_{i=1}^{T} \pi_i \tag{4}$$

So $rs_T - rs_0 = 0$ implies

$$\sum_{i=1}^{T} \pi_i = 0 \tag{5}$$

Thus, under the assumption that long-run neutrality holds, a policy rule in the form of equation 3 essentially amounts to a price-level targeting rule, since any shock that generates positive inflation must be offset at some point by negative inflation rates. This result obviously carries over to cases in which the contemporaneous inflation rate in equation 3 is replaced by some finite moving average lag structure on past inflation; and even when the rule is extended to include a term in the output gap, as in the general form of interest rate change rules described by equation 2, it continues to bear a close resemblance to price-level targeting. Accordingly, it should not be surprising that such myopic interest rate change rules can generate extremely poor business cycle properties in models with strong inflation persistence and convexity in the Phillips curve.

No policy rules apply

What types of rules, if any, should policymakers rely upon? They should not rely mechanically on any monetary policy rule. Fully state-contingent policy rules are not relevant possibilities in a world of incomplete information about the structure of the economy and the nature of shocks, and there is no clearly superior choice between simple (or partially state-contingent) rules and discretion; see Flood and Isard (1989).

We believe that the effectiveness and credibility of monetary policy can be greatly enhanced if policymakers are transparent about their policy objectives, their paradigm (or model) of macroeconomic behavior, their forecasts, and their assessments of the risks. As discussed earlier, it is also critically important for policymakers to be forward-looking, and to adjust their nominal interest rate instrument based on forward-looking assessments of inflation expectations and real interest rates.

Some research has suggested that simple linear inflation-forecast-based rules can come close to optimizing traditional forms of explicit policy objective functions in the context of plausible nonlinear macro models; see Isard and Laxton (1999) and Isard, Laxton, and Eliasson (1999). Additional research into the effectiveness and robustness of inflation-forecast-based rules may be worthwhile and useful for highlighting risks and avoiding the types of errors that have been made in the past. But with the continuing evolution of the world economy and the periodic occurrence of new types of economic shocks, there will inevitably be times when our best macroeconomic models are recognized to be seriously deficient and when continued adherence to policy rules associated with those models would have strongly adverse welfare consequences. Thus, while simple inflation-forecast-based policy rules may provide useful guidelines for policymakers in attempting to achieve their policy objectives, discretion is also important.

F. A Small Model of the Czech Economy

This section uses a small open economy model of the Czech economy to illustrate how small macro models can be used to support Inflation Targeting. We first specify a small macro model of the economy and show how a macro model, once specified, can be used to develop a forward-looking monetary policy reaction function. Then, given this reaction function we illustrate some of the properties of the model and show how it can be used to derive confidence intervals around the forecasts for inflation and the short-term interest rate.

Table 1 presents the equations of the model and Table 2 defines notation and time periods correspond to calendar quarters. Most of the equations in Table 1 reflect behavioral assumptions; the others amount to definitions or arbitrage conditions. While the parameters of the model have been calibrated to be consistent with some empirical work done at the Czech National Bank (CNB), we emphasize that this version of the model—which is intended for illustrative purposes—is preliminary and does not represent the official views of policymakers at the CNB. Nevertheless, it is hoped that the development of simple models, such as the one studied here, will provide a useful start in moving toward a complete forecasting and policy analysis system which explicitly recognizes the important roles of structure, judgment and uncertainty.

The Phillips curve

Equation (1) is a nonlinear Phillips curve that describes the behavior of the inflation rate, where inflation in period t is measured as the change in the log of the price level over the year from period t-4 through period t. The specification is based on a convex functional form proposed by Chadha, Masson and Meredith (1992) and studied by Laxton, Meredith and Rose (1995). The model posits that the short-run tradeoff between output and inflation is roughly linear when output is in the neighborhood of potential, but that the tradeoff starts to worsen considerably as the output gap rises above 2 percent.[24] Indeed, in the limit as the output gap approaches 6 percent, the economy is assumed to run into a short-run capacity constraint and the short-run Phillips curve becomes vertical. This estimate of the degree of potential short-run capacity in the model is reflected in the parameter estimate of .06 in equation (1) and has been calibrated to be consistent with estimates of capacity limits derived from pooled estimation from the group of major industrial countries—see Laxton, Meredith and Rose (1995).[25] The effects of output gaps in the region where the Phillips curve is roughly linear has been calibrated to be consistent with estimates provided by economists at the CNB.[26] The Phillips curve specification allows for a significant influence of the contemporaneous change in import prices, reflecting a very large share of imported goods in the basket of the price index that the CNB targets. Note that the coefficients of the first two right-hand-side terms sum to unity, consistent with the long-run natural rate hypothesis.

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[24] The output gap in the model is defined to be the log of GDP minus the log of potential GDP.

[25] There is obviously considerable uncertainty about this estimate of the short-run capacity constraint because a fundamental role of the monetary authority is to be forward-looking and to prevent the economy from getting to close to it. Indeed, Laxton Rose and Tambakis (1999) show that this presents an interesting conundrum for policymakers because policies which are successful at stabilizing the business cycle and avoiding large boom and bust cycles will actually destroy the empirical evidence on which these good policies are based.

[26] Despite the problems inherent in attempting to estimate nonlinear Phillips curves with a limited number of observations it might still be useful to attempt such a study for the countries in transition.

Inflation expectations and other sources of inflation persistence

Equation (2) is a fairly standard forward- and backward-looking representation of the private sector's inflation expectations. In line with other work on empirical Phillips curves, it features a small weight on the forward-looking, model-consistent component. The large weight on the backward-looking component is consistent with the view that wages and prices are sticky, reflecting in part the influence of contractual arrangements, but in addition the presence of a large proportion of the population that is uninformed. This estimated weight is roughly consistent with reduced-form evidence on Phillips curves for other countries, which also suggests a very small weight on the forward-looking or model-consistent component.[27]

The output gap and real monetary conditions

Equation (3) relates the output gap to its own lagged value and a lagged measure of real monetary conditions. The measure of real monetary conditions is assumed to depend on the real exchange rate and an average real interest rate term that places a weight of 0.75 on the 1-year real interest rate and a weight of 0.25 on a 3-year real interest rate—see Equation (4). These elasticities are based on estimates provided by economists at the CNB and suggest that the effects of a 100 basis point increase in the average real interest rate on the output gap is equivalent to a 1.7 percent appreciation in the real effective exchange rate.

Real interest rate definitions

Equations (5) and (6) define the one-year (4-quarter) and three-year (12-quarter) real interest rates. Equation (7) defines abbreviated notation and equation; and equation (8) defines an average three-year-ahead measure of inflation expectations in a manner consistent with the behavior of one-year ahead of inflation expectations, as described in equation (2). The first term on the right-hand-side of equation (8) is the model-consistent component of the annualized inflation rate expected over the next 12 quarters, which receives a weight of 0.10, while the backward-looking component receives a weight of 0.9.

Exchange rate and interest rate determination

Equation (9) defines the real exchange rate; an increase represents a real appreciation of the domestic currency. Equation (10), which includes an error term, can be regarded as a generalized form of the interest rate-parity arbitrage condition. Equation (11) assumes that the future spot rate expected by the private sector is a weighted average of the forward-looking model-consistent expectation and a component that is essentially backward-looking. The latter component is simply the lagged spot rate adjusted for the expected inflation differential.[28] This specification provides a way of reconciling the notion that market participants are rational and

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[27] For example, see J. Fuhrer (1997).

[28] Adjustment for the expected inflation differential is necessary for ensuring that the behavior of the real exchange rate is independent of the target rate of inflation.

forward looking with econometric evidence that exchange rates cannot be explained very well by macroeconomic fundamentals alone. It is also motivated by survey evidence that participants in foreign exchange markets rely heavily on "technical analysis," which essentially links their exchange rate forecasts (expectations) to the level of exchange rates in the recent past.[29] Equation (12) and equation (13) represent the expectations theory of the term-structure, which relates the yield on four-period and twelve-period maturities to the cumulative yield on a sequence of one-period contracts. However, as is the case with the foreign exchange market it is assumed that the weight on the model consistent solution is 0.40 suggesting that a large proportion of bond market participants are myopic and base their expectations of future short-term interest rates on a simple extrapolation of the currently observed rate. Note, however, that a key aspect of the model is that expectations are assumed to adjust considerably faster in the bond market and foreign exchange market (weights of 0.4 on the model-consistent solutions) than they do in the goods market and the labor market (weights of 0.1 on the model-consistent solutions in the inflation expectation equations).

Other definitions

Equation (14) simply defines the inflation rate as the change in the price level over four quarters, and equation (15) is an analogous definition of the rate of inflation of import prices (i.e., of foreign prices converted into domestic currency units).

Closing the model with a monetary policy reaction function

The model can only be closed by specifying a policy reaction function for the monetary authorities. While the fundamental role of the monetary authorities in the model is to provide an anchor for inflation expectations, the nonlinear structure of the Phillips curve also suggests that there can be first-order benefits from stabilizing the business cycle. As shown by Clark, Laxton and Rose (2000) the combination of nonlinearity in the Phillips curve and lags in the monetary transmission mechanism suggests that there can be important benefits from following a forward-looking monetary policy reaction function and for this reason we focus our attention on inflation-forecast-based rules.[30]

The optimal calibration of an inflation-forecast-based (IFB) rule

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[29] See Isard (1995).

[30] Clarida, Gali and Gertler (1997) provide some econometric evidence that suggests that monetary policy in several countries since 1979 seems to be guided more by forecasts of future inflation as opposed to contemporaneous or lagged inflation.

Table 3. Optimal Calibrations of an Inflation-Forecast-Based Rule

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Inflation-Forecast-Based Rule:

$$rs_t = \lambda rs_{t-1} + (1-\lambda)\left[rr_t^* + \pi 4_{t+4} + \alpha(\pi 4_{t+4} - \pi^*) + \beta y_t\right] \text{ for } 0 \le \lambda < 1$$

$$rs_t = \lambda rs_{t-1} + \alpha(\pi 4_{t+4} - \pi^*) + \beta y_t \text{ for } \lambda = 1$$

Notation

rs	=	policy interest rate
rr*	=	measure of equilibrium real interest rate
π	=	inflation target
$\pi 4$	=	rate of inflation over previous four quarters
y	=	output gap

Optimized Weights

Weights			Variability Measures (Standard Deviations)		
λ	α	β	Inflation	Output Gap	Policy Rate
1.00	6.95	0.70	1.56	1.23	3.04

The specific forms of the IFB rules are presented in Table 3. In these rules the short-term rate, rs, is assumed to be controlled directly by the monetary authorities and is adjusted in response to their one-year-ahead forecast of inflation ($\pi 4_{t+4}$), the contemporaneous value of the output gap (y) and an equilibrium measure of the short-term real interest rate (rr*).[31] The two reaction functions also include a lagged short-term interest rate term to allow for interest rate smoothing. In the first reaction function the weight on the lagged interest rate term in principle can vary between zero and some value below one, while in the second reaction function the weight on the lagged interest rate term is imposed to be exactly one. Note, that in this last case the measure of the equilibrium real interest rate (rr*) drops out of the equation and the reaction function becomes an interest-rate-change rule where the change in interest rates responds only to deviations of forecast inflation from the target inflation rate and to the contemporaneous output gap. The optimal calibration of the IFB rule is determined by specifying a loss function and studying the properties of the model presented in Table 1 and 2 under different assumptions for the parameters in the IFB rules.

[31] Once the model has been developed further it would be interesting to search for the optimal horizon of the inflation forecast in the IFB rule.

Table 1: A Small Model of the Czech Economy

(1) $\pi 4_t = 0.25 \pi 4_t^m + 0.75 E_t^P \pi 4_{t+4} + 0.30\,[(0.06)^2 / (0.06 - y_{t-1}) - 0.06] + \varepsilon_t^\pi$

(2) $E_t^P \pi 4_{t+4} = 0.10\ E_t^{mc} \pi 4_{t+4} + (1.0 - 0.10)\, \pi 4_{t-1}$

(3) $y_t = 0.80\, y_{t-1} - rmci_{t-1} + \varepsilon_t^y$

(4) $rmci_t = 0.30\,(0.25\, rr4_{t-1} + 0.75\, rr12_{t-1}) + 0.20\, z_{t-1} + \varepsilon_t^y$

(5) $rr4_t = rs4_t - \pi 4_t^e$

(6) $rr12_t = rs12_t - \pi 12_t^e$

(7) $\pi 4_t^e = E_t^p\ \pi 4_{t+4}$

(8) $\pi 12_t^e = E_t^p\, \pi 4_{t+12} = 0.10\,(E_t^{mc} \pi\, 4_{t+4} + E_t^{mc} \pi 4_{t+8} + E_t^{mc} \pi 4_{t+12})/3 + (1 - 0.10)\, \pi 4_{t-1}$

(9) $z_t = s_t + p_t - p_t^f$

(10) $s_t = E_t^P s_{t+1} + (rs_t - rs_t^f)/4 + \varepsilon_t^s$

(11) $E_t^P s_{t+1} = 0.40\ E_t^{mc} s_{t+1} + (1 - 0.40)\left[s_{t-1} - (E_t^P \pi_{t+1} - E_t^P \pi_{t+1}^f)/2\right]$

(12) $rs4_t = 0.40 \sum_{i=0}^{3} rs_{t+i}/4 + (1 - 0.40)\, rs_t$

(13) $rs12_t = 0.40 \sum_{i=0}^{11} rs_{t+i}/12 + (1 - 0.40)\, rs_t$

(14) $\pi 4_t = p_t - p_{t-4}$

(15) $\pi 4_t^m = (p_t^f - p_{t-4}^f) - (s_t - s_{t-4})$

Table 2. Notation; Time Periods Correspond to Calendar Quarters

$\pi 4_t$	:	Change from *t-4* to *t* in the log of the net price deflator (Emil ?)
$\pi 4_t^m$	:	Change from *t-4* to *t* in the log of the import price deflator.
$E_t^P \pi 4_{t+4}$	:	Private sector's expectations in quarter *t* of inflation over next four quarters.
$E_t^{mc}\, \pi 4_{t+\tau}$	:	Model consistent expectations in quarter *t* of inflation over four quarters ending in $t+\tau$.
$\pi 12_t^e$	:	Expectations in quarter *t* of inflation over next twelve quarters.
$\pi 4_t^e$	:	Expectations in quarter *t* of inflation over the next four quarters.
y	:	Output gap.
ε^{π}	:	Shock in inflation equation.
ε^{y}	:	Shock in output gap equation.
ε^{s}	:	Shock in exchange rate equation.
z	:	Log of the real exchange rate
s	:	Log of the nominal exchange rate.
p	:	Log of RPIX deflator.
pf	:	Log of foreign price level.
rs	:	Short-term (one quarter) nominal interest rate.
rsf	:	Foreign short-term nominal interest rate.
$E_t^p \pi_{t+1}$	:	Private sector's expectations in quarter *t* of inflation one quarter ahead.
$E_t^p \pi_{t+1}^f$	:	Private sector's expectations in quarter *t* of foreign inflation one quarter ahead.
$E_t^{mc}\, s_{t+1}$	:	Model consistent expectation at *t* of exchange rate at *t + 1*.

$E_t^p S_{t+1}$: Private sector's expectations in quarter t of exchange rate at $t + 1$.

rs12 : Nominal interest rate on a twelve-quarter bond.

rr12 : Real interest rate on twelve-quarter bonds.

Stochastic simulation methodology

The simulations extend over a horizon of 100 periods (calendar quarters). In each period the economy experiences three types of exogenous shocks: a shock to the output gap, a supply shock to the inflation rate, and a shock to the exchange rate. These exogenous shocks are drawn randomly from independent normal distributions with zero means and standard deviations of 0.8, 0.4 and 1.9 percentage points respectively.

The initial state of the economy is characterized by a steady state where all variables are zero. Following the realizations of the shocks in the first period, the authorities use their prespecified policy rule—along with the assumption that the realizations of random shocks in future periods will coincide with their expected values of zero—to determine the interest rate setting for that period and to generate forecasts, over a horizon of 50 periods, of the future time-paths of all of the endogenous macroeconomic variables in the model, including interest rates.[32] The shocks for the second period are then realized, after which the authorities update their forecasts and adjust their policy settings. And so forth until the end of period 100.

The 100-period simulation is repeated 10 times, each time drawing a different sequence of the random shocks, but saving the shocks and subjecting each different form and calibration of policy rule to the same sequences of shocks. For each specified policy rule, the process of generating 10 simulations over 100 quarters results in 1000 observations on the outcomes for inflation, output, and the policy interest rate.

The policy loss function and optimal calibration of the IFB Rule

The literature on optimal policy rules has traditionally relied on quadratic loss functions that are separably additive in the deviation of inflation from target, the output gap, and sometimes also the change in the nominal interest rate; see, for example, Rudebusch and Svensson (1999) and Wieland (1998). To remain consistent with this literature, we adopt an objective function in which the period-t loss has the following general form

[32] The only exogenous variables in the model are the foreign price level and the foreign interest rate. These variables are held constant in the simulation experiments.

$$L_t \quad = \quad (\pi 4_t - \pi^{TAR})^2 \quad + \quad \theta[y_t]^2 \quad + \quad v(rs_t - rs_{t-1})^2 \tag{6}$$

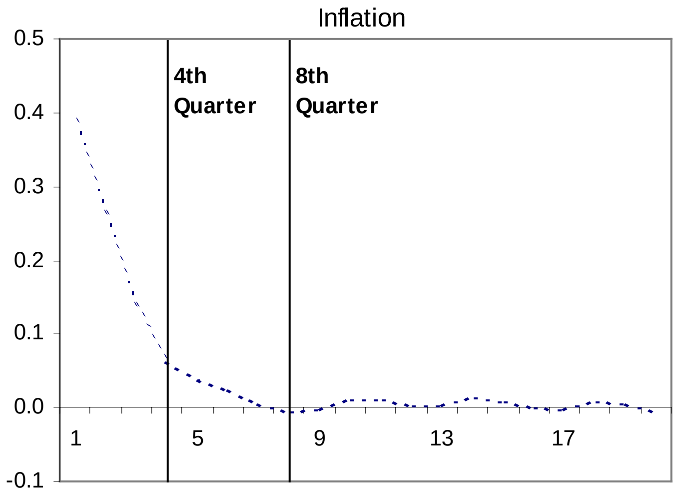
where $\pi 4$ is year-on-year RPIX inflation, y is the output gap, rs is the one-quarter interest rate, and $[\theta, \upsilon]$ are the relative weights on output gap variability and interest rate volatility. These relative weights have been set at 1 and 0.5 to be consistent with other studies on monetary policy rules. The optimal parameters for the reaction functions reported in Table 3 have been derived numerically by searching over a grid of policy-rule parameter values (in increments of .05) for the calibration that minimizes the value of the loss function averaged over the 1000 observations generated by the stochastic simulations. The best rule is an interest rate change rule (λ = 1.0) where the policy rate is adjusted fairly aggressively (with a weight of 6.95) in response to deviations of forecast inflation from target but there is also a significant weight on the output gap (0.70). As can be seen in Table 3, this policy rule is quite successful at producing low variability in inflation and the output gap. It is important to emphasize however that the analysis presented here ignores uncertainty about the level of potential output.

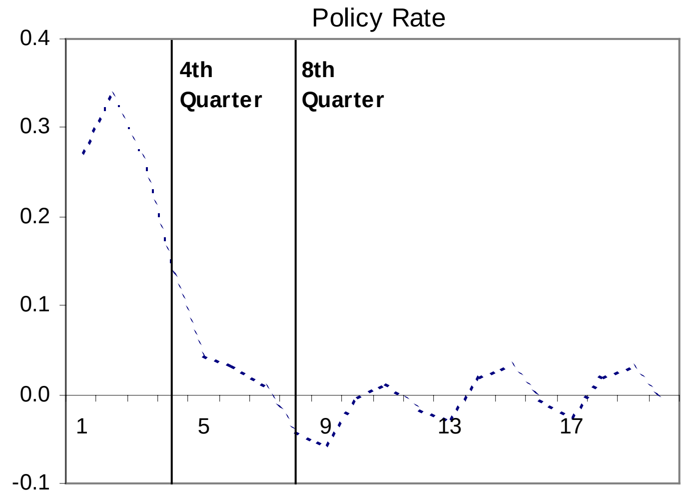
Some illustrative deterministic simulations

Figure 6 reports the responses of the short-term interest rate and year-on-year net inflation for the three shocks that were used to optimally calibrate the IFB rule in Table 3. The top panel reports the responses for a supply shock or a 0.004 shock to the Phillips curve residual. The middle panel reports the results for a 0.019 shock to the residual in the exchange rate equation, and the bottom panel reports the results for a 0.008 shock to the residual in the output gap equation. The responses in the figures have been multiplied by 100 to provide approximate deviations from control in percentage points. The figures also have vertical lines drawn at the 4th and 8th quarters to make it easier to see when inflation and the short-term interest rate can be expected to return approximately to their control values. We emphasize that these shocks are purely transitory and that the short-term interest rate would have to be adjusted more aggressively in the presence of highly persistent shocks.

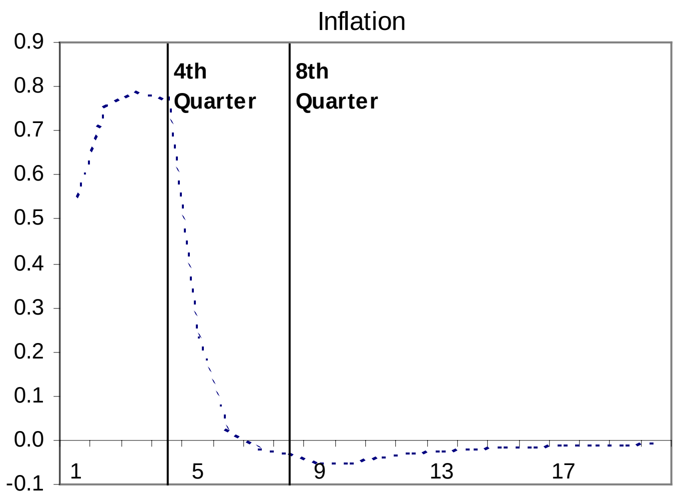
Figure 6 : Response of Policy Rate and Inflation to Three Types of Shocks

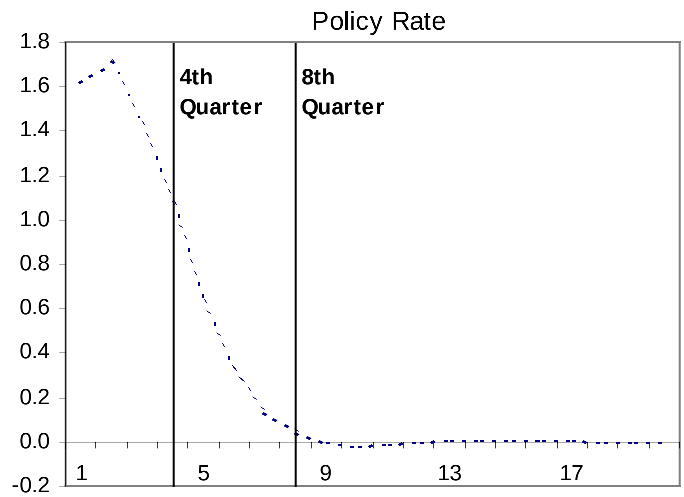
Supply Shock : Phillips Curve Residual



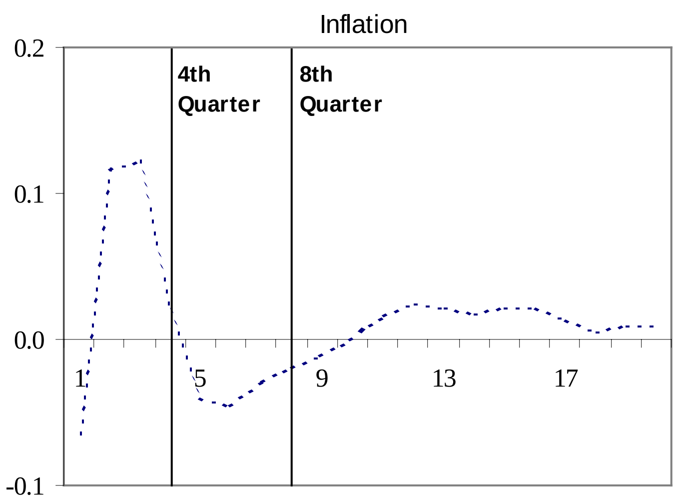


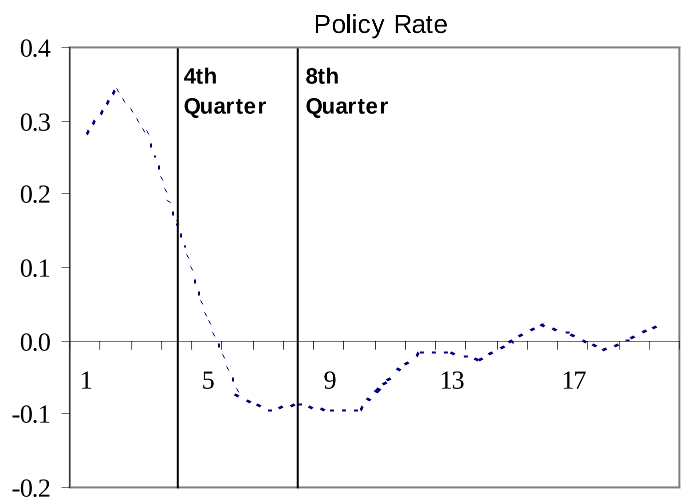
Exchange Rate Shock : UIP Equation Residual





Demand Shock : Gap Equation Residual





Supply shock (increase in Phillips curve residual of 0.004)

Inflation rises by 0.4 percentage points on impact and then gradually returns back to the target within 7–8 quarters. For this shock it is necessary to raise the short-term interest rate by around 0.3 percentage points in the short run and this results in an appreciation in the real exchange rate. This combined with the increase in market interest rates produces a sufficient tightening in real monetary conditions to return inflation close to control within 4 quarters.

Exchange rate equation shock (increase in UIP equation residual of 0.019)

The direct effect of this shock would result in a 1.9 percent depreciation in the value of the exchange rate. Because of the important role of the exchange rate in both the Phillips curve equation and the output gap equation, this shock requires a much larger increase in the short-term interest rate. Indeed, in the short run, the short-term interest rate rises by about 160 basis points. Note that the effects of this shock have much more persistent effects on the year-to-year net inflation rate and in fact grow over the first year of the simulation horizon reflecting the lags in the Phillips curve. Note, however, that after the first year inflation falls sharply and is very close to the target by the 6th quarter of the simulation horizon.

Demand shock (increase in output gap residual of 0.008)

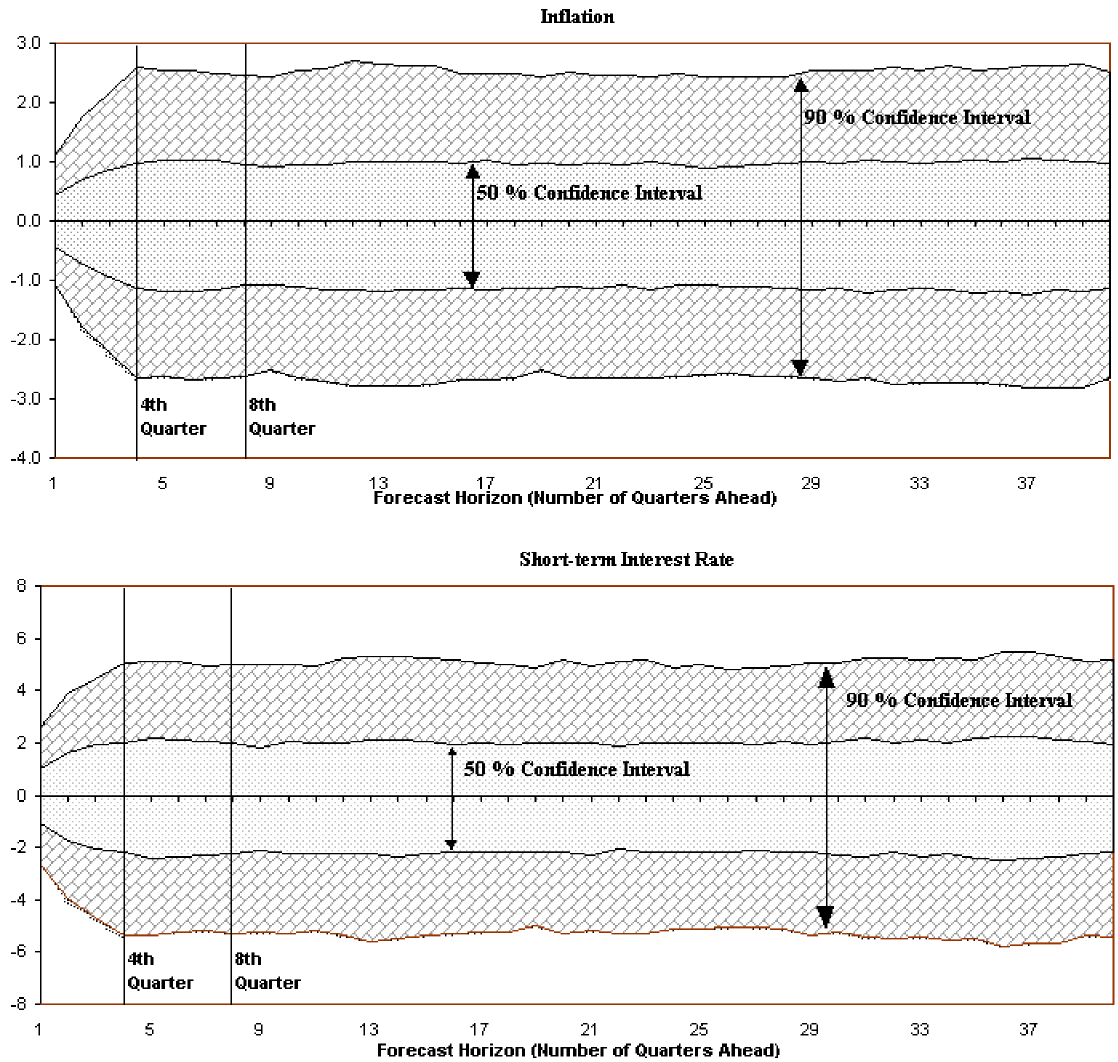
The direct effect of this shock would be to raise aggregate demand by 0.8 percent above potential output. This size of a demand shock also requires an increase in the short-term interest rate of 30 basis points and the resulting tightening in real monetary conditions is sufficient to ensure that inflation never departs significantly from the target. Note that inflation actually declines in the very short run. This reflects a significant appreciation in the exchange rate which dominates the dynamics of the model in the very short run. However, over time the effect of the positive output gap dominates the more direct exchange rate channel and inflation peaks at 0.1 percentage points above control in the 2nd and 3rd quarters. This example illustrates that demand shocks in the model have very small effects on inflation provided that the monetary authority is committed to anticipating and reacting promptly to excess demand pressures. However, because of the convex structure of the Phillips curve there can be large costs from delaying interest rate reactions and allowing large boom and bust cycles to occur.

Deriving model-based confidence intervals for the forecast

As mentioned above, an important principle of inflation targeting is transparency, and most central banks that have adopted inflation targeting frameworks have taken steps to try to communicate the arguments behind their policy settings and the speed at which they plan to bring inflation back to target. However, while in some cases central bankers have been willing to provide information about their forecast of future inflation, most central bankers are very reluctant to release a future path for the policy rate, fearing that market participants may not fully realize the uncertainties in their forecasts. One obvious solution to this potential communication problem is not only to provide a point forecast for inflation and the policy rate but also to provide confidence intervals around these point forecasts.

Figure 7 provides estimates of confidence intervals that were derived from the stochastic simulations discussed earlier. Note that in the experiments considered here, the monetary authority not only is successful in providing an anchor for inflation expectations and delivering low variability in inflation, but also acts in a way that tends to bound uncertainty in the long-term outlook for inflation and interest rates. The reason that there is bounded uncertainty in the forecast at long horizons is that the long-term inflation outlook takes account of the central bank's likely reactions to future shocks.

Figure 7: Confidence Intervals for Inflation and the Short-term Interest Rate



Comparison to Bank of England's approach

How does this approach compare with the Bank of England's approach to creating the fan charts? In the regular monthly *Inflation Reports* released by the Bank of England the Monetary Policy Committee (MPC) provides its best guess for inflation over a two-year horizon based on a constant interest rate assumption. In order to highlight uncertainty in the inflation forecast, the MPC also provides a fan chart showing estimates of confidence intervals around its most likely forecast for inflation. The MPC's fan chart is created by assuming a univariate statistical distribution and the confidence intervals are computed by making assumptions about the moments of this distribution.[33] There are a few differences between the MPC's approach and the more model-based approach considered here.

The estimates derived and presented in Figure 7 are based on a quantitative model of the monetary transmission mechanism including information about how the monetary authorities are likely to respond to revisions in their own inflation forecast. Indeed, one of the potential benefits of basing the inflation forecast on a core quantitative macro model is that it is easier to provide forecasts for more variables over longer horizons and to derive estimates of confidence intervals based on both the structure of the model and assumptions about the distributions of the model's error terms. The confidence intervals provided in Figure 7 are for forecasts as long as 10 years ahead and look more like sausages inside buns than the two-year-ahead fan charts that are presented by the MPC.

This sausage-inside-a-bun shape to the confidence intervals reflects a few critical assumptions. First, it reflects the fact that the monetary policy rule is successful in delivering low inflation variability and providing an anchor for inflation expectations. Thus even though the monetary authority doesn't know the future values of the shocks, as long as it responds to the these shocks appropriately each period and aims its forecast of inflation back to the target based on the IFB rule, it may be successful in bounding uncertainty in its own inflation forecast. By contrast, policy rules that allow significantly greater persistence in the inflation process will be associated with confidence intervals that look more like fan charts over the first few years of the forecast horizon rather than the sausage-in-the-bun shapes associated with more aggressive IFB rules that are more successful in bounding inflation forecast uncertainty.

Another difference is that the MPC's methodology for creating the fan chart allows them to enter an assumption to introduce skewness into the distribution. This is sometimes used by the MPC to communicate a change in their assessment of the balance of the risks and in the fan chart shows up in a distribution that is fatter on one side than on the other side. The approach suggested here could obviously be extended to allow for abnormal distributions on the disturbance terms. However, one advantage of a macro-model based approach is that it provides an explicit mechanism where skewness in the forecast distribution can result from perceived nonlinearities in the structure of the economy rather than just assumptions about distributions. This will be the case for example in the current model when the initial level of the output gap is quite high and there is a significant risk of overheating.

G. Concluding Remarks

This chapter has argued that a forward-looking inflation-forecast-targeting strategy provides a useful framework for monetary policy. It has also argued that macroeconomic models have an important role to play in helping policymakers to coherently analyze the appropriate settings of their policy instruments and to communicate the rationale for policy decisions.

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[33] For a discussion about how the fan carts are created see Britton, Fisher, and Whitley (1998).

In practice, inflation-forecast targeting does not imply mechanical adherence to any specific rule for setting the policy interest rate. Successful inflation-forecast targeting requires good analysis, the sensible exercise of discretion, and considerable communication and transparency to explain the rationale for policy decisions and maintain the credibility of the monetary policy framework.

Models can be very useful in promoting the consistency of policy analysis and in helping the authorities communicate the rationale for their policy actions. The core projection model should be relatively simple and easy to understand, but should not be a model in which the timing of monetary policy decisions is unimportant and monetary policy errors have only second-order implications for welfare. The core projection model should be used primarily as an organizational device and its success will depend ultimately on how well it serves policymakers to incorporate all relevant information in the projection process.

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