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Abstract

This paper examines the implications of changes in economic behaviour for simple inflation-forecast–based monetary rules of the type currently used at two inflation-targeting central banks. Three types of changes in economic behaviour are considered, changes that are motivated by developments in monetary and fiscal policy in the 1990s: changes in monetary policy credibility, changes in the slope of the Phillips curve, and changes in the degree of income stabilization from automatic fiscal transfers. Analysis is conducted using stochastic simulations of a model of the Canadian economy. Two questions are posed: First, what are the implications of these types of changes in economic behaviour for the stochastic properties of the economy? Second, how are efficient inflation-forecast–based rules affected by these changes in behaviour? Perhaps the most interesting results are with respect to credibility. When monetary credibility increases, the central bank can attain more stable output and inflation. But increasing credibility is a double-edged sword. To reap its benefits, the central bank must, in general, adjust its reaction function. If it does not, volatility can increase.

Résumé

Les auteurs examinent les conséquences des changements de comportement des agents économiques pour l’application de règles monétaires simples reposant sur la prévision de l’inflation, du genre de celles actuellement utilisées par deux banques centrales ayant établi des cibles en matière d’inflation. Ils analysent trois types de changement de comportement causés par l’évolution des politiques monétaire et budgétaire depuis le début des années 1990 : les changements de crédibilité de la politique monétaire, les variations de la pente de la courbe de Phillips et les modifications du degré de stabilisation automatique des revenus assuré par les paiements de transfert et les rentrées fiscales. L’analyse des auteurs se fonde sur l’exécution de simulations stochastiques au moyen d’un modèle de l’économie canadienne. Deux questions sont abordées. Premièrement, quelles sont les incidences de ces changements de comportement sur les propriétés stochastiques de l’économie? Deuxièmement, comment ces changements influent-ils sur une règle efficace de politique monétaire basée sur la prévision de l’inflation? Les résultats les plus intéressants de l’étude se situent probablement au chapitre de la crédibilité. Lorsque la crédibilité de la politique monétaire s’accroît, la banque centrale réussit mieux à atténuer les variations de la production et de l’inflation. Cependant, il s’agit là d’une arme à double tranchant. Pour jouir des avantages liés à une plus grande crédibilité, la banque centrale doit généralement modifier sa fonction de réaction : sinon, la volatilité peut augmenter au lieu de diminuer.

1. Introduction

In the 1990s, there has been a remarkable convergence of inflation rates across most industrialized countries towards relatively low inflation. With this success in unwinding inflation, the focus of monetary policy is shifting away from inflation reduction and towards maintaining low and stable rates of inflation. Mirroring these events, research in and analysis of monetary policy in a low-inflation environment is expanding rapidly.

One strand of research focuses on the question of which monetary rules provide the best way of maintaining low and stable rates of inflation. In the theoretical area, recent contributions by Svensson (1997a; 1997b) and Ball (1997; 1998) have examined optimal rules in the context of relatively simple linear models, and compared these to familiar rules, such as Taylor-style rules. Quantitative research with richer models has typically involved either stochastic simulations of a model under alternative rules, or in the case of linear or linearized models, analytic model solutions under different rules. These models are typically estimated on historical data or calibrated to deliver properties that match those of historical data. Alternative rules are typically evaluated in terms of the stochastic properties for the economy that they imply, particularly the trade-off between output and inflation variability along the efficient policy frontier. Examples in this vein abound.[1]

A second strand of the research focuses on what happens to economic behaviour at low rates of inflation. Various channels have been suggested, one of which is credibility. As central banks have demonstrated their resolve to unwind past inflation and re-establish a low-inflation regime, there is some evidence of increased credibility (see Svensson [1993], and Johnson [1998]). More credible monetary policy provides a firmer anchor for expectations of inflation, and this in turn will affect price adjustment (e.g., see Canzoneri [1980]). But low inflation may also influence price adjustment in other ways. For example, Ball, Mankiw, and Romer (1988) consider the implications of lower inflation in menu-cost models and suggest that a shift to low inflation may reduce the slope of the Phillips curve. In other work, Akerlof, Dickens, and Perry (1996) and Fortin (1996) examine the potential for low inflation in combination with downward rigidity in nominal wages to reduce real wage flexibility.

These two strands of research are brought together in this paper. In particular, the implications of changes in economic behaviour for efficient monetary policy rules are examined. Three types of changes in economic behaviour are considered: changes in the credibility of monetary policy, changes in the slope of the Phillips curve, and changes in fiscal policy. The focus on these particular changes in economic behaviour can be attributed to Canada's experience in the

1. A sampling includes Judd and Motley (1992); Bryant, Hooper, and Mann (1993); Fuhrer (1994); Tetlow and von zur Muehlen (1996); Black, Macklem, and Rose (1998); Batini and Haldane (1988); Levin, Weiland, and Williams (1998); and Svensson and Rudebusch (1998).

1990s. More generally, however, this choice is designed to address the types of changes that are taking place in many countries as monetary policy re-establishes a low-inflation regime and fiscal policy re-establishes sustainable, cyclically adjusted, government budget deficits. An alternative view of these modifications is that they allow exploration, in a crude way, of the implications of uncertainty about some important coefficients in the model.

Attention is focused on one class of monetary policy rules—rules that call for the central bank to raise (lower) short-term interest rates when the rule-consistent forecast of inflation is above (below) the inflation target. Following Batini and Haldane (1998), we call rules in this class inflation-forecast-based (IFB) rules.[2]

The main motivation for focusing on IFB rules is a practical one—rules in this class are popular among inflation-targeting central banks. In particular, the Bank of Canada and the Reserve Bank of New Zealand regularly use specific parameterizations of IFB rules in quarterly model-based staff economic projections. (See Coletti et al. [1996] for Canada, and Black et al. [1997] for New Zealand.) These rules have also received considerable attention at the Bank of England (see Batini and Haldane [1998]).

In general, IFB rules are not optimal rules. Rather, IFB rules have typically been viewed as simple, intuitive, and parsimonious rules that deliver reasonable economic properties over a wide range of disturbances (see Coletti et al. [1996] and Batini and Haldane [1998]). In particular, by being forward looking, these rules imply considerably lower output variability than do rules based on the current deviation of inflation from target (see Black, Macklem, and Rose [1998] and Batini and Haldane [1998]). In the context of a linear model of the U.K. economy, Batini and Haldane (1998) also find that efficient IFB rules provide a good approximation to the optimal rules.

The use of simple rules has also been prompted by the view that they are more likely to be robust across plausible models than are more complex rules that have been optimized to a particular model. In general, optimal rules depend on all the state variables in the system. Once non-linear models are considered, optimal control results cannot generally be achieved with any explicit (i.e., closed-form) rule. In the context of the models typically used for policy analysis at central banks, complex optimal rules are often viewed as impractical since they rely on the details of the structure and parameterization of the underlying economic model over which there is considerable uncertainty in practice. IFB rules, because they use model-consistent inflation forecasts, also rely on the structure and parameterization of the model, but all this information is summarized in a single variable—the inflation forecast. As a result, the rule retains its simple form and depends only on a small number of parameter choices. As discussed in Bryant, Hooper, and Mann (1993) and more recently in Levin, Wieland, and Williams (1998), simple Taylor-style rules can be more robust to

2. In Svensson and Rudebusch's (1998) taxonomy, IFB rules are implicit instrument rules that respond to rule-consistent inflation forecasts.

model uncertainty than more complex optimal rules. Just how robust are simple IFB rules is examined below.

Analysis is conducted using stochastic simulations of a model of the Canadian macroeconomy, called the Canadian Policy Analysis Model (CPAM). CPAM is a one-domestic-good, small-open-economy description of the Canadian economy. It features forward-looking, though not entirely model-consistent, expectations, an endogenous supply side, behavioural equations for the principal components of demand, and reaction functions for both the monetary and fiscal authorities. It has been calibrated to have the same steady state and similar dynamics as the Bank of Canada's Quarterly Projection model (QPM), which is the Bank's main model for economic projections. CPAM is smaller, however, and has been configured to simulate much faster than QPM so that stochastic simulations on the scale required by this project are feasible. The trade-off between output and inflation variability for IFB rules is examined by generating the efficient frontier for reaction functions in this class. Also considered is how these frontiers shift when economic behaviour changes.

The paper is organized as follows. Section 2 reviews the Canadian experience in the 1990s, with particular emphasis on the implications of low inflation for monetary credibility and the slope of the Phillips curve, and on the consequences of the move to explicit deficit targets in the mid-1990s for the cyclical properties of automatic fiscal transfers. Section 3 outlines the model, the stochastic specification, and the properties of the model in stochastic simulation. Section 4 reviews in some detail the properties of IFB rules in the base model. Section 5 then examines the implications of changes in monetary credibility, the slope of the Phillips curve, and the behaviour of fiscal policy for economic outcomes and efficient IFB rules. Section 6 concludes.

2. Changing economic behaviour

This section reviews evidence supporting the idea that economic behaviour has changed in the current low-inflation regime. The first subsection describes the Canadian monetary experience in the 1990s and presents some suggestive evidence of increasing Bank of Canada credibility. The second subsection reviews some empirical work that points toward a flattening Phillips curve. The third subsection describes recent Canadian fiscal history and the reasons why the cyclical behaviour of fiscal policy may have changed over time. In addition to providing some motivation for this work, the evidence in the following sections provides a metric to evaluate the calibration of such issues as the degree of increased credibility.

2.1 More firmly anchored expectations

In February 1991, the Bank of Canada and the Minister of Finance jointly announced a series of inflation-reduction targets. The targets specified a decelerating path for the year-over-year rate of CPI inflation, with a target of 3 per cent inflation to be achieved by the end of 1992, declining to a target of 2 per cent inflation by the end of 1995. The 1 to 3 per cent target range for inflation was subsequently extended (in December 1993) beyond 1995 to the end of 1998 and extended again (in February 1998) to 2001. The targets were specified in terms of the total CPI, but the short-run operational target was set in terms of the CPI excluding food, energy, and indirect taxes. Figure 1 summarizes Canada's inflation experience in the 1990s relative to the inflation target.

As shown in Figure 1, at the time of the 1991 announcement of an inflation target, the headline rate of CPI inflation was over 6 per cent, having been boosted temporarily by the shift to a value-added tax (the Goods and Services Tax). Inflation subsequently fell sharply, going below the target range initially, and then coming back into the range as the range itself declined in line with the path outlined in the initial announcement. As Figure 1 highlights, in Canada's 7-year experience with an explicit inflation target, inflation has largely remained within the range. Departures from the range have been on the down side, which, in the context of establishing the credibility of a new regime, may have been less damaging than departures on the up side.

In addition to introducing the inflation-control targets, the Bank of Canada has taken other steps in an effort to enhance the transparency and accountability of monetary policy and, in so doing, to increase the Bank's credibility. Since May 1995, the Bank has published a detailed account of inflation developments and the conduct of monetary policy in its semi-annual *Monetary Policy Report*. Other developments include the introduction of an operating band for the overnight rate, tying the Bank rate to the top of the operating band for the overnight rate, and the issuance of press releases explaining changes in the Bank rate.

Has credibility increased? Several studies have examined this question, and overall they conclude credibility is improving.[3] Johnson (1998), for example, uses survey measures of expected inflation from 1984 to 1995 to examine the credibility of monetary policy across 18 industrialized countries, including Canada. He concludes that Canada and New Zealand have the most credible targets among the inflation-targeting countries. Perrier (1997) uses survey data on expected inflation from the Conference Board of Canada. He concludes that these data suggest that the Bank of Canada has developed increasing credibility over the inflation-targeting period. These studies are based on formal regression analysis, but the flavour of their results can be captured by simply looking at the behaviour of survey measures of inflation in the 1990s.

3. Studies include Svensson (1993), Johnson (1997; 1998), Amano et al. (1997), and Perrier (1997).

In the Conference Board of Canada's quarterly *Survey of Forecasters* (September 1997, the most recent available), the average forecast rates of inflation for 1997 and 1998 are 1.8 and 1.9 per cent, respectively—virtually at the midpoint of the 1 to 3 per cent inflation target range. The Conference Board also surveys businesses; from the results, one can infer the distribution of expected price increases over the next six months. Figure 2 provides a time series of the percentage of business respondents that expected inflation would be a certain level or less. As shown, a full 100 per cent of the respondents expect Canadian inflation to be 3 per cent (the upper band of the inflation range) or less over the first half of 1998. Longer-term inflation forecasts, reported by the Consensus Economics Inc. survey of forecasters, also show a similar convergent trend. These forecasts suggest that longer-term (two, five, and ten years ahead) inflation expectations are in line with the midpoint (2 per cent) of the official inflation target band (Figure 3).

The dispersion of inflation forecasts across forecasters provides an alternative measure of monetary uncertainty. This measure is motivated by the Zarnowitz and Lambros (1987) finding on U.S. data that greater interpersonal differentiation of expectations tends to be associated with greater intraperson uncertainty. Figure 4 plots the standard deviation of 1-year-ahead inflation expectations across forecasters (as surveyed by the Conference Board of Canada) for the years 1985 to 1997. The downward trend is suggestive of reduced uncertainty.

For the inflation-targeting years, a more direct measure of credibility is provided by the average deviation of inflation forecasts from the inflation target. Figure 5 presents the root-mean-squared deviation of the 1-year-ahead inflation forecasts from the Bank's inflation target for the eight forecasters surveyed by the Conference Board over the 1993 to 1997 period. Here the evidence of a trend decline is less compelling, but comparing 1996–97 to 1993–95, there is some evidence that private sector forecasts are now closer to the mid point of the Bank's target range.

Drawing inferences about monetary credibility from surveys of expected inflation is hindered by the fact that expectations of inflation may be low simply because inflation is low. A more compelling test would be to examine what happens to expected inflation following a shock that pushes inflation above the 1 to 3 per cent target range. For better or for worse, this experiment is not available. There are, however, indications from a variety of other sources that expectations of low inflation have become more deeply rooted in the 1990s.

One source is fixed-income markets. The difference between the yield on Government of Canada long-term Real Return Bonds and comparable maturity nominal bonds may be considered a proxy for long-term inflation expectations. (However, factors such as liquidity and inflation uncertainty play a role in determining the differential.) As shown in Figure 6, the evolution of bond yield differentials suggests that there has been a decline in the premium for inflation expectations over the past five years. Bond yield differentials have fallen from about 4 per cent in 1993 to about

2 per cent by year-end 1997, suggesting again a convergence of inflation expectations to the midpoint of the Bank's inflation range.[4]

Another indication of increased credibility for low inflation is the changing nature of debt and wage contracts. Debt contracts appear to be lengthening on average. The percentage of new 5-year mortgages increased from 32 per cent in the mid-1980s to about 44 per cent in December 1995, while the percentage of 1-year mortgages fell from 33 to 11 per cent (see Montplaisir [1997]). In labour markets, the proportion of union labour with cost-of-living adjustments (COLAs) appears to be on a downward trend, suggesting that workers are less concerned with inflation. Agreements with COLA clauses represented 9.5 per cent of the total in 1997, down from 14.6 per cent in 1996 and 23.3 per cent in 1992. Finally, the average duration of private sector labour contracts also appears to be increasing. This evidence is summarized in Figure 7, which plots the average duration of private sector labour contracts.

2.2 Changes in the slope of the Phillips curve

The model used in this paper, like the Bank of Canada's main model for economic projections, features an asymmetry in price adjustment: The positive effect of excess demand on inflation is stronger than the negative effect of an equivalent degree of excess supply. (This is described in more detail in Section 3 below.) Empirical evidence of this type of asymmetry, documented in Laxton, Rose, and Tetlow (1993), led to this feature being included in the Bank's model. Turner (1995) and Debelle and Laxton (1996) have also found significant asymmetry of this sort for Canadian data.[5] This type of asymmetry, which is usually motivated by the presence of capacity constraints, depends on the output gap. Thus, while price adjustment depends on the state of the economic cycle, it does not vary systematically with the inflation rate.

Both theory and empirical work suggest, however, that the slope of the Phillips curve may not be invariant to the average rate of inflation. On the theoretical front, Ball, Mankiw, and Romer (1988) show that menu-cost models suggest that the slope of the Phillips curve may become flatter at low rates of inflation. The basic idea is that, in the presence of menu costs, prices adjust at discrete intervals rather than continuously and higher inflation leads to shorter intervals (since relative prices

4. For a more detailed discussion of the inflation forecasts implicit in the differential between real and indexed bonds in Canada, see Côté et al. (1996) and *Monetary Policy Report* (1997), Technical Box 3.
5. A number of other studies have also found evidence of this type of asymmetry in price adjustment for variety of countries. These include Dupasquier and Ricketts (1998) for Canada; Turner (1995), Clark et al. (1996), Debelle and Laxton (1997) for the United States; and Fisher, Mahadeva, and Whitley (1996) for the United Kingdom. In addition, Laxton, Meredith, and Rose (1995) find strongly significant asymmetry for a pooled sample of G-7 countries, and Bean (1996) reports evidence for modest asymmetry for a panel of OECD countries. Other studies, however, find little evidence of asymmetry, and conclude the Phillips curve is linear. These include Braun (1984) and Gordon (1994) for the United States, and Cozier and Wilkinson (1991) for Canada. These conflicting results reflect differences in the measures of expected inflation and excess demand, as well as differences in the estimated Phillips curves, and highlight the uncertainty associated with the Phillips curve.

get out of line more rapidly).[6] More recently, Conlon and Liu (1997) show that a similar prediction arises from the Caplin and Spulber (s,S) pricing model. Conlon and Liu relax the assumption that firms change prices only in response to price misalignment and consider additional reasons to change prices (e.g., changing product mix or introduction of new models). The authors show that this modification of an (s,S) pricing model leads it to predict, among other things, that the Phillips curve becomes flatter at lower rates of inflation. Finally, the Lucas (1973) “islands” model, when combined with the well-documented positive correlation between the level and volatility of inflation, also suggests that the slope of the Phillips curve may decline when inflation is lower.

On the empirical front, a number of studies report evidence that the Phillips curve is flatter at lower rates of inflation. Ball, Mankiw, and Romer (1988) find that the output-inflation trade-off across a number of countries is affected by the level of inflation. They also find that controlling for the level of inflation reduces significantly the effect of Lucas’ measures of volatility. Defina (1991) updates the data used by Ball, Mankiw, and Romer and reconfirms the result that lower average inflation leads to flatter Phillips curves. Hess and Shin (1995) use cross-sectional data for 50 U.S. states and arrive at similar results for the 1977 to 1991 period.

For Canada, Dupasquier and Ricketts (1997; 1998) consider five different models of asymmetric price adjustment and examine the testable implications of each model on aggregate price data. They find a significant and positive relationship between the expected rate of inflation and the slope of the Phillips curve. However, when the Lucas and menu-cost models are considered together, they find it difficult to discriminate empirically between the two. Nevertheless, their empirical evidence is suggestive of a flattening of the Phillips curve in an environment of low and stable inflation.

Indirect evidence of a flatter Phillips curve at low inflation may also be inferred from so-called sacrifice ratios (i.e., the percentage output loss associated with a 1 per cent disinflation). More specifically, if the Phillips curve becomes flatter at lower rates of inflation, then it should be expected that disinflations that began at lower inflation rates to be more costly. Debelle (1996) examines the last three Canadian disinflations and finds a negative relationship between the initial level of inflation and the resulting sacrifice ratio. In particular, the sacrifice ratio associated with the 1974–76 disinflation when the initial level of inflation was 11.5 per cent is 0.4; the ratio for the 1981–85 disinflation is 2.0 when inflation was 12.9 per cent; and the sacrifice ratio of the 1990–93 disinflation when inflation was 5.3 per cent is 3.5.

Overall, it is concluded that the evidence of a flatter Phillips curve in a low-inflation regime, while not overwhelming, is suggestive.

6. Note that this is consistent with the evidence cited above that the average duration of debt and wage contracts has increased in Canada with the decline in the average rate of inflation.

2.3 Changes in fiscal policy

Fiscal policy has changed considerably in Canada in the 1990s relative to the two previous decades. From the mid-1970s to the mid-1990s, unsustainable structural deficits produced a steady increase in the ratio of net government debt to gross domestic product, rising from 5 per cent in 1974 to 70 per cent in 1996.[7] While Canada has not been alone in experiencing rising levels of government indebtedness through this period (in comparison with other countries), Canada's debt accumulation was particularly large. For the G-7 countries as a whole, the comparable ratio of net debt-to-GDP rose from 16 per cent in 1974 to 47 per cent in 1996. Over this period, Canada's net debt-to-GDP ratio moved from fourth highest among the G-7 countries to second highest.

Faced with mounting debt-service costs and deteriorating credibility in credit markets, Canadian fiscal authorities in the 1990s launched a variety of measures intended to first stabilize and eventually reduce the debt-to-GDP ratio. Beginning with its 1994/95 budget, the Canadian federal government began to commit itself to explicit deficit-to-GDP targets.[8] Deficit targets were set to provide economic agents and financial markets with an anchor as to where fiscal policy was going. Two-year rolling deficit targets, rather than long-term targets, were set as a way to ensure that significant fiscal actions would be taken in the short term to achieve the medium-term objective of a balanced budget. Over the four years in which the deficit targets have been in place, the Canadian federal government has consistently overachieved its announced target. More precisely, the deficit-to-output targets were 5.4 per cent in 1994/95, 4.2 per cent in 1995/96 and 3.0 per cent in 1996/97. The realized deficit-to-output ratios in the corresponding years were 3.5, 3.0, and 1.0 per cent. In addition to the actions of the federal government, six of Canada's ten provinces and both of its territories have enacted either legislation or constitutional constraints on government deficits, taxes, expenditure, or debt.[9] These measures (together with cyclical improvements in economic activity) have reduced the overall government deficit as a proportion of GDP from approximately 8.0 per cent in 1992 to about 2.0 per cent in 1996. Preliminary data for 1997 suggest that the overall government net debt-to-GDP ratio in Canada has been falling. With fiscal surpluses forecast for 1998 and 1999, further reductions in the debt-to-GDP ratio are expected.[10]

With the rise in debt levels and the subsequent move to deficit targets in the 1990s, the automatic stabilization role of fiscal policy has been constrained in this decade. Kneebone and McKenzie (1997) study the stabilization role of Canadian government budgets and argue that the federal government's large debt forced it to minimize the exposure of the federal budget to cyclical variations. Indeed, evidence present in Bayoumi and Laxton (1994) and Leibfritz, Roseveare, and

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7. Unless otherwise specified, net government debt is net consolidated debt across federal, provincial, and municipal governments as measured on a National Accounts basis.
8. In 1996, approximately 80 per cent of the stock of public debt was federal.
9. See Millar (1997).
10. See OECD, *Economic Outlook* (Vol. 62, Annex Table 35, December 1997).

van de Noord (1994) suggests that fiscal policy in Canada, as well as in several other industrialized countries, has been less countercyclical during the most recent recession than in previous ones.[11] This notion is supported by Figure 8, which plots the output gap, the deficit-to-output ratio along with the debt-to-output ratio. It is apparent that, while the deficit-to-output ratio displayed countercyclical movements over most of the sample, it did not do so during the most recent period when the level of debt-to-output ratio reached almost 70 per cent. Despite weak levels of economic activity through 1993–96, the deficit declines dramatically as a proportion of GDP over this period. This suggests that the high debt-to-output ratio may have constrained the federal government from behaving countercyclically, as it has done in the past. Looking ahead, however, as debt levels in Canada fall back to more acceptable levels in the future, the automatic stabilizers in the tax and transfer system may once again be able to offer a greater degree of income stabilization. The implications of this type of shift in fiscal policy is explored in Section 4.

3. The model and stochastic specification

3.1 The model

This section provides an overview of the model—CPAM—used for the stochastic simulation analysis. Space constraints preclude a detailed description of CPAM in this paper, so the focus is on its broad features and certain key relationships that are important for the analysis here. For a complete description of the model and its properties in response to a variety of standard deterministic shocks, see Black and Rose (1997).[12]

CPAM has a quarterly frequency and is made up of about 140 equations, of which perhaps 30 describe the essential agent behaviour. The model has an explicit steady state and is dynamically stable over a wide range of disturbances. It accounts for three stocks—production capital, government bonds, and net foreign assets—and the steady state describes an equilibrium of a small open economy.

CPAM has many features similar to the Bank of Canada's QPM and is calibrated to reflect current Bank of Canada staff judgments regarding exogenous variables, the numerical steady-state solution, and many features of dynamic properties in deterministic simulations. However, CPAM is smaller and configured to simulate much faster than QPM, which is essential for the stochastic analysis provided in this paper.

11. In the U.S. context, Bayoumi and Eichengreen (1994) find evidence the cyclical responsiveness of state budgets to be significantly reduced by fiscal constraints such as legislative or constitutional restrictions.
12. CPAM was prepared for the Bank of Canada by David Rose at QED Solutions, with input from Richard Black on the tuning to QPM properties. CPAM exploits several features of the work done by QED Solutions for the Reserve Bank of New Zealand in the development of their new Forecasting and Policy System (FPS) model.

CPAM represents a small open economy that produces a single domestic good. There are four groups of domestic agents in the model: firms, consumers, and the fiscal and monetary authorities. Profit-maximizing firms combine labour and capital in a Cobb-Douglas technology to produce the single good. Trend population growth and trend productivity growth are exogenous.

Consumers come in two types. There are forward-looking consumers who make decisions with a view to picking the best path for current and future consumption, and “rule-of-thumb” consumers who spend all their income in each period. Thus, all assets are held by the forward-looking agents. The behaviour of the forward-looking consumers is characterized using the Blanchard (1985) and Weil (1989) model of overlapping generations, but in a discrete-time format, as in Frenkel and Razin (1992). CPAM uses a version of this approach with some adaptations to speed up the adjustment to asset equilibrium.

There is single consolidated federal-provincial-municipal fiscal authority. Fiscal policy is characterized as the choice of target ratios for debt to output, for spending on goods and services to output, and for transfers to the household sector to output.[13] There is an indirect tax on consumption and a personal direct tax. The indirect tax rate is treated as an exogenous fiscal choice. The fiscal authority’s intertemporal budget constraint is respected, and the fiscal targets met, through a reaction function that sets the personal direct tax rate endogenously. The fiscal reaction function is described in more detail below.

Monetary policy is characterized as a choice of a target inflation rate for consumer prices. This target is achieved through a monetary reaction function, where the instrument is the short-term (90-day) interest rate, but where this instrument influences the real economy is through its affect on the slope of the term structure. This reaction function is described in more detail below.

The domestic absorption deflator at factor cost serves as the numeraire for the model’s accounts and is the core measure of aggregate domestic prices in the model. All other price indexes are built from this core price and external trade prices. Thus, for example, the consumption-good price in the model is determined as a weighted combination of the import price and the domestic price for consumption goods, all appropriately adjusted for indirect taxes, using the model’s accounting identity structure. In the model’s small-open-economy paradigm, the foreign price is exogenous, and the law of one price holds on the margin. The Phillips curve in CPAM relates core inflation to domestic demand conditions. But a major part of consumer-price dynamics comes from the direct effect of import prices on consumer prices. The exchange rate therefore plays a central role in the monetary transmission mechanism.

The steady-state *real* exchange rate in CPAM is determined endogenously to support the overall asset equilibrium. Given a supply of labour and relative factor prices, an equilibrium stock

13. Government spending on goods and services plays no productive role in the model in the sense that utility depends only on private consumption and government spending does not affect productivity.

of capital is determined from the conditions for profit maximization. The stock of government bonds comes from the fiscal policy choice of a debt-to-output ratio. The residual asset level—the stock of net foreign assets (which is negative for Canada)—is determined by households' consumption and savings decisions. In the long run, the real exchange rate adjusts to deliver the trade balance that is required to support the steady-state net foreign asset position. In the short run, however, the real exchange rate responds to interest rates, and to monetary policy actions in particular. In the steady state, domestic real interest rates are tied to exogenous foreign values; but in the short run, they are determined by a version of the uncovered interest parity condition.

Selected aspects of the model require a more elaborate exposition for the purposes of this paper and are discussed below.

3.1.1 The Phillips curve

The Phillips curve proximately determines the rate of inflation of the model's numeraire price, the domestic absorption deflator at factor cost. Since the central bank is presumed to formulate its actions based on the anticipated course of consumer prices, and since a significant proportion of consumption goods is imported, the dynamics of domestic prices are just part of the overall inflation story. Nevertheless, the Phillips curve is central to the monetary transmission mechanism in the model. The essence of the model equation is as follows:

$$\pi_t = \alpha_1(0.6E\bar{\pi}_t + 0.4E\bar{\pi}_t^c) + \alpha_2\pi_{t+1} + (1-\alpha_1-\alpha_2)\sum_{i=1}^{4}\lambda_i\pi_{t-i} + \beta_1\tilde{y}_t + \beta_2\tilde{y}_{t-1} + 0.09\tilde{y}_t^+ + 0.03\tilde{y}_{t-1}^+ + \xi_t^\pi, \tag{1}$$

where π is the rate of inflation in domestic absorption deflator at factor cost, π^c is the rate of inflation in consumer prices, $E\bar{\pi}_t$ and $E\bar{\pi}_t^c$ are averages of expectations formed in the current and previous periods, π_{t+1} is the model-consistent inflation rate next period, and $\tilde{y}$ and $\tilde{y}^+$ are the output gap and the positive output gap respectively.[14]

The CPAM Phillips curve has many standard features. It imposes the long-run natural-rate hypothesis (i.e., there is no permanent trade-off between output or employment and the rate of inflation). In the short run, however, there is a dynamic link between excess demand, $\tilde{y}_t$, and

14. As a general rule, parameters that are varied to study the effects of changes in economic behaviour are denoted by Greek letters, whereas parameters that do not change throughout the analysis are simply represented by their values. In the base model, $\alpha_1 = 0.25$, $\alpha_2 = 0.43$, $\beta_1 = 0.02$, and $\beta_2 = 0.04$.

inflation, π_t.[15] Based on the empirical evidence cited in Section 2.2 above, this linkage is asymmetric, such that the positive effect of excess demand on inflation is stronger than the negative effect of an equivalent degree of excess supply. The form of this function in CPAM is the same as in QPM—a piece wise linear version with a steeper slope when excess demand is positive, as provided by the $\tilde{y}_t^+$ terms in equation (1).

The first part of equation (1) captures intrinsic and expectational dynamics. The structure is based on a contracting paradigm, with periodic bargaining, as in Fuhrer and Moore's (1995a, 1995b) "real wage" version of Taylor's (1980) model. Annual bargaining is assumed, so the terms $E\bar{\pi}_t$ and $E\bar{\pi}_t^c$ are averages of expectations formed in the current and previous three recent quarters when contacts still extant were signed. Thus, for example,

$$E\bar{\pi}_t = 0.25 \sum_{i=0}^{3} E_{t-i}\pi_{t-i} \tag{2}$$

where $E_{t-i}\pi_{t-i}$ is the expectation that was formed i quarters in the past. The equation for $E\bar{\pi}_t^c$ has the same form. The presence of both expectations reflects the view that both consumers and firms have some influence in the wage bargaining process, with firms caring more about the real wage in producer prices, and consumers caring more about the real wage in consumer prices.

The $E\bar{\pi}_t$ and $E\bar{\pi}_t^c$ terms are thought of as reflecting cost pressures, but that is not the only source of inertia. The term π_{t+1} represents a 1-quarter-ahead, model-consistent forecast, and there are also lags of the actual inflation rate (with $\sum\lambda_i = 1$) reflecting quarterly price adjustment by firms conditional on the underlying cost trend.

3.1.2 Expectations of inflation

Inflation expectations are modelled using a variant of the Buiter-Miller (1985) mixed model with both forward- and backward-looking components. A typical equation is:

$$E_t\pi_t = (1-\gamma_1-\gamma_2)(0.7\pi_{t-1} + 0.3\pi_{t-2}) + \gamma_1\Pi_{t+4} + \gamma_2 E_t\pi_t^* . \tag{3}$$

15. In simulation, the level of potential output in the model comes from evaluating the production function at full employment and trend factor productivity, but with the existing stock of capital. This treats capital as a quasi-fixed factor and employment as completely variable in the short run, as is traditional in such models.

The backward-looking component is a weighted average of the previous two observations of inflation. The forward-looking component is a model-consistent forecast. The term Π_{t+4} stands for a 4-quarter rate of change, which makes this term the forecast rate of inflation over the next four quarters, the assumed bargaining horizon.[16]

An explicit weight is also added on the *perceived* target inflation rate $(E_t\pi_t^*)$. This variable is determined as follows:

$$E_t\pi_t^* = 1.35E_{t-1}\pi_{t-1}^* - 0.425E_{t-2}\pi_{t-2}^* + 0.0375(\Pi_{t+16} + \Pi_{t+20}). \qquad (4)$$

The perceived target rate of inflation evolves as a second-order transfer function, with the underlying process driven by a weighted average of the model-consistent forecast for the 4-quarter inflation rate four and five years ahead. This term has a relatively small weight, $\gamma = 0.1$, in the expectations equation (3). It is designed to represent the effects of credibility. If the monetary authority is expected to keep inflation within a reasonable range of the target level in the medium term, then the expected target will remain very close to the announced target. This will provide something of an anchor to expectations, damping their response to short-term cyclical effects. By contrast, if the monetary authority's reaction function is not expected to keep inflation close to the target, this term will pull expected inflation away from the announced target, even if the recent history is good and the short-run prospects are for inflation to remain close to that target level. This captures the idea that it can takes more than a few good outcomes for the monetary authority to gain credibility, that credibility is fragile, and once lost, is hard to regain.[17]

3.1.3 The monetary reaction function

The reaction function in CPAM is an IFB rule of the form:

$$rsl_t = rsl^* + \theta(\Pi_{t+8}^c - \Pi^{c,T}) + \xi_t^{rsl} \qquad (5)$$

where *rsl* is the slope of the term structure of interest rates (the short rate less the long rate), and Π_{t+8}^c is the forecast annual rate of consumer-price inflation two years ahead, which is resolved in simulation as the model-consistent solution. In our experiments, the monetary authority has a fixed target for the inflation rate, given by $\Pi^{c,T}$. This is set at 2 per cent per annum, the midpoint of the current target range for inflation in Canada. The shock term ξ_t^{rsl} captures discretionary monetary shocks as well as other influences on the term structure, such as effects of changes in the slope of

16. In the base model, $\gamma_1 = 0.55$, and $\gamma_2 = 0.1$.
17. For a detailed examination of the effects of varying the weight on the perceived target in deterministic simulation, see Maclean (1998).

the U.S. term structure or changes to the risk premiums embedded in long rates. Finally, θ is the weight that the monetary authority places on forecast deviations of inflation from target. With θ set to 3.0, this IFB rule provides a good approximation to the standard or reference reaction function used by the Bank staff in the context of QPM for economic projections and policy advice. This rule is referred to as the reference rule.

To hit the inflation target, the monetary authority acts to move the intermediate target variable, *rsl*, raising (lowering) relative short rates when inflation is expected to be above (below) the target rate eight quarters ahead. The desired outcome for *rsl* is achieved by setting the true instrument variable—the short-term nominal interest rate—at the required level. The model contains a description of the dynamics of the term structure of interest rates, in both real and nominal terms. Thus, the short nominal rate instrument is adjusted, taking into account any movements in long rates in order to achieve a particular desired setting for *rsl*, and ultimately for the expected path of inflation.

The use of *rsl* in the reaction function instead of simply the level of the real short rate follows QPM and reflects several considerations. For our purposes, the main one is the following. Historical movements in both long and short rates reflect changes in the equilibrium real interest rate as well as monetary policy action and inflation expectations. Moreover, short rates reflect changes in the stance of monetary policy more strongly than long rates. Thus, to a large extent, the spread serves to isolate the monetary component of real interest rate changes. This helps to identify monetary and non-monetary shocks in the historical data (which is important for the stochastic analysis as described in the following section).[18]

3.1.4 Fiscal reaction function

In CPAM, the fiscal equivalent of the inflation target is a set of three target ratios that define fundamental fiscal policy. These ratios are the level of debt relative to output, the level of spending relative to output, and the level of transfers to the household sector relative to output. The rate of personal direct taxation and the government budget deficit adjust to validate these target choices.

The level of government expenditures is simply modelled as a fixed proportion of trend output that transfers payments to households can vary not only with trend output but also with the business cycle. In this sense, transfers represent automatic stabilizers much like unemployment insurance and welfare payments. Transfers are defined as:

$$\Gamma_t = 0.5\Gamma_{t-1} + 0.5\Gamma_t^* + \psi\tilde{y}_t \qquad (6)$$

18. For a discussion of the yield curve as an indicator of monetary stance, see Clinton (1995), and Côté and Macklem (1996),

where Γ_t is government transfers, Γ_t^* is the steady-state level of transfers, and ψ is set equal to zero in the base-case rule.

The model's fiscal policy reaction function is given by:

$$\tau_t = 0.4\tau_{t-1} + 0.6\left(\tau_t^* + \delta\left(B_t/Y_t - (B_t/Y_t)^*\right)\right) \tag{7}$$

where the rate of personal taxation, τ_t, is adjusted in order to close the system. The term τ_t^* represents the tax rate necessary to support the target level of government absorption, transfers to persons, and debt service in equilibrium. The key feature of the fiscal reaction function is that the tax rate adjusts to ensure that the debt target, $(B_t/Y_t)^*$, is achieved. If the actual debt ratio, (B_t/Y_t), is too high, then τ_t will rise to increase revenues and bring the ratio down. In the base-case fiscal reaction function, δ is set equal to 0.8. Note that the fiscal policy reaction function is not forward looking in the sense that only contemporaneous measures of deviations from target are considered. Finally, the reaction function assumes that fiscal authorities prefer to smooth tax rates. This assumption is captured by placing some weight (0.4) on the lagged value of the tax rate.

3.2 The stochastic specification

Stochastic simulations require a model and a distribution from which to draw random shocks. In the case of estimated models, the distribution of shocks is usually based on the distribution of the residuals of the various equations in the model. For calibrated models, however, there is no equally obvious approach. Most previous studies using calibrated models to evaluate policy rules have based the distribution of shocks on the properties of the residuals from various estimated reduced-form equations under the assumption that the shocks are i.i.d. A somewhat different tack is taken in this paper.

The method employed uses an *N*-variable VAR to identify *N*-types of shocks. More specifically, an estimated VAR is used to produce impulse responses to innovations in each of the *N* variables under consideration. These impulse responses are then used to define the shock terms for the structural model such that the dynamic response of the variable being shocked in the structural model matches the VAR impulse over the first six quarters. In this way, both the standard deviation and the persistence of the shocks are captured.[19]

19. This method of using a VAR to obtain the shocks to the structural model is developed in Black, Macklem, and Rose (1998) and is described in detail in the appendix to that paper. The implementation in the current paper is a special case of the general method described in this appendix with $i = j$.

This approach is implemented using a 6-variable VAR that captures six types of shocks. The variables in the VAR are potential output (Y^*), world commodity prices ($PCOM$), the price level (PY), the sum of consumption plus investment ($C + I$), the real exchange rate (z), and the slope of the term structure (rsl). Potential output and real commodity prices are treated as exogenous variables in the VAR (consistent with the model), and shocks to these variables have obvious interpretations. The shock to the price level is interpreted as a supply shock that takes the form of a shift in the expectations-augmented Phillips curve. The shock to $C + I$ is interpreted as a domestic demand shock, and the real exchange rate shock as a change in investor confidence in the value of the Canadian dollar (or, more formally, as a risk premium shock in the interest parity condition). Finally, the shock to *rsl* is interpreted as a discretionary monetary disturbance. Together these six shocks are designed to capture the principal macro disturbances facing the Canadian economy, though there are certainly other types of shocks that have played a role.[20]

The VAR is estimated over the sample period 1961Q1 to 1992Q4 and therefore ends just as the inflation targets begin.[21] Potential output is measured as the HP filter of actual output (using the usual setting for the smoothness parameter of 1600).[22] Real commodity prices are defined as the Bank of Canada Commodity Price Index (which is defined in U.S. dollars), divided by the U.S. GDP deflator. The domestic price level is measured as the GDP deflator. To be consistent with the structural model, the real exchange rate is defined as the nominal rate with the G-6 countries times the aggregate price level for the G-6, all divided by domestic absorption deflator at factor cost. The yield spread is the 90-day corporate paper rate, less the yield on 10-year Government of Canada bonds. Consumption in the model is broadly defined to include expenditures on consumer goods and services, housing and inventories, while investment includes spending both on structures and on machinery and equipment. The sum of consumption plus investment therefore includes all these components. The yield spread enters the VAR system in levels and the other five variables are in log levels. Since potential output and real commodity prices are viewed as exogenous, the equations for these variables include only lags of the dependent variable, one lag in the case of potential output and four lags for commodity prices. In general, the endogenous variables in the system include four lags of all endogenous variables, as well as one lag of potential output and four lags of real commodity prices.

20. Two obvious omissions are fiscal shocks and shocks to foreign demand. In the latter case, this reflects both the small-open-economy structure of the model and the inability to identify a sensible export demand shock in the estimated VAR. More generally, though, the trade-off between the dimension of the VAR and the number of degrees of freedom makes it difficult to consider VARs beyond six variables.
21. Recall the first inflation target in Canada was set for the end of 1992.
22. We recognize that the HP filter is a crude measure of potential output (Guay and St-Amant 1996), but its simplicity and transparency are attractive. We also experimented with the Bank's measure of potential output, which adds structural information to an HP filter, based on QPM. The results were generally similar using this alternative, but in a few cases the responses using the simple HP-filter measure were more conformable with CPAM.

The moving-average representation of the VAR is identified by imposing a Wold causal ordering on the variables in the VAR. The ordering {*Y*,PCOM,C+I,PY,z,rsl*}, which is loosely motivated by the structure of the model, is used. Two over-identifying restrictions are also imposed on the VAR. The first restriction is that there be no contemporaneous cross-correlation between potential output and real commodity prices, since these are exogenous variables in the model. The second restriction is that the lags of the real commodity prices do not appear in the equation for the GDP price deflator. This restriction reflects our judgment that the large effects of the oil-price shocks in 1973 and 1979 on inflation have more to do with the fact that the Bank of Canada accommodated these oil-price shocks, than with the strong structural link between relative prices and the aggregate price level. As a first approximation, we therefore turn off any direct effect of relative prices on the aggregate price level. The impact of this restriction is to improve the conformability between the effects of a commodity price shock in the VAR and the model.

Figure 9 reports the impulse responses of the variables in the VAR to each of the six shocks. The shocks are of magnitude one standard deviation, and the variables being shocked are along the diagonal of the matrix of graphs. The graphs should be read vertically—each column presents the impulse response to one of the shocks. Qualitatively, the VAR impulse responses correspond reasonably well with textbook effects of these six shocks, and quantitatively they also match up well with the effects of these same shocks in deterministic simulations.[23]

The variance decomposition for the endogenous variables in the VAR, shown in Table 1, provides some information on the relative importance of the different types of disturbances. Note that the exogenous shocks—potential output and commodity prices—explain about half the variance after six quarters in *C+I* and prices, while for the real exchange rate and the yield spread, the variance decomposition is more evenly spread across all six types of disturbances.

3.3 Model properties in stochastic simulation

Stochastic simulation of the model using the VAR-based shocks provides a convenient way to summarize the model’s properties and allows for some comparison of the data generated by the model with historical data. Of course, to seriously evaluate the model against history requires a characterization of the historical monetary and fiscal reaction functions. Given the absence of explicit monetary and fiscal targets over much of the historical period as well as the changes in monetary and fiscal arrangements over time, seriously modelling these historical reaction functions is problematic. A less ambitious avenue is therefore pursued.

In an effort to compare the model against history, the stochastic properties of the model are examined using the base-case staff fiscal reaction function together with a range of IFB rules of the

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23. See Black and Rose (1997) for a discussion of these six shocks in deterministic simulations with the model.

form of equation (6).[24] The examination begins with the reference rule (i.e., $\theta=3$), which is the approximation of the staff's current monetary rule. Less vigorous versions of this rule (i.e., lower values for θ) are then considered. These less vigorous rules are motivated by the observation that monetary policy today devotes more attention to inflation control than has been the case on average over history. Thus, rather than trying to pick a single reaction function and argue that this captures history, we consider a reasonable range of rules, and examine the ability of the model to generate data that have stochastic properties similar to those in the actual data.

For each reaction function, stochastic simulations are performed with the model, using the shock structure derived from the VAR. The model is run over 136 quarters and the first 8 quarters are dropped. This leaves 128 quarters, which corresponds to the length of historical sample over which the VAR is estimated. Eighty replications of history are performed; thus the total number of simulations is 80x136=10,880.[25] The distributions for variables of interest are built up by averaging across time and across replications.

Table 2 reports the standard deviations and AR(1) coefficients for selected variables in the model for three calibrations of the rule given by equation (4): $\theta=3$, which is the approximation to the staff rule, and two less vigorous rules, $\theta=1$ and $\theta=0.5$. As a basis of comparison, the first column in Table 2 reports comparable statistics for the variables in question over the period 1961Q1 to 1992Q4, the estimation period for the VAR. The components of demand are expressed as a ratio of output so as to avoid the need for detrending. In the case of output itself, moments are reported for the quarterly growth at annual rates (Δy_t), the 4-quarter growth rate ($\Delta_4 y_t$), and the deviations of log output from its Hodrick-Prescott trend ($\tilde{y}_t^{HP}$).

The results for all three rules have several features in common. For all three rules, the model does very well in matching the amplitude and the persistence of the business cycle as captured by standard deviations and the AR(1) coefficients for the various measures of detrended output. For all three rules, the main demand components of output also display similar behaviour in the model relative to history; this is particularly the case for $(C+I)/Y$ and for $TBAL/Y$.[26] Finally, in all three cases, the volatility of the real exchange rate in the model is somewhat lower than in the data. Since the simulations include shocks to the real exchange rate that are backed out of the VAR, this latter result suggests that the astructural VAR equation for the real exchange rate is explaining more

24. The fiscal reaction function is discussed further in Section 5.4.
25. Based on experiments with up to 1000 replications, 80 replications were found to provide reasonably accurate results for the moments of interest here.
26. The properties of the components of *C+I* in the model do not match those in the data as closely as do those for the total. This largely reflects that fact that, in splitting the *C+I* shocks from the VAR in order to put them in the model, we assume that the consumption and investment shocks are perfectly correlated. The standard deviation of *G/Y* is also lower in the model than in the data, since there is no fiscal shock in our analysis.

of the variation in the exchange rate than is the structural model. This result is perhaps not too surprising given the general lack of success in the profession in modelling exchange rates.

While these three rules produce quite similar behaviour for real variables, the same is not true for nominal variables. For the reference rule ($\theta = 3$), the standard deviation of inflation is about half that over history—1.7 percentage points compared with 3.1 percentage points in the data. This marked improvement in inflation control relative to history is consistent with the fact that monetary policy has become more focused on price stability since the late 1980s. For lower values of θ, the standard deviation of inflation is higher. More specifically, for $\theta = 0.5$, the standard deviation of inflation is slightly above that in the data, while for $\theta = 1.0$ it is slightly below.

Looking across the three rules, the rule with $\theta = 1.0$ does the best in matching up with history, and appears to do quite well on an absolute scale. Note, in particular, that the model matches very closely the moments describing output and its components, the nominal interest rate (*rn*), and the yield spread (*rsl*), and that it does a reasonably good job on inflation. The one weakness noted above is the low variability of the exchange rate in the model relative to the data.[27] Overall, what is learned from this exercise is that, while there may be some room for improvement in the model's stochastic properties, the model's performance is at least sufficient for us to have some confidence in the relevance of our analysis.

4. Efficient policy frontiers for inflation-forecast-based rules

The above results suggest that it is possible to control inflation considerably better than has been done historically, with about the same volatility in output and interest rates. These results, however, are based on reaction functions that are arbitrary special cases of the more general IFB rules of the form of

$$rsl_t = rsl^* + \theta(\Pi^c_{t+j} - \Pi^{c,T}) \tag{8}$$

where *j* is the number of quarters into the future the monetary authority looks in evaluating the expected deviation of inflation from its target.[28] For any given value of *j*, the efficient policy frontier for the *j*-period-ahead IFB rule can be computed by performing stochastic simulations with

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27. There is more than one way to solve this problem in the model. One approach would be to simply increase the standard deviation of the real exchange rate shock. Another would be to adjust the weights on the backward- and forward-looking components of exchange rate expectations, so that, via the uncovered interest rate parity condition, exchange rate volatility increases. Still another way would be for the equilibrium real exchange rate to fluctuate more in response to shocks. We plan to explore these alternatives in future work.
28. One potential problem with this type of rule has been documented by Bernanke and Woodford (1997). They show that strict targeting of inflation forecasts is typically inconsistent with the existence of a rational expectations equilibrium and that policies approximating strict inflation-forecast targeting are likely to have undesirable properties. However, since a structural forecast of inflation is used in the experiments, the previously noted problems can be largely avoided. (See Bernanke and Woodford for more details.)

the model for alternative values of θ. By computing the frontiers for each value of *j*, we can then build up a family of frontiers. The efficient frontier across reaction functions in the class of equation (8) is then given by the envelope of the frontiers computed for each *j*.

The results of this exercise are summarized in Figure 10. These results are based on stochastic simulations of the model, using the shocks for the non-monetary variables as derived from the VAR. Since the goal here is to compare the stochastic properties of the economy under alternative monetary rules, the *rsl* shocks (ξ_t^{rsl}) from the VAR (which is interpreted as largely reflecting discretionary monetary shocks) are set to zero. If the monetary authority is following a rule, there should be no discretionary monetary shocks. Following some initial experimentation to determine the relevant ranges for *j* and θ, stochastic simulations with the model were conducted for 65 reaction functions for *j*=0,1,2, . . . ,9 and for θ between 0.5 and 25. To make this computationally feasible, the number of replications was reduced from 80 to 20.[29]

Figure 10 plots the root mean squared deviation (RMSD) of inflation from its target against the RMSD of the output gap for the reaction functions considered. For *j*=0,3,5,6,7,8, separate efficient frontiers are shown. For each of these values of *j*, the hull defined by varying θ is shaded to provide a general impression of the space spanned by reaction functions for this value of *j*. The shading gets darker for successively higher values of *j*. The efficient frontier for rules for any given *j* is described by the edge closest to the origin of the shaded area corresponding to that *j*. The edge closest to the origin of the envelope of all the shaded slices describes the global efficient frontier for IFB rules under consideration.[30]

Two results stand out in Figure 10. First, for a given *j*, increasing θ tends to produce a lower inflation variability at the cost of a higher output variability. Second, increasing *j* tends to reduce the RMSD of output.

The efficient frontier for *j*=0 highlights the effects of increasing θ for a given *j*. Along this frontier, several points are labelled. As shown, increasing θ traces out a trade-off between inflation and output variability. This trade-off arises for two reasons in our model. First, as stressed by Taylor (1979, 1994), controlling inflation in the face of demand shocks requires leaning against the output gap. However, when price shocks arise (i.e., shifts in the expectations-augmented Phillips curve), returning inflation to its target will tend to widen the output gap in the short run, thereby producing a trade-off between the volatility of output and inflation. The second reason for a trade-off reflects the lags in the effects of monetary policy in the model. Even if there are only demand shocks as the monetary authority pursues increasingly vigorous reaction, there comes a point when controlling

29. This is a large-scale computational problem. With 65 reaction functions simulated for 20 replications over 136 periods, the total number of simulations is 176,800. To accomplish this, we distributed the computing across 30 Sun Sparc Ultras, which ran over two nights (a total of about 20 hours).
30. This includes the frontiers for the *j*'s shown separately in Figure 10 as well as those that are not (i.e., *j* = 2,4,9).

inflation more tightly in the short run begins to induce larger secondary cycles in output. Thus, while a more vigorous reaction function may do a better job of stabilizing inflation, the secondary cycles in output associated with this policy will begin to destabilize output, resulting in a trade-off.

For a given θ, increasing *j* has the effect of shifting the efficient frontier to the left. To be more precise, starting from *j*=0, increasing *j* up to 3 shifts the efficient frontier towards the origin. Thus, the frontier for *j*=1 completely dominates the frontier for *j*=0, the *j*=2 frontier dominates the *j*=1 frontier, and *j*=3 dominates *j*=2. This result simply reflects the fact that, given the lags in the effects of monetary actions, monetary policy is more effective when it is forward looking.

Increasing *j* above 3 shifts the efficient frontier to the left rather than towards the origin, so a partial trade-off emerges. For example, comparing the frontiers for *j*=3 and *j*=5, we see that increasing *j* from 3 to 5 shifts the frontier up and to the left. Therefore, at very low variability for inflation (bottom right corner of Figure 10), the *j*=3 rule continues to dominate the *j*=5 rule. Increasing *j* above 5 continues to shift the efficient frontier to the left up to *j*=8. With each leftward shift, new opportunities to stabilize output are opened up, but the lowest attainable variability for inflation increases.

Why does increasing the forecast horizon for inflation in the IFB (up to eight quarters) result in more stable output at the cost of more variable inflation? Again, there are two reasons. First, in the presence of price shocks, the more forward-looking rules are more tolerant of inflation in the short run. These more forward-looking rules therefore do not react as sharply to price shocks, which tends to produce smaller deviations of output from potential, at the cost of a more protracted deviations of inflation from target. Second, following a demand shock that pushes inflation away from target, the more forward-looking rules begin to return monetary policy to a neutral setting before inflation reaches its target. In so doing, they tend to produce softer landings in output and thus lower output variability. But the benefits of looking ahead, in terms of output variability, work only up to a point. If the central bank looks too far ahead, its reactions to current conditions eventually become too timid, and both inflation and output variability increase. In the model, this point comes at a forecasting horizon of eight quarters, which is about the control lag in the model between monetary actions and their effect on inflation through the output gap.

These results have much in common with those reported in Batini and Haldane (1998) in the context of a linear, open-economy model of the U.K. economy. In particular, they also find that, by lengthening the forecast horizon in the IFB rule, the monetary authority can achieve considerable output stabilization. Indeed, they find that putting an explicit weight on output in the reaction function fails to reduce appreciably the variance of output relative to the IFB rule that minimizes output variance.[31] This reflects the fact that the IFB rule that minimizes output variance in their linear model comes very close to producing the lowest attainable output variance.

Figure 11 depicts the global IFB efficient frontier in Figure 10 with the reaction functions for selected points of interest labelled. The point labelled $j8\theta 3$ denotes the outcome when the model is simulated with the reference rule. Note that there are a great many points closer to the origin than $j8\theta 3$, suggesting that considerably better outcomes are attainable in inflation-output variability space. Two points of particular interest are $j8\theta 9$ and $j5\theta 7$. The rule $j8\theta 9$ produces the lowest available RMSD of output among the efficient rules, while the rule $j5\theta 7$ has lowest available RMSD for inflation with the same RMSD for output as the reference rule (rounded to one decimal point).

Table 3 provides more detailed results for these three rules.[32] Consistent with Figure 11, the rule $j8\theta 9$ produces lower standard deviations of both inflation and output than the $j8\theta 3$ reference rule. Note that these two rules use the same forecasting horizon, eight quarters, but differ in the choice of θ. Not surprisingly, the more vigorous $j8\theta 9$ rule produces more variability in the yield spread and the nominal interest rate. This suggests that it might be possible to rationalize the reference rule if some weight in the central bank objective function is placed on interest rate smoothing. Note, however, that the average *level* of output is higher for the $j8\theta 9$ rule. For both rules, the mean of the output gap is negative, but the absolute size of this negative mean shift in output is larger for the $j8\theta 3$ rule, owing to the greater output variability with this rule. The negative mean shift arises because inflation is more sensitive to excess demand than to excess supply. Therefore, the cumulated excess supply gaps in the model (when output is measured against the deterministic measure of potential in the model) have to be larger than the cumulated excess demand gaps to prevent inflation from drifting upwards over time.

Comparing the $j8\theta 3$ rule to the $j5\theta 7$ rule suggests that considerably better inflation control is achievable at a very small additional cost in terms of output variability relative to the reference rule, although again the efficient rule is more vigorous resulting in more volatility in interest rates. With the $j5\theta 7$ rule, the standard deviation of inflation falls to about 1 percentage point, so inflation is expected to be outside bands of +/-1 percentage point around the target about a third of the time. This is a substantial improvement relative to the reference rule, for which inflation is expected to be outside bands of +/-1 percentage point about 54 per cent of the time.

The efficient policy frontier also suggests that even better inflation control is achievable at the cost of less stability in output. For example, with the rule $j4\theta 7$, inflation is expected to be outside bands of +/-1 percentage point about 24 per cent of the time. For the rule $j3\theta 13$, this number falls

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31. Interestingly, the choice of the forecasting horizon in Batini and Haldane that minimizes output variance is between four and six quarters. Given that they use the quarterly inflation rate in their IFB rule (rather than 4-quarter inflation rate used here), this horizon is roughly in line with the 8-quarter horizon in our analysis.
32. These results, as in Table 3, are based on 80 replications of history. As a result, they do not match up exactly with the results in Figures 10 and 11, which are based on 20 replications. However, the fact that they are reasonably close suggests that 20 replications are enough to get a broad description of the efficient surface.

to only 13 per cent of the time. In practice, however, points below $j4\theta\,7$ on the frontier are unlikely to be feasible as they entail a large number of negative realizations of the nominal interest rate. As a crude way of controlling for the effects of the infeasibility of negative nominal interest rates, we restrict our attention to rules for which the standard deviation of the nominal interest rate is less than or equal to the mean nominal interest rate of 5 per cent. This has the effect of truncating the lower portion of the surface—shown as the dark-shaded area—leaving the feasible efficient frontier as the edge of the lighter-shaded area.[33] The analysis to follow focuses on this feasible efficient frontier.

5. What happens when economic behaviour changes?

5.1 More credible monetary policy

To examine the implications of a more credible monetary policy, it is necessary to have a metric against which credibility is measured as well as a method of varying credibility in the model.

As a metric of credibility, survey data on inflation expectations is used to compare the stochastic behaviour of the inflation expectations of the representative forecaster with the stochastic behaviour of the model's inflation forecast over the comparable horizon. As discussed in Section 2, the Conference Board of Canada surveys economic forecasters on their expectations for the average rate of inflation one year ahead. Based on the eight forecasters in the sample over the entire period, Figure 5 plots the RMSD of the expected deviation of the average rate of inflation one year ahead from the inflation target for each of the inflation-targeting years. The idea is that, the more credible the target, the smaller should be the average deviation of expected inflation one year ahead from the target. Given the lags in the effects of monetary policy and the Bank's stated horizon of six to eight quarters for bringing inflation back into line with the target, the expected deviation of the 1-year-ahead forecast from target will not typically be zero. However, the more firmly expectations are anchored on the target, the smaller this deviation should be on average. Indeed, in Figure 5 there is some evidence, albeit weak, that this RMSD has trended downwards since 1993. Over the full inflation-targeting period (1992–1997), the average RMSD of the 1-year-ahead inflation forecast from target is 0.5 percentage points. For the two most recent years (1996–97), the comparable RMSD is 0.4 percentage points.

Recall that, in the model, expectations of inflation depend on lags of inflation, the model-consistent solution, and the perceived inflation target. In the absence of completely model-consistent expectations, the credibility of the inflation target—the degree to which expectations of inflation are anchored on the target—is a meaningful question in the model. To compare the degree

33. For a more formal look at the zero bound on nominal interest rates, see Black, Coletti, and Monnier (1998) and Orphanides and Wieland (1998).

of monetary credibility in the model to our measure of credibility in the 1990s, the RMSD of the 1-year-ahead forecast of inflation in the model is computed across stochastic simulations using the reference rule ($j8\theta 3$), which is our approximation of the current staff rule. The resulting RMSD is 0.7 percentage points (see Table 4)—slightly higher than the comparable statistic from the survey data. This suggests that, on average, inflation is returning to the target more gradually in the model using the current staff rule than private sector forecasters would expect it to. This is interpreted as suggesting that private sector expectations of inflation in the 1990s are more firmly anchored on the inflation target than are inflation expectations in the model.[34]

To vary credibility in the model, we adjust the weight that is placed on the perceived target in characterizing expectations of inflation. Recall, the perceived target is anchored by the 4- to 5-year-ahead model-consistent solution for inflation, so, provided that the monetary authority follows a sensible monetary rule, this will be close to the actual target. Credibility is increased in two steps. In step one, called *cred-I*, the weight on the perceived target is increased until the RMSD of the model's 1-year-ahead inflation forecast falls to 0.5 percentage points when the model is simulated using the reference rule.[35] In step two, labelled *cred-II*, the same procedure is carried out until the RMSD in the model's 1-year-ahead inflation falls to 0.4 percentage points.[36] The increased weight on the perceived target in expectations comes at the expense of the weight on lagged inflation. This reflects the idea that, when monetary policy is more credible, private agents place more weight on the inflation objective, and less weight on the recent history of inflation when forming inflation expectations. The results of this exercise are reported in the second and third columns of Table 4; the first column reproduces the results in the base model with $j8\theta 3$ for easy reference.

As expected, greater credibility reduces the variability of inflation—the standard deviation of inflation falls from 1.6 percentage points in the base model to 1.2 percentage points for *cred-II*. But with this improvement in inflation control comes more variability in output. For *cred-II*, the standard deviation of the output gap is 2.9 per cent as compared to 2.4 in the base model. At first glance, this latter result may be surprising. If expectations are more firmly anchored on the inflation target, the monetary authority should not have to move as aggressively to offset the effects of price shocks, suggesting that more credibility should be associated with less variability in output. In fact, there is nothing wrong with this intuition; it is just that it is not the entire story. With greater credibility, the forecasted deviation of inflation from target eight quarters ahead in the staff's IFB rule is considerably smaller than in the base model. As a result, interest rates move much less with the

34. An important identifying assumption underlying this interpretation is that the shocks in the inflation-targeting period are representative of the shocks estimated over the period 1961Q1 to 1992Q4 using our VAR-based method. If for some reason the shocks to inflation have been smaller in the 1990s than has been the case on average over the past 30 years, then one would expect the 1-year-ahead private sector inflation forecasts in the 1990s to be closer to the target on average than the comparable forecasts in the model.

35. This requires increasing γ_2 from 0.1 to 0.45 (its maximum possible value given the unit-sum restriction) so the total weight on the perceived inflation target in expectations ($\alpha_1\gamma_2$) increases from 0.0025 to 0.1125.

36. In this case, γ_2 was set to 0.45 and α_1 was increased from 0.25 to 0.5, so the total weight on the perceived target in expectations is 0.225.

increase in credibility. The standard deviation of the yield spread drops from 1.7 percentage points in the base model to only 1.0 percentage point for *cred-II*. With this considerably more timid response in interest rates, output volatility increases because the monetary authority is not leaning hard enough against demand shocks. More generally, this result highlights the fact that, if the monetary authority does not adjust its reaction function in the face of changing credibility, increases in monetary credibility can result in more variability, not less.

This conclusion is reinforced when the efficient policy frontier for IFB rules is re-computed with inflation expectations modelled as in *cred-I* and *cred-II*. The results of this exercise are shown in Figure 12. As shown, the effect of increasing credibility is to shift the efficient policy frontier closer to the origin. Thus credibility is a good thing in the sense that, with more credibility, the monetary authority can achieve less variability both in inflation and output. But to achieve these gains, the monetary authority may have to change its IFB rule, since the rules on the frontier in the base-case model need not be on the frontier when credibility is increased. A particularly dramatic example is the case of the rule $j8\theta 9$. In the base model, this rule is on the frontier and produces the lowest attainable RMSD of output (labelled $j8\theta 9$-B in Figure 12). When credibility is increased to *cred-I*, this rule shifts up and to the right (labelled $j8\theta 9$-I), so both output and inflation variability increase. In the case of *cred-II*, this rule shifts further up and to the right. In fact, it shifts so far that it is off the scale of the figure! The reason is that, with the improvement in credibility, the 8-quarter-ahead forecasting horizon in the IFB rule is now too far ahead. With higher credibility, the control-lag in the model between monetary actions and inflation has shortened, and the monetary reaction function has to adjust to this new reality. When it does, better outcomes are attainable.

To illustrate the gains associated with credibility, the fourth column of Table 4 reports more detailed results for the rule on the *cred-II* frontier that produces the lowest attainable RMSD for output ($j7\theta 11$-II). This rule should be compared to the rule $j8\theta 9$ on the base frontier (Table 3). Moving from $j8\theta 9$-B to $j7\theta 11$-II reduces the standard deviation of inflation from 1.1 to 1.0 percentage points, so the proportion of time outside bands of +/-1 per cent drops from 39 per cent to 32 per cent. At the same time, the standard deviation of the output gap falls from 2.0 per cent to 1.7 per cent. This is achieved with less volatility in the nominal interest rate and the yield spread.

In summary, these results highlight why central banks are making greater efforts to increase their credibility—they can get better outcomes in terms of inflation and output at the same time as doing less with interest rates and the exchange rate. But the results also reveal a dark side to increased credibility. If the central bank does not reoptimize its reaction function, increased credibility may result in worse outcomes.

5.2 A flatter Phillips curve

A flatter Phillips curve presents a double-edged sword for the monetary authority. On the one hand, it means that returning inflation to its target following a price shock is going to be more costly in terms of output relative to potential, so the variance trade-off may worsen. On the other hand, in the presence of demand shocks, a flatter Phillips curve means that inflation will move away from its target more slowly, so the variance of inflation may fall.

To explore the implications of a flatter Phillips curve for IFB rules, the efficient policy frontier was re-computed using a version of the model with a lower elasticity of inflation relative to the output gap. More specifically, the coefficients (β_1 and β_2) on the output gap in the Phillips curve were reduced by 25 per cent (to 0.015 and 0.03 respectively).[37] In deterministic simulations, this has the effect of increasing the sacrifice ratio (measured as the cumulated output cost associated with reducing inflation by 1 percentage point) from 2.6 in the base model to 4.0 in the flatter Phillips curve model. This change to the Phillips curve is in line with Dupasquier and Ricketts' (1997) estimates for Canada of the implications of reducing inflation from its historical average rate to 2 per cent, the targeted rate.

Figure 13 compares the efficient frontier in the base model (dark shading) with the efficient frontier with a flatter Phillips curve (light shading). The impact of a flatter Phillips curve is to shift the efficient frontier sharply to the right, so for a given level of inflation control, output volatility is higher. Thus, everything else being equal, a flatter Phillips curve is unambiguously a bad thing. Whereas changing credibility had a significant effect on the calibration of efficient rules, reducing the slope of the Phillips curve does not have a pronounced effect on which rules are good ones. Efficient rules do change somewhat, but the changes are small and there is no systematic pattern. More interesting perhaps is that the cost of a flatter Phillips curve in terms of output variability is higher for efficient rules with a short forecasting horizon (i.e., low *j*). This reflects the fact that efficient short-horizon rules achieve better inflation control than longer-horizon rules by responding more strongly to prospective inflationary pressures at the cost of more output variability. And, the flatter the Phillips curve, the larger the marginal cost in terms of output variability of better inflation control.

The greater importance of the slope of the Phillips curve for the less forward-looking rules becomes much more pronounced at higher levels of credibility. The lower bound of the dark shaded area in Figure 14 is the efficient frontier for *cred-II* studied above. The lower edge of the medium-shaded area is the frontier for *cred-II* but with a flatter Phillips curve. To provide a reference point, the base-case frontier for IFB rules is included (the light shaded area). For our experiments, the net effect of higher credibility and a flatter Phillips curve is to shift the efficient frontier towards the

37. Note that, in reducing the average slope of the Phillips curve, the asymmetry in the Phillips curve with respect to the sign of the output gap has not been changed. In general, this asymmetry may also be a function of the rate of inflation (e.g., see Ball and Mankiw [1994]). In future work we plan to explore the implications of this possibility.

origin relative to the base frontier. But what is more interesting is that, with high credibility, rules that do a good job of stabilizing output are affected very little by a flatter Phillips curve. This reflects the fact that these rules are the more forward-looking ones and are thus more patient in their approach to inflation control. They can therefore rely more on the beneficial effects of credibility to bring inflation expectations in line with the target and less on the output gap channel. The cost of a flatter Phillips curve is therefore less on the margin. Thus, credibility is an antidote to a flatter Phillips curve, because it shifts the efficient frontier towards the origin and because, for more forward-looking rules, it reduces the effects of a flatter Phillips curve.

While increased credibility and a flatter Phillips curve have been presented as separate effects, they may well be linked. To the extent that greater credibility for low inflation has reduced the variance of inflation and/or resulted in less frequent price adjustments (due, for example, to a lengthening in the duration of nominal contracts), greater monetary credibility may itself be contributing to a flatter Phillips curve.

5.3 A more countercyclical fiscal policy

Finally, the implications of more countercyclical fiscal transfers are considered. Fiscal policy in the base case is calibrated to be broadly consistent with the deficit-targeting regime currently in place in Canada. In particular, the debt-targeting rule in the model ensures that the deficit-to-output ratio remains relatively stable.

Looking ahead in Canada, once debt levels have been effectively reduced to more acceptable levels, the fiscal authorities will again have the option of pursuing a more countercyclical policy of income stabilization via automatic transfers. To explore the implications for monetary policy of this type of shift in fiscal policy, an alternative calibration of the fiscal rule is considered. In this, the cyclically adjusted budget deficit in the model behaves much as it did over the pre-deficit-targeting period.

Fiscal policy is summarized by the behaviour of the fiscal stance indicator, f, which is defined as follows:

$$f_t = \left(D_t - D_t^*\right) / Y_t^{HP} \tag{9}$$

where D_t is the consolidated government deficit in real terms, D_t^* is the structural deficit and Y_t^{HP} is Hodrick-Prescott trend output. Table 5 shows AR(1) coefficient of the fiscal stance indicator, its standard deviation, and its contemporaneous correlation with the economic cycle. The historical summary statistics are calculated using annual data over the 1970 to 1993 period, prior to the first announcement of the federal government's deficit-to-GDP targets.

Table 5 also reports the same summary statistics for the base and alternative fiscal rules when the monetary rule is the reference rule $j8\theta3$.[38] The alternative fiscal policy rule is calibrated to get a greater stabilization effect from fiscal policy. This is neatly summarized by the reduction in the correlation between f_t and the deviation of (log) output from its HP filter from -0.9 to -0.4, and the reduction in standard deviation of f_t from 1.2 to 0.5 percentage points. The alternative calibration for fiscal policy is accomplished by increasing the stabilization role of both transfers to households (equation 6) and taxation (equation 7).

Figure 15 compares the efficient frontier in the base model (light shadinf) to the efficient frontier with the alternative fiscal rule (dark shading). A more countercyclical fiscal policy shifts the efficient frontier to the left, so that for a given level of inflation control, output volatility is lower. There is also a slight shift in the efficient frontier towards the origin, so that for a given level of output control, inflation volatility is marginally lower. Adopting a more countercyclical fiscal policy also changes which monetary policy rules are most efficient, but the changes are quite small. Note, however, that for arbitrary reaction functions, a more countercyclical fiscal policy need not reduce output variability. As shown in the last column of Table 4, this is the case for the reference rule. Note that, for this rule, the change in the fiscal reaction function results in a small increase in output variability.

The shift in the efficient frontier when fiscal policy is more countercyclical can be explained by considering two important points. First, the fiscal authority is better suited to stabilize output fluctuations over the near term through the use of automatic transfers. This comes about because an increase in automatic transfers to households from the government sector, for example, can have an immediate impact on aggregate demand. However, monetary policy typically requires several quarters to have a significant impact. In particular, since transfers to households from the government sector go entirely to rule-of-thumb consumers, consumption can increase quickly in response to the automatic stabilizers.

Second, fiscal and monetary policy are generally complementary across most of the shocks. In the case of a demand shock, for example, the more active fiscal policy is in stabilizing output, the less significant is the inflationary pressure. The complementary nature of monetary and fiscal policy, combined with the timeliness of automatic transfers, implies that more automatic stabilization leads to "better" outcomes for both inflation and output. There is, however, an important exception to this rule. In the case of a price shock, the monetary authority generates volatility in aggregate demand in an attempt to control inflation. Automatic stabilizers, however, work to minimize the volatility in output. In this instance, the timeliness of this type of fiscal policy makes it more difficult for the monetary authority to achieve the inflation control it desires.

38. More detailed simulation results with the alternative fiscal rule and the reference monetary rule are presented in the last column of Table 4. Note that shifting from the base fiscal rule to the alternative has very little impact on the moments reported. This is also the case when the best historical monetary rule $j8\theta1$ is used.

6. Conclusions

In recent years, central banks in New Zealand, Canada, and the United Kingdom have taken a number of steps to improve the transparency and accountability of monetary policy, in order to build credibility for low inflation. These steps include the joint commitment of the central bank and the elected government to an explicit inflation target, regularly published reports on inflation developments and monetary policy, and more frequent and direct communication with market participants and the public.

Our results highlight several aspects of credibility. First, they illustrate why central banks want to improve their credibility. With a more credible monetary policy—in other words, private sector expectations that are more firmly anchored on the inflation target—it is possible to simultaneously reduce the variability of inflation, output, and interest rates. In other words, central banks can get more of what they want—stable output and inflation—while at the same time doing less in terms of moving interest rates.

Second, our results suggest that, to reap these benefits, the central bank may have to adjust its reaction function to take account of the change in credibility. If the central bank does not adjust its rule, increased credibility can result in more volatility, not less. This finding highlights the sensitivity of IFB rules—of the type currently being used among some inflation-targeting central banks—to changes in economic behaviour that alter relationships in the monetary transmission mechanism.

Third, to the extent that increased credibility for low inflation also reduces the slope of the Phillips curve, some of the benefits of credibility will be eroded. Whereas increasing credibility tends to shift the efficient policy frontier towards the origin, a flatter Phillips curve has the opposite effect. In our experiments, the net effect of increased credibility and a flatter Phillips curve is to shift the efficient frontier towards the origin. However, the more interesting result is how rules at various forecasting horizons are affected quite differently by these changes. More forward-looking rules, because they are more patient in their inflation control and can therefore benefit more from the stabilizing effects of credibility on expectations, are much less affected by a flattening of the Phillips curve than are shorter-horizon rules that control inflation more precisely through the output gap channel.

Finally, our results suggest that a fiscal policy with more countercyclical automatic stabilizers shifts the efficient policy frontier facing the central bank marginally towards the origin, so reductions in both inflation and output variability are attainable. Again, however, to realize these gains, the monetary authority may have to adjust its reaction function. For example, for our reference reaction function, more countercyclical automatic stabilizers leave the variance of inflation unchanged but increase slightly the variance of output.

Perhaps the overriding message from our results is a cautionary one for inflation targeters. Inflation targeting, by keeping the medium-term focus clearly on inflation control, may avoid serious monetary policy errors. Moreover, success in realizing an inflation target may build monetary credibility, and thereby open up a new zone of previously unattainable and unambiguously better outcomes. But an inflation target is not a rule, and efficient rules change as credibility shifts. In practice, of course, this is complicated by the fact that central banks have only imperfect indicators of their credibility. This suggests that it may be preferable to use a rule that performs reasonably well in a range of possible environments, rather than providing the best outcome in one environment. Using a minimax criterion (as does Sargent (1998)), which minimizes the maximum loss, may provide one way to formalize this idea. In future work, we hope to explore this issue further while expanding our analysis to a broader range of rules. Interestingly, some preliminary work suggests that simple Taylor rules do not suffer from the same sort of senstivity as do IFB rules. In particular, increases in credibility shift the entire Taylor rule efficient frontier towards the origin, even without a change in its parameter values. In other words, a monetary authority using a Taylor rule does not have to adjust its rule to reap the benefits of increased credibility. This conclusion collaborates the results in Levin, Wieland, and Williams (1998), which suggest that Taylor rules are more robust than other rules to changes in model specification.

Table 1: Variance decomposition for VAR

Variables	Contribution, after 6 quarters, of innovations in *Y**	*PCOM*	*C+I*	*PY*	*z*	*rsl*
C+I	25.5	21.8	19.7	7.9	13.7	11.3
PY	27.3	25.3	25.2	22.0	0.1	0.0
z	14.3	17.7	18.6	16.9	11.4	21.1
rsl	14.9	25.0	22.1	15.6	11.5	10.9

Table 2: Stochastic properties of the model for selected IFB rules

Variable	History: Standard deviation	History: AR(1)	Model: θ = 3.0: Standard deviation	Model: θ = 3.0: AR(1)	Model: θ = 1.0: Standard deviation	Model: θ = 1.0: AR(1)	Model: θ = 0.5: Standard deviation	Model: θ = 0.5: AR(1)
Δy	4.2	0.31	3.9	0.40	3.9	0.39	3.9	0.39
$\Delta_4 y$	2.7	0.85	2.8	0.93	2.8	0.94	2.9	0.94
$\tilde{y}^{HP}$	1.6	0.84	1.8	0.87	1.8	0.86	1.8	0.86
$(C+I)/Y$	2.0	0.91	1.5	0.89	1.5	0.90	1.5	0.90
C/Y	1.6	0.86	0.9	0.94	1.0	0.94	1.1	0.95
I/Y	1.6	0.98	0.9	0.86	0.9	0.86	0.9	0.87
$TBAL/Y$	1.9	0.94	1.5	0.92	1.5	0.92	1.5	0.92
G/Y	1.3	0.94	0.5	0.93	0.5	0.93	0.5	0.94
rsl	1.5	0.83	1.9	0.85	1.9	0.86	2.2	0.88
rn	3.5	0.94	3.7	0.87	3.9	0.90	5.3	0.93
z	6.7	0.95	3.9	0.90	3.8	0.90	3.7	0.90
Π^c	3.1	0.97	1.7	0.96	2.4	0.97	3.7	0.98

Table 3: Comparing alternative IFB rules

	RULES		
	***j*8θ3**	***j*8θ9**	***j*5θ7**
RMSD $(\Pi^{c}-\Pi^{c,T})$	1.57	1.14	0.99
SD $(\Pi^{c}-\Pi^{c,T})$	1.56 (0.25)*	1.13 (0.15)	0.99 (0.13)
MEAN $(\Pi^{c}-\Pi^{c,T})$	0.12 (0.52)	-0.08 (0.25)	0.04 (0.23)
RMSD $(\tilde{y})$	2.60	2.17	2.64
SD $(\tilde{y})$	2.36 (0.41)	2.00 (0.26)	2.42 (0.40)
MEAN $(\tilde{y})$	-0.98 (0.62)	-0.82 (0.49)	-0.96 (0.62)
SD (rsl)	1.67 (0.31)	2.24 (0.28)	2.28 (0.25)
SD (rn)	3.42 (0.67)	4.16 (0.50)	4.07 (0.49)
SD (z)	3.81 (0.67)	2.76 (0.49)	3.31 (0.62)
% time outside bands			
+/- 1	54	39	31
+/- 2	21	9	4
Median duration in quarters of departures from bands			
+/- 1	7	5	4
+/- 2	4	3	2

* Bracketed terms are one standard error as computed across stochastic simulations.

Table 4: Stochastic properties for selected IFB rules when credibility changes

	Base model *j*8θ3	**Cred-I** *j*8θ3	**Cred-II** *j*8θ3	**Cred-II** *j*7θ11	**Fiscal** *j*8θ3
RMSD$(\Pi^c - \Pi^{c,T})$	1.57	1.45	1.27	0.98	1.57
SD$(\Pi^c - \Pi^{c,T})$	1.56 (0.25)*	1.44 (0.21)	1.21 (0.18)	0.97 (0.12)	1.57 (0.25)
MEAN$(\Pi^c - \Pi^{c,T})$	0.12 (0.52)	0.15 (0.45)	0.39 (0.38)	0.22 (0.18)	0.11 (0.54)
RMSD$(\tilde{y})$	2.60	2.68	3.12	1.77	2.64
SD$(\tilde{y})$	2.36 (0.41)	2.43 (0.45)	2.92 (0.54)	1.70 (0.25)	2.40 (0.44)
MEAN$(\tilde{y})$	-0.98 (0.62)	-0.95 (0.75)	-0.50 (1.04)	0.28 (0.42)	-1.00 (0.64)
SD(rsl)	1.67 (0.31)	1.27 (0.25)	0.99 (0.22)	1.59 (0.21)	1.69 (0.32)
SD(rn)	3.42 (0.67)	2.71 (0.58)	2.16 (0.53)	2.94 (0.42)	3.44 (0.69)
SD (z)	3.81 (0.67)	3.88 (0.65)	4.01 (0.63)	2.71 (0.44)	3.94 (0.70)
RMSD$(E_t\Pi^c_{t+4} - \Pi^{c,T})$	0.70 (0.12)	0.54 (0.10)	0.40 (0.10)	0.16 (0.02)	0.70 (0.13)
% time outside bands					
+/- 1	54	50	43	32	55
+/- 2	21	18	11	4	21
Median duration in quarters of departures from bands					
+/- 1	7	6	5	4	7
+/- 2	4	4	3	2	4

* Bracketed terms are one standard error as computed across stochastic simulations.

Table 5: Stochastic properties of the fiscal indicator

	1970-1993	**Base Case**	**Alternative**
AR(1)	0.6	0.4	0.5
SD(f)	1.2	0.5	1.1
CORR$(f, \tilde{y}^{HP})$	-0.9	-0.4	-0.8

Figure 1
Consumer price index in Canada
(Monthly, year-over-year percent change)

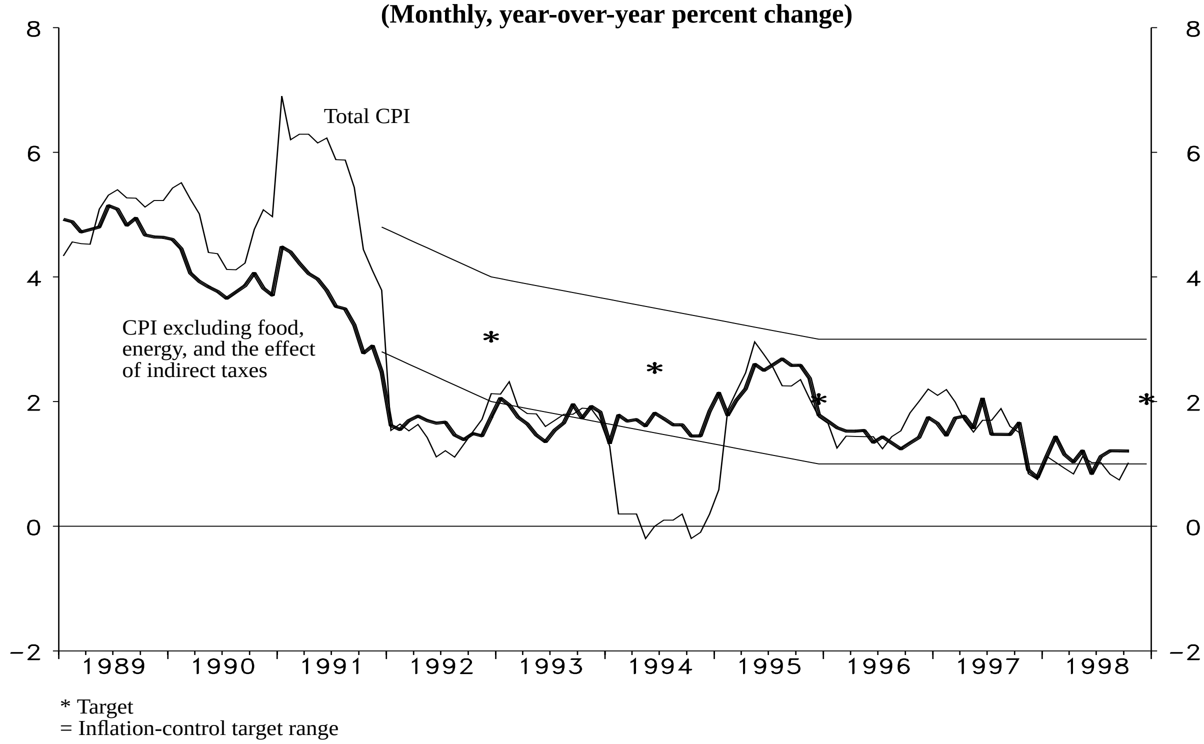
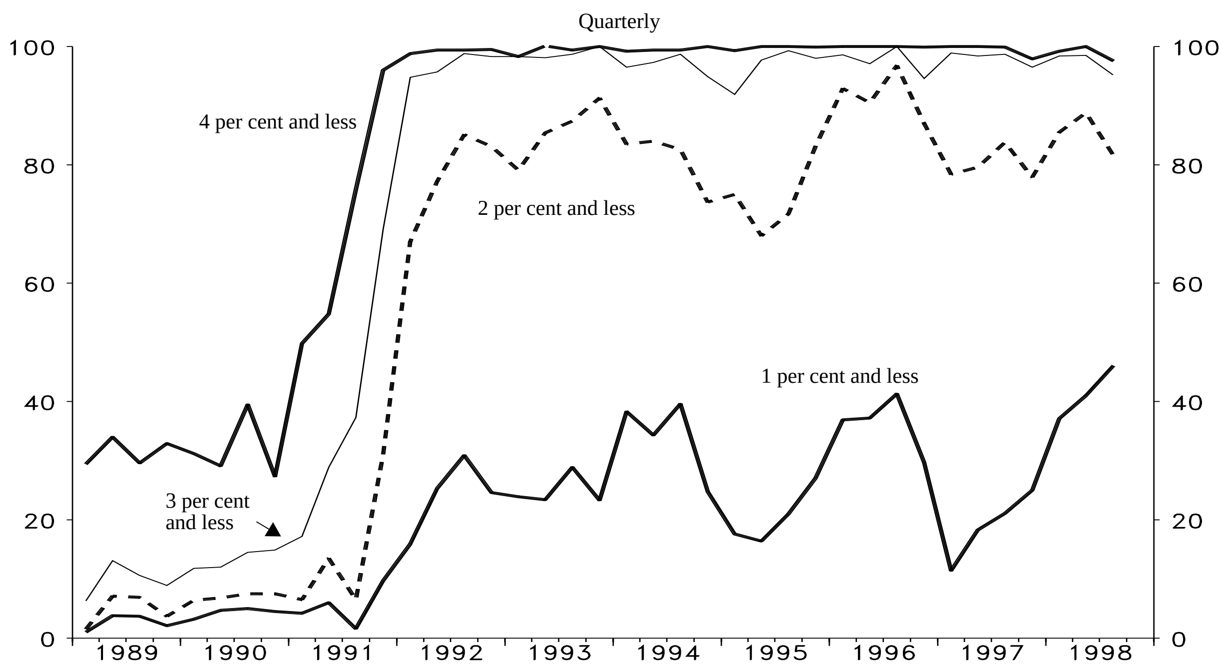


Figure 2
Percentage distribution of expected price increases over the next six months



Source: Conference Board of Canada, *Index of Business Confidence*

Figure 3
Consensus forecasts of CPI inflation

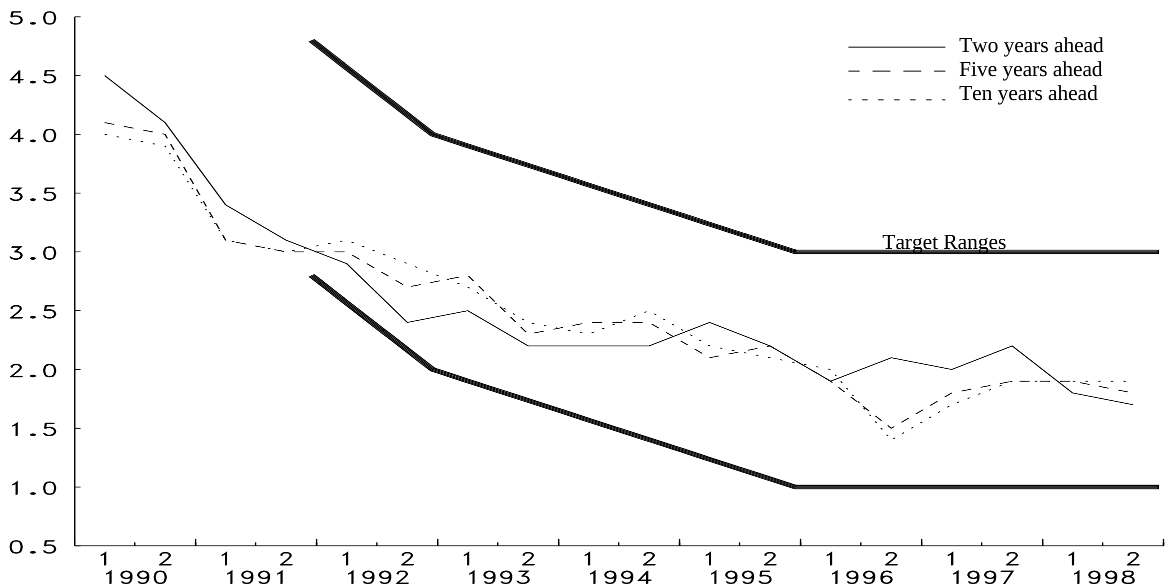


Figure 4

Standard deviation of one-year-ahead inflation forecasts across forecasters
(plotted against date forecast was made)

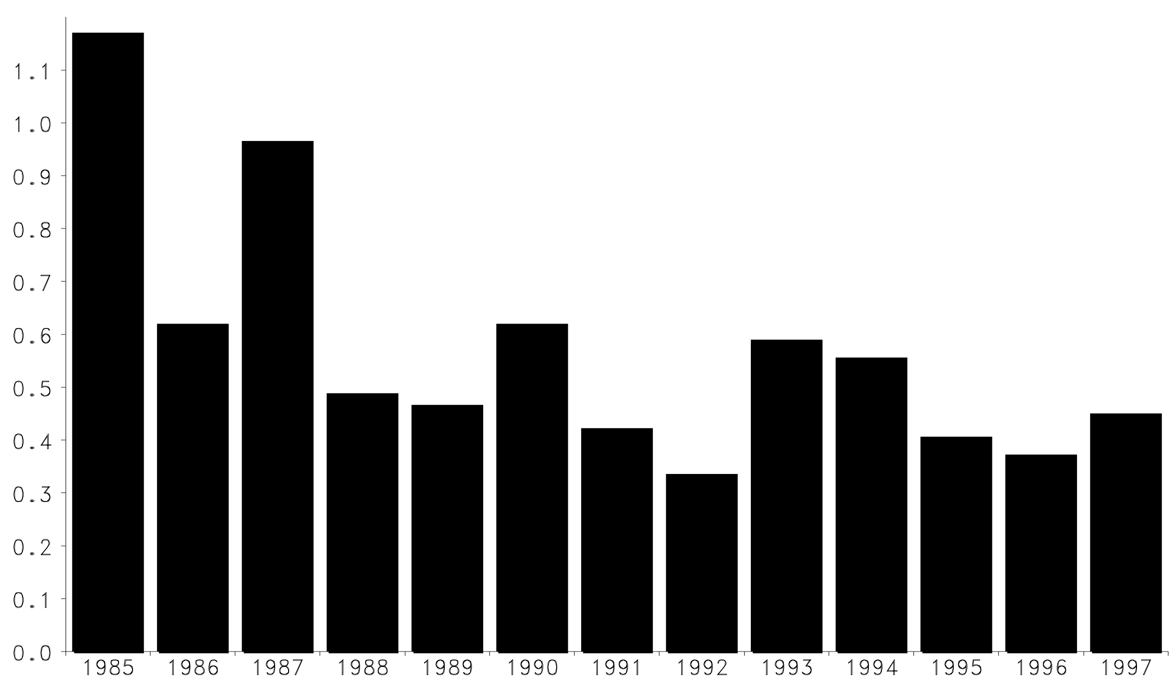


Figure 5
Root mean squared deviation of one-year-ahead inflation forecasts from target
(plotted against date forecast was made)

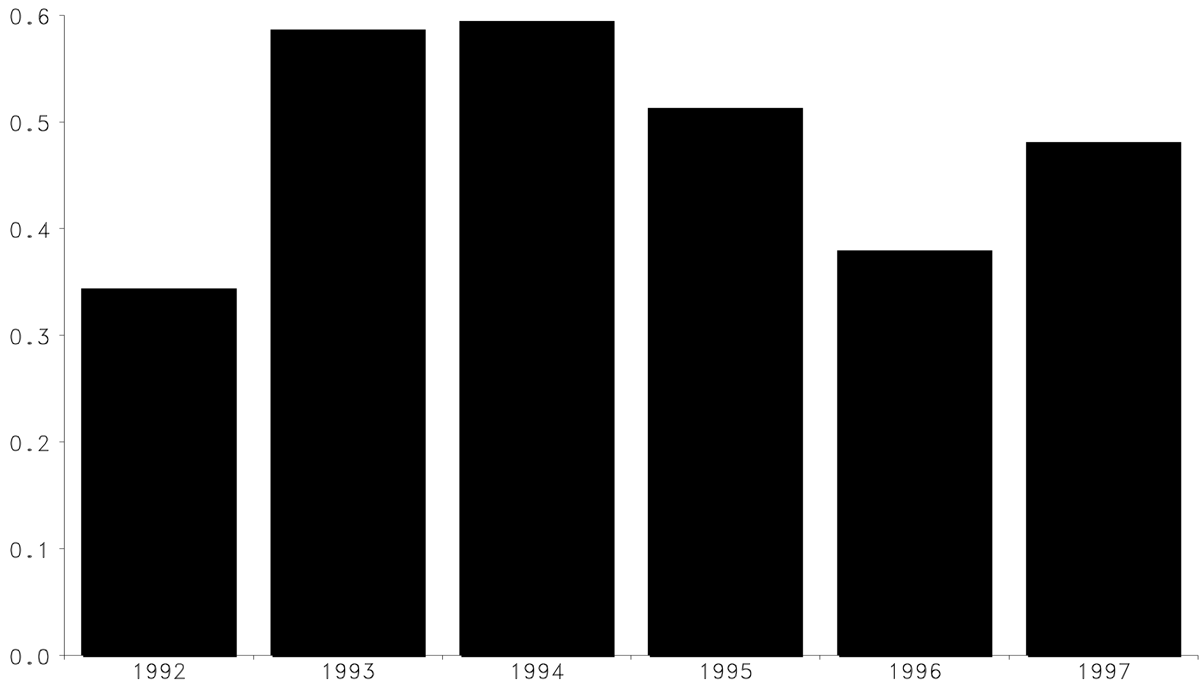
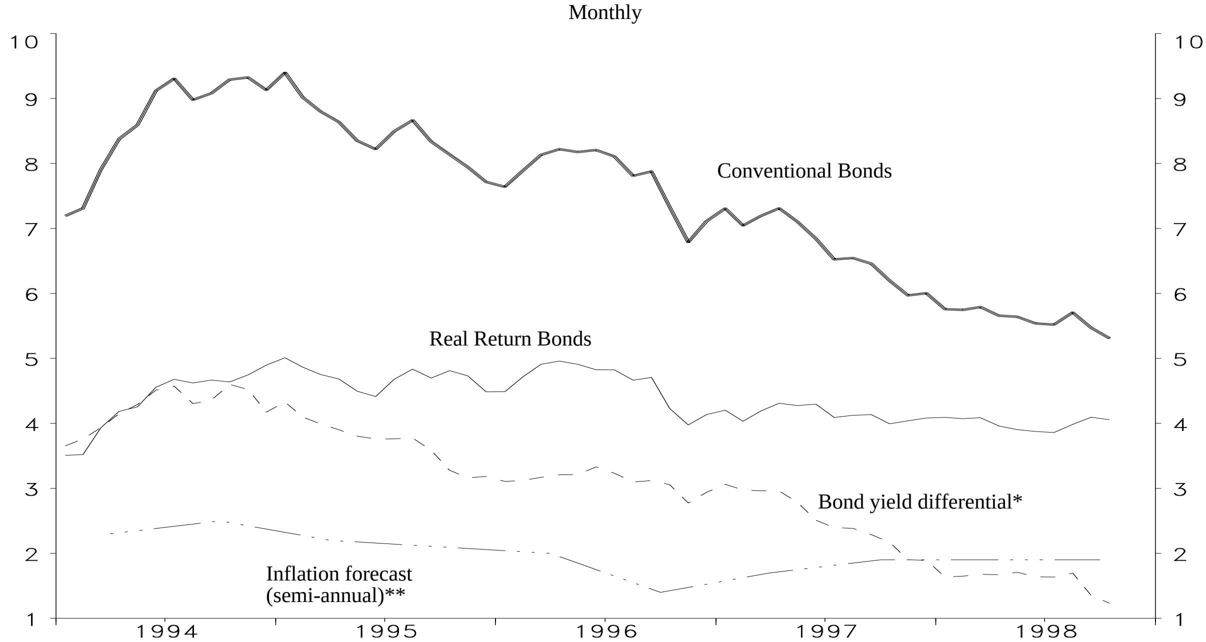


Figure 6
CPI inflation forecasts 6 to 10 years ahead
and 30-year bond yield
Monthly



* The differential is calculated using the appropriate compound interest formula.
** Source: Consensus Economics Inc.

Figure 7

Average duration of contracts, major wage settlement – private sector (months)
6 period backward moving average of average duration of contracts

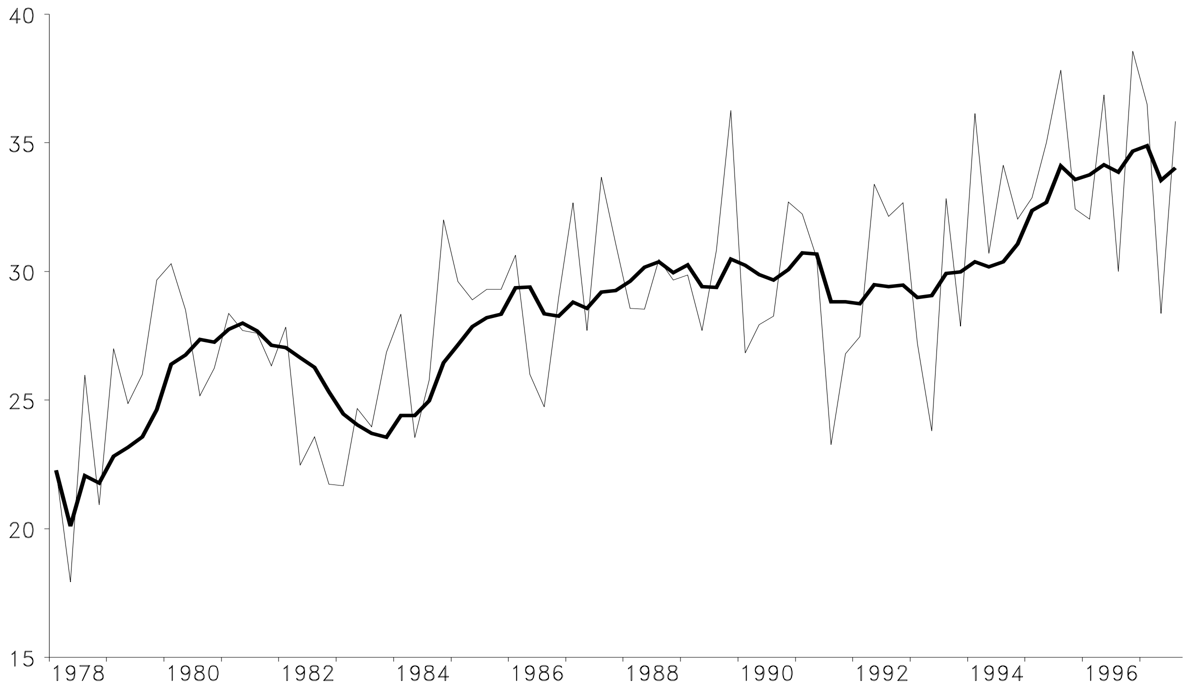
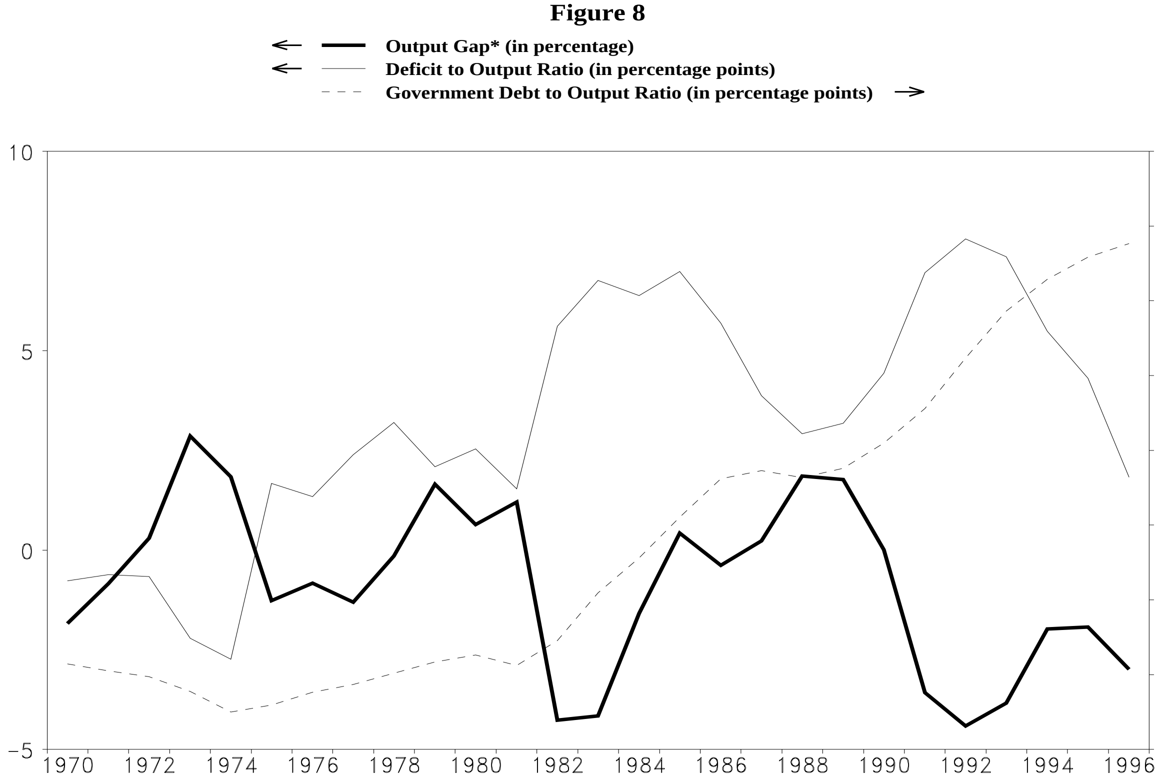
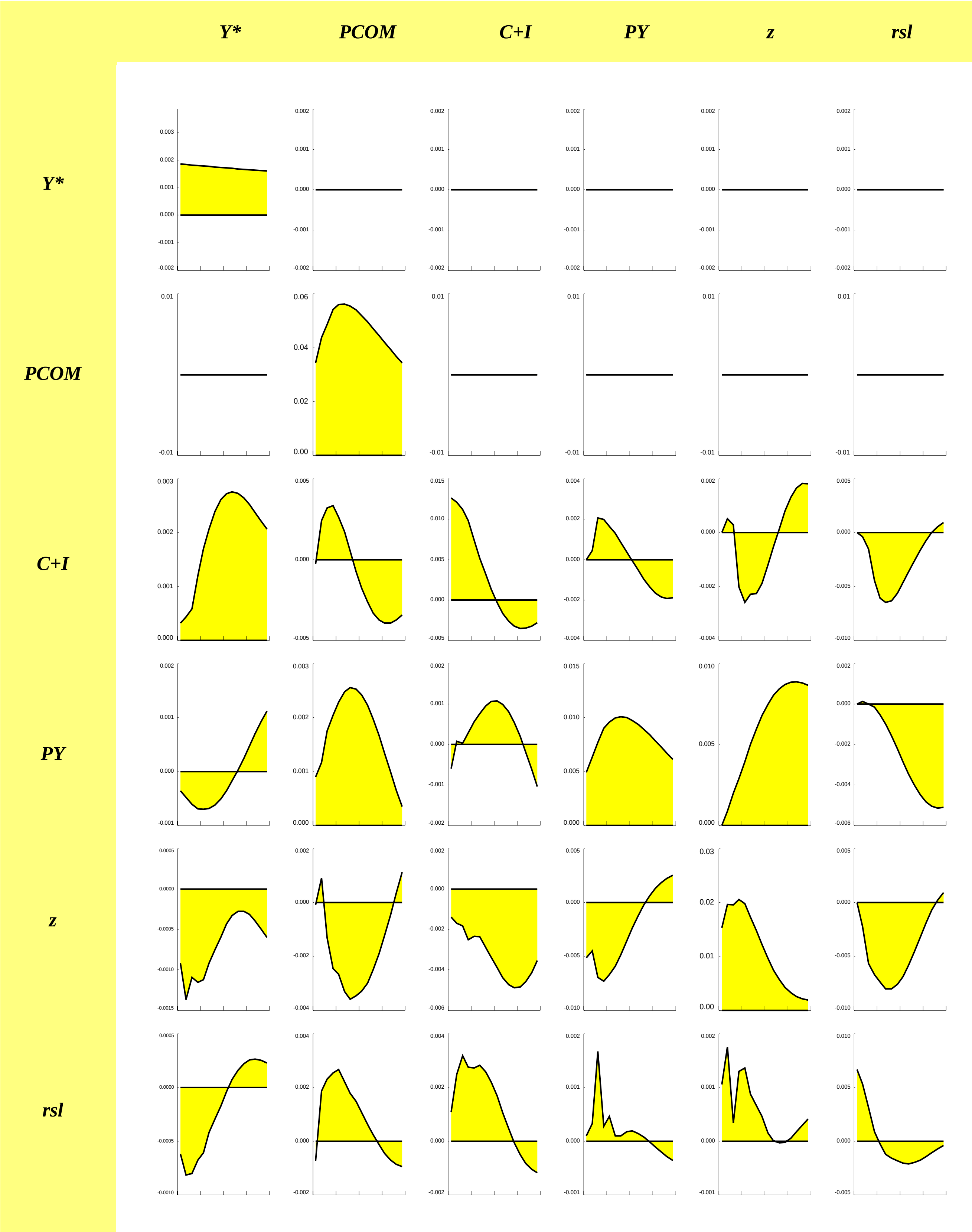


Figure 8



* Bank of Canada estimate

Figure 9: Impulse Response Functions



1961Q1 to 1992Q4

Figure 10
Efficient Policy Frontiers for IFB Rules

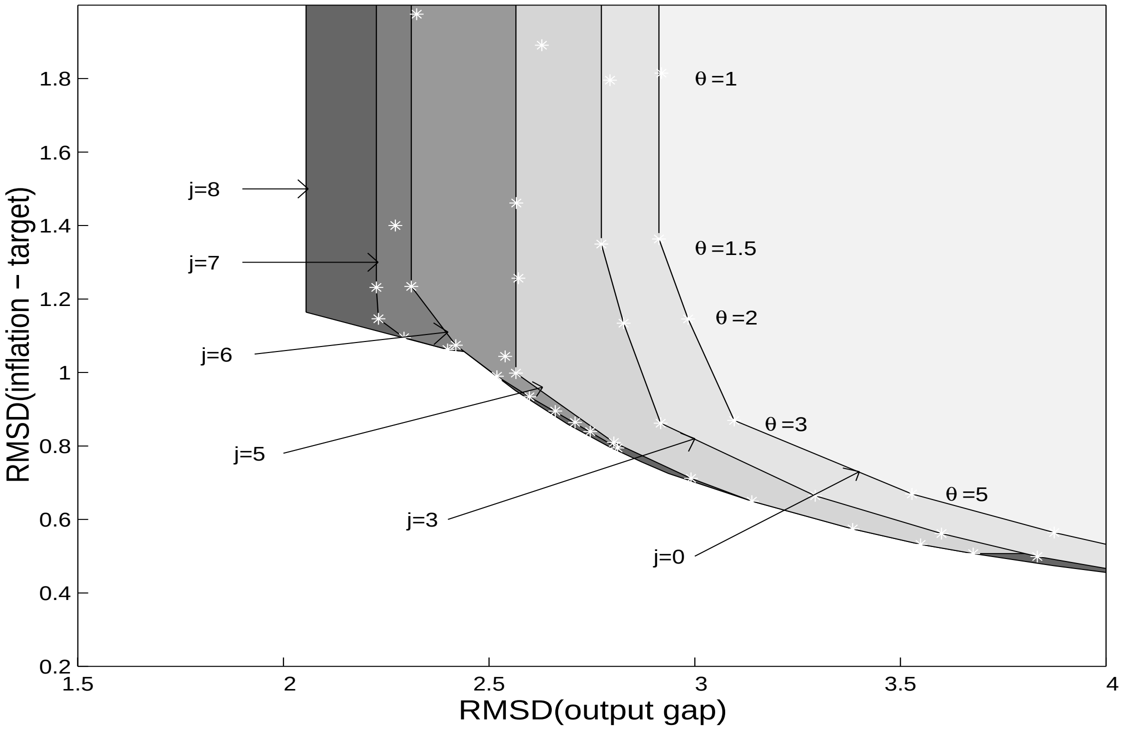


Figure 11
Global Efficient Policy Frontier for IFB Rules

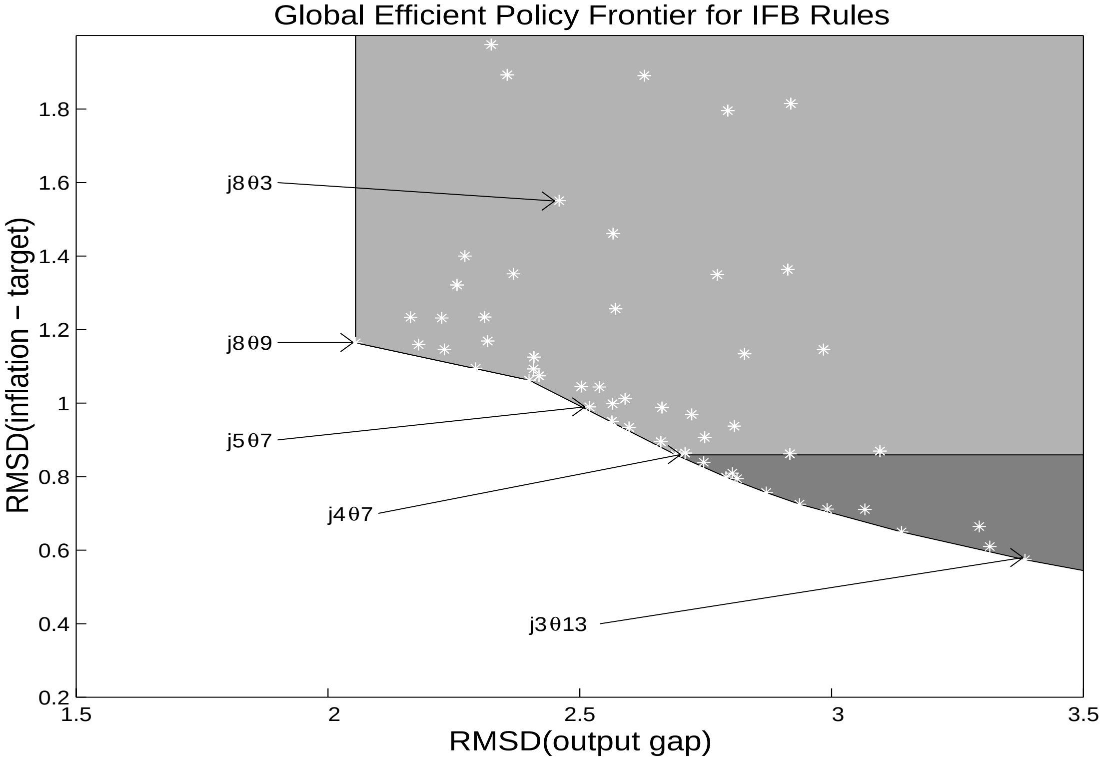


Figure 12

Efficient Policy Frontiers for IFB Rules with Different Levels of Monetary Credibility

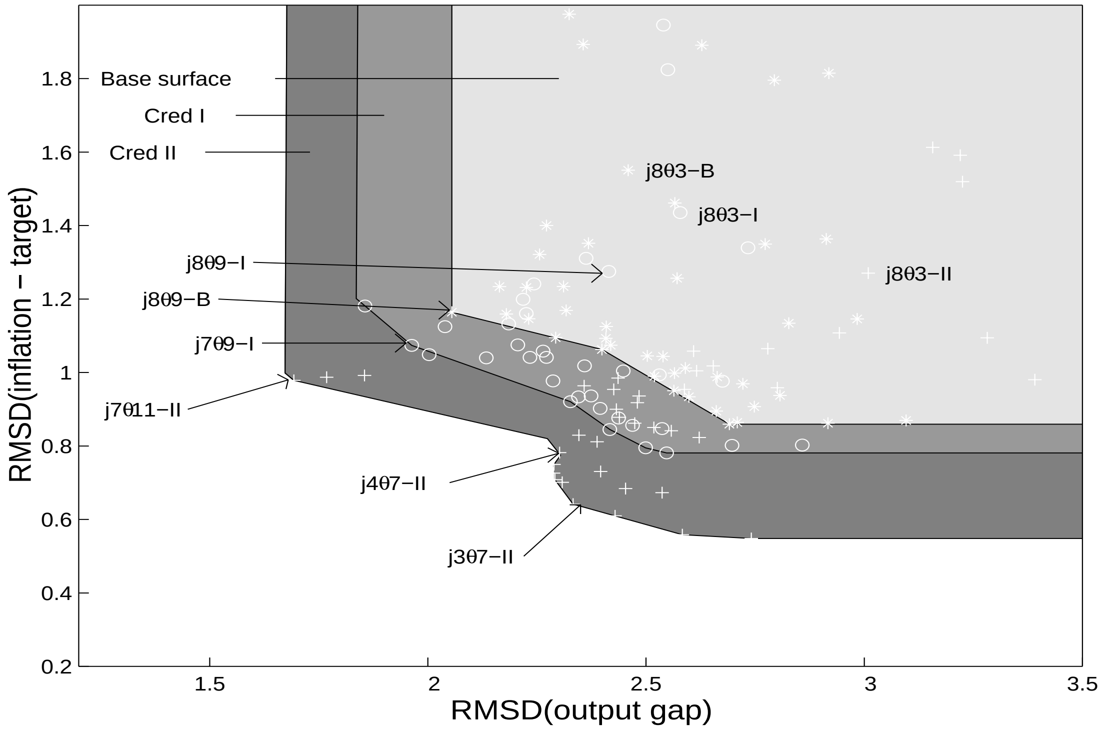


Figure 13

The Efficient IFB Frontier With a Flatter Phillips Curve

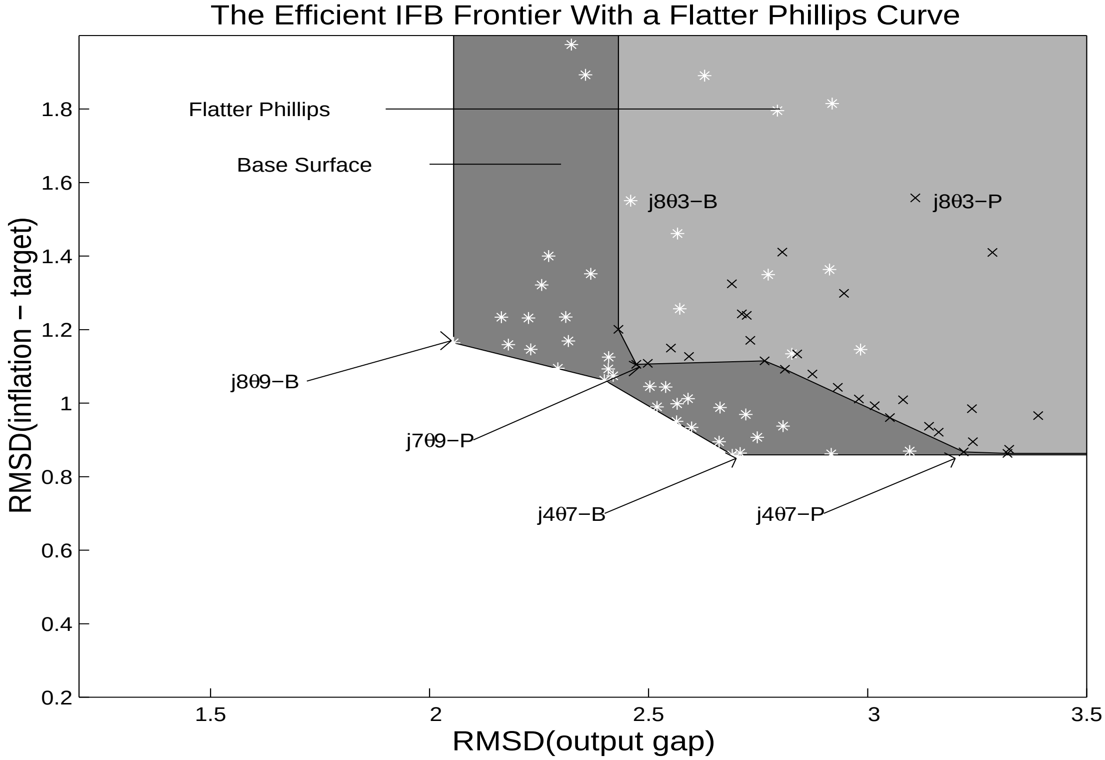


Figure 14
The Implications of a Flatter Phillips Curve When Policy is More Credible

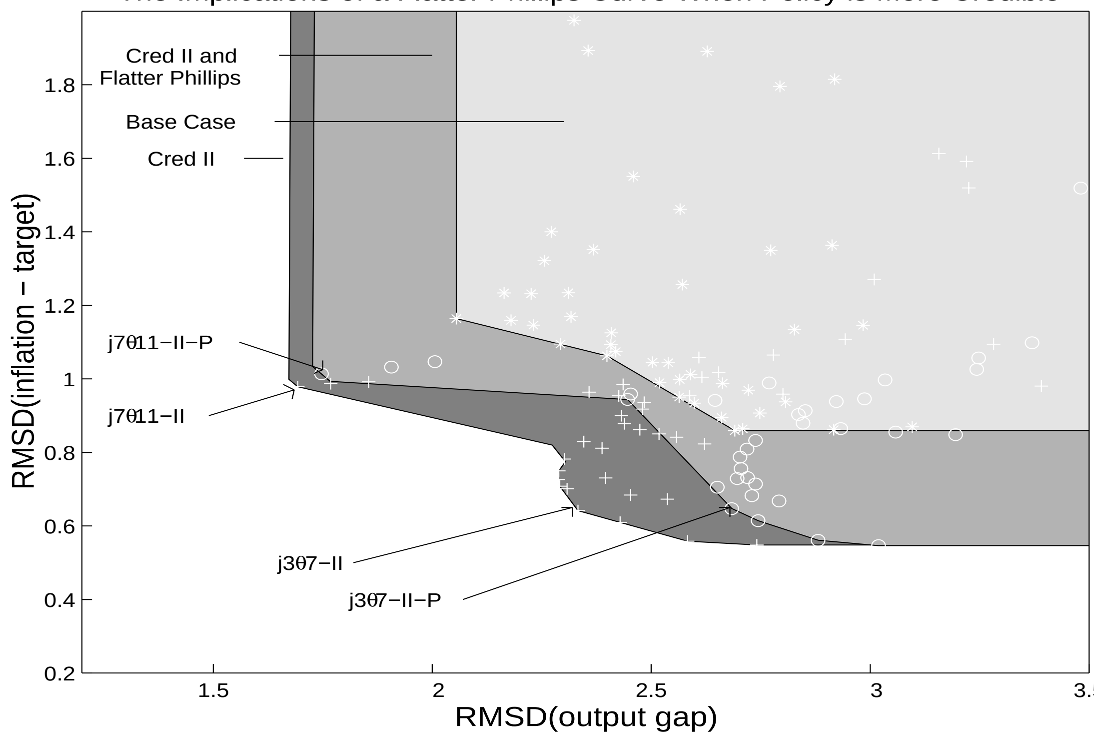
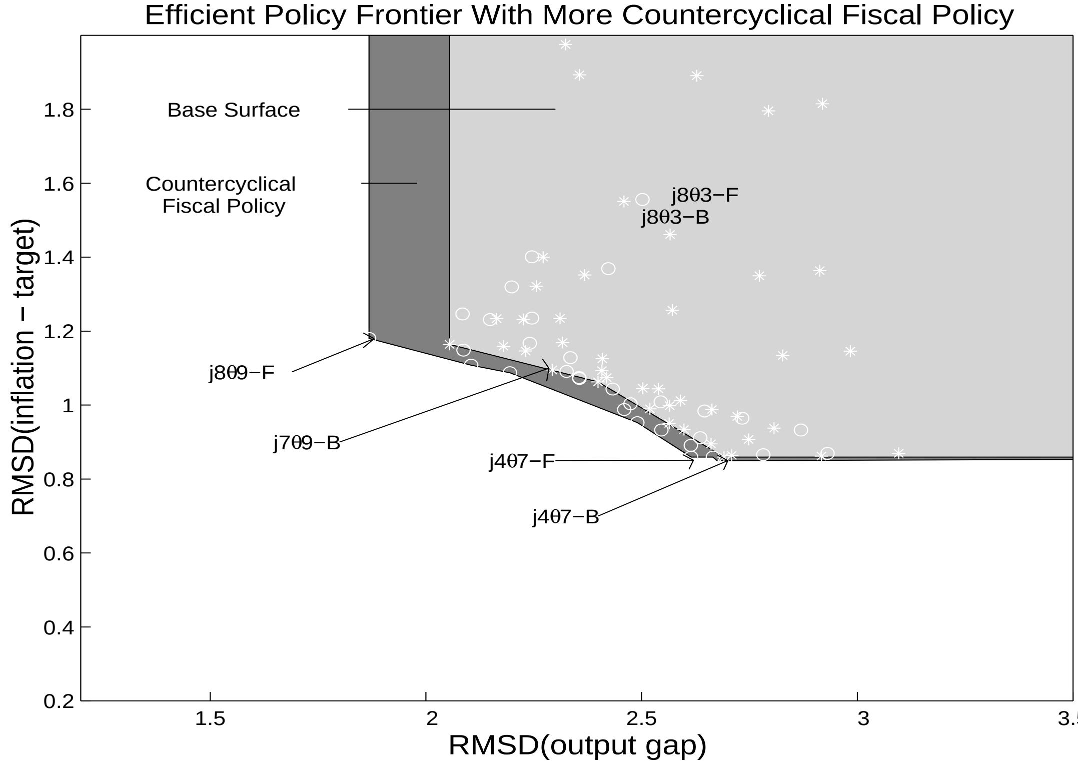


Figure 15
Efficient Policy Frontier With More Countercyclical Fiscal Policy



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