POLICY RULES FOR OPEN ECONOMIES

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Abstract

This paper examines the choice of a monetary policy rule in a simple macroeconomic model. In a closed economy, the optimal policy is a 'Taylor rule' in which the interest rate depends on output and inflation. In an open economy, the optimal rule changes in two ways. First, the policy instrument is a 'Monetary Conditions Index' – a weighted average of the interest rate and the exchange rate. Second, on the right side of the rule, inflation is replaced by 'long-run inflation', a variable that filters out the transitory effects of exchange-rate movements. The model also implies that pure inflation targeting is dangerous in an open economy, because it creates large fluctuations in exchange rates and output. Targeting long-run inflation avoids this problem and produces a close approximation to the optimal instrument rule.

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Table of Contents

1.	Introduction	1
2.	The Model	2
	2.1 Assumptions	2
	2.2 Calibration	4
3.	Efficient Instrument Rules	5
	3.1 The Variables in the Rule	5
	3.2 Interpretation	6
	3.3 Efficient Coefficients for the Rule	7
4.	Other Instrument Rules	9
5.	The Perils of Inflation Targeting	11
	5.1 Strict Inflation Targets	11
	5.2 The Case of New Zealand	13
	5.3 Gradual Adjustment?	14
6.	Long-run Inflation Targets	15
	6.1 The Policies	15
	6.2 Results	17
7.	Conclusion	19
Appendix A:	Domestic Goods and Imports	20
Appendix B:	The Variances of Output and Inflation	21
References		22

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1. Introduction

What policy rules should central banks follow? A growing number of economists and policy-makers advocate targets for the level of inflation. Many also argue that inflation targeting should be implemented through a 'Taylor rule' in which interest rates are adjusted in response to output and inflation. These views are supported by the theoretical models of Svensson (1997a) and Ball (1997), in which the optimal policies are versions of inflation targets and Taylor rules.

Many analyses of policy rules assume a closed economy. This paper extends the Svensson-Ball model to an open economy and asks how the optimal policies change. The short answer is they change quite a bit. In open economies, inflation targets and Taylor rules are suboptimal unless they are modified in important ways. Different rules are required because monetary policy affects the economy through exchange rate as well as interest-rate channels.[1]

Section 2 presents the model, which consists of three equations. The first is a dynamic, open-economy IS equation: output depends on lags of itself, the real interest rate, and the real exchange rate. The second is an open-economy Phillips curve: the change in inflation depends on lagged output and the lagged change in the exchange rate, which affects inflation through import prices. The final equation is a relation between interest rates and exchange rates that captures the behaviour of asset markets.

Section 3 derives the optimal instrument rule in the model. This rule differs in two ways from the Taylor rule that is optimal in a closed economy. First, the policy instrument is a weighted sum of the interest rate and the exchange rate – a 'Monetary Conditions Index' like the ones used in several countries. Second, on the

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1 Svensson (1997b) also examines alternative policy rules in an open-economy model. That paper differs from this one and from Svensson (1997a) in stressing microfoundations and forward-looking behaviour, at the cost of greater complexity.

right side of the policy rule, inflation is replaced by 'long-run inflation'. This variable is a measure of inflation adjusted for the temporary effects of exchange-rate fluctuations.

Section 4 considers several instrument rules proposed in other papers at this conference. I find that most of these rules perform poorly in my model.

Section 5 turns to inflation targeting. In the closed-economy models of Svensson and Ball, a simple version of this policy is equivalent to the optimal Taylor rule. In an open economy, however, inflation targeting can be dangerous. The reason concerns the effects of exchange rates on inflation through import prices. This is the fastest channel from monetary policy to inflation, and so inflation targeting implies that it is used aggressively. Large shifts in the exchange rate produce large fluctuations in output.

Section 6 presents a more positive result. While pure inflation targeting is undesirable, a modification produces much better outcomes. The modification is to target 'long-run inflation' – the inflation variable that appears in the optimal instrument rule. This variable is not influenced by the exchange-rate-to-import-price channel, and so targeting it does not induce large exchange-rate movements. Targeting long-run inflation is not exactly equivalent to the optimal instrument rule, but it is a close approximation for plausible parameter values.

Section 7 concludes the paper.

2. The Model

2.1 Assumptions

The model is an extension of Svensson (1997a) and Ball (1997) to an open economy. The goal is to capture conventional wisdom about the major effects of monetary policy in a simple way. The model is similar in spirit to the more complicated macroeconometric models of many central banks.

The model consists of three equations:

$$y \;=\; -br_{-1} - de_{-1} + ly_{-1} + e \tag{1}$$

$$p \;=\; p_{-1} + ay_{-1} - g(e_{-1} - e_{-2}) + h \tag{2}$$

$$e \;=\; qr + v \tag{3}$$

where y is the log of real output, r is the real interest rate, e is the log of the real exchange rate (a higher e means appreciation), p is inflation, and e, h, and v are white-noise shocks. All parameters are positive, and all variables are measured as deviations from average levels.

Equation (1) is an open-economy IS curve. Output depends on lags of the real interest rate and the real exchange rate, its own lag, and a demand shock.

Equation (2) is an open-economy Phillips curve. The change in inflation depends on the lag of output, the lagged change in the exchange rate, and a shock. The change in the exchange rate affects inflation because it is passed directly into import prices. This interpretation is formalised in Appendix A, which derives (2) from separate equations for domestic goods and import inflation.

Finally, Equation (3) posits a link between the interest rate and the exchange rate. It captures the idea that a rise in the interest rate makes domestic assets more attractive, leading to an appreciation. The shock v captures other influences on the exchange rate, such as expectations, investor confidence, and foreign interest rates. Equation (3) is similar to reduced-form equations for the exchange rate in many textbooks.

The central bank chooses the real interest rate r. One can interpret any policy rule as a rule for setting r. Using Equation (3), one can also rewrite any rule as a rule for setting e, or for setting some combination of e and r.

A key feature of the model is that policy affects inflation through two channels. A monetary contraction reduces output and thus inflation through the Phillips curve, and it also causes an appreciation that reduces inflation directly. The lags in

Equations (1) – (3) imply that the first channel takes two periods to work: a tightening raises *r* and *e* contemporaneously, but it takes a period for these variables to affect output and another period for output to affect inflation. In contrast, the direct effect of an exchange-rate change on inflation takes only one period. These assumptions capture the common view that the direct exchange-rate effect is the quickest channel from policy to inflation.

2.2 Calibration

In analysing the model, I will interpret a period as a year. With this interpretation, the time lags in the model are roughly realistic. Empirical evidence suggests that policy affects inflation through the direct exchange-rate channel in about a year, and through the output channel in about two years (e.g. Reserve Bank of New Zealand 1996; Lafleche 1996).

The analysis will use a set of base parameter values. Several of these values are borrowed from the closed-economy model in Ball (1997). Based on evidence discussed there, I assume that l, the output-persistence coefficient, is 0.8; that α, the slope of the Phillips curve, is 0.4; and that the total output loss from a one-point rise in the interest rate is 1.0. In the current model, this total effect is $b + dq$: b is the direct effect of the interest rate and dq is the effect through the exchange rate. I therefore assume $b + dq = 1.0$.

The other parameters depend on the economy's degree of openness. My base values are meant to apply to medium-to-small open economies such as Canada, Australia, and New Zealand. My main sources for the parameters are studies by these countries' central banks. I assume $g = 0.2$ (a one per cent appreciation reduces inflation by two tenths of a point) and $q = 2.0$ (a one-point rise in the interest rate causes a two per cent appreciation). I also assume $b / d = 3.0$, capturing a common rule of thumb about IS coefficients. Along with my other assumptions, this implies $b = 0.6$ and $d = 0.2$.[2]

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[2] Examples of my sources for base parameter values are the Canadian studies of Longworth and Poloz (1986) and Duguay (1994) and the Australian study of Gruen and Shuetrim (1994).

3. Efficient Instrument Rules

Following Taylor (1994), the optimal policy rule is defined as the one that minimises a weighted sum of output variance and inflation variance. The weights are determined by policy-makers tastes. As in Ball (1997), an ‘efficient’ rule is one that is optimal for some weights, or equivalently a rule that puts the economy on the output variance/inflation variance frontier. This section derives the set of efficient rules in the model.

3.1 The Variables in the Rule

As discussed earlier, we can interpret any policy rule as a rule for *r*, a rule for *e*, or a rule for a combination of the two. Initially, it is convenient to consider rules for *e*. To derive the efficient rules, I first substitute Equations (3) into (1) to eliminate *r* from the model. I shift the time subscripts forward to show the effects of the current exchange rate on future output and inflation. This yields:

$$y_{+1} \quad = \quad -(b/q + d)e + ly + e_{+1} + (b/q)v \tag{4}$$

$$p_{+1} \quad = \quad p + ay - g(e - e_{-1}) + h_{+1} \tag{5}$$

Consider a policy-maker choosing the current *e*. One can define the state variables of the model by two expressions corresponding to terms on the right sides of Equations (4) and (5): $ly + (b/q)v$, and $p + ay + ge_{-1}$. The future paths of output and inflation are determined by these two expressions, the rule for choosing *e*, and future shocks. Since the model is linear quadratic, one can show the optimal rule is linear in the two state variables:

$$e \quad = \quad m[ly + (b/q)v] + n[p + ay + ge_{-1}] \tag{6}$$

where *m* and *n* are constants to be determined.

In Equation (6), the choice of e depends on the exchange-rate shock n as well as observable variables. By Equation (3), n can be replaced by $e - qr$. Making this substitution and rearranging terms yields:

$$wr + (1 - w)e \; = \; ay + b(p + \; ge_{-1}) \tag{7}$$

where $\quad w = mbq \,/\, (q - mb + mbq), \qquad \mathrm{a} = q(m\,l + na\,) \,/\, (q - mb + mbq),$

$$b = nq \,/\, (q - mb + mbq)$$

This expresses the optimal policy as a rule for an average of r and e.

3.2 Interpretation

In the closed-economy model of Svensson and Ball, the optimal policy is a Taylor rule: the interest rate depends on output and inflation. Equation (7) modifies the Taylor rule in two ways. First, the policy variable is a combination of r and e. And second, inflation is replaced by $p + \; ge_{-1}$, a combination of inflation and the lagged exchange rate. Each of these modifications has a simple interpretation.

The first result supports the practice of using an average of r and e – a 'Monetary Conditions Index' – as the policy instrument. Several countries follow this approach, including Canada, New Zealand and Sweden (see Gerlach and Smets 1996). The rationale for using an MCI is that it measures the overall stance of policy, including the stimulus through both r and e. Policy-makers shift the MCI when they want to ease or tighten. When there are shifts in the e/r relation – shocks to Equation (3) – r is adjusted to keep the MCI at the desired level.

The second modification of the Taylor rule is more novel. The term $p + \; ge_{-1}$ can be interpreted as a long-run forecast of inflation under the assumption that output is kept at its natural level. With a closed-economy Phillips curve, this forecast would simply be current inflation. In an open economy, however, inflation will change because the exchange rate will eventually return to its long-run level, which is normalised to zero. For example, if e was positive in the previous period, there will be a depreciation of e_{-1} at some point starting in the current period. By

Equation (2), this will raise inflation by ge_{-1} at some point after the current period. I will use the term ‘long-run inflation’ and the symbol p^* to stand for $p + ge_{-1}$.

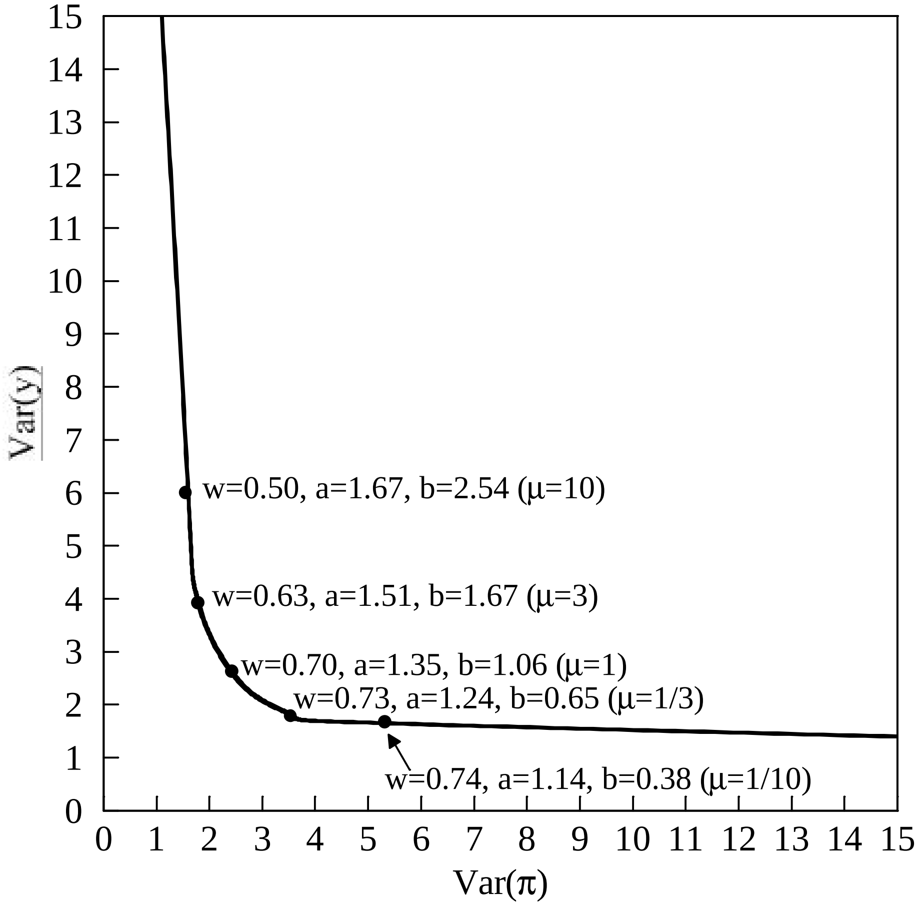
More broadly, one can interpret $p + ge_{-1}$ as a measure of inflation that filters out direct but temporary effects of the exchange rate. For a given output path, an appreciation causes inflation to fall, but it will rise again by ge_{-1} when the appreciation is reversed. The adjustment from p to p^* is similar in spirit to calculations of ‘core’ or ‘underlying’ inflation by central banks. These variables are measures of inflation adjusted for transitory influences such as changes in indirect taxes or commodity prices. Many economists argue that policy should respond to underlying inflation and ignore transitory fluctuations. My model supports this idea for the case of fluctuations caused by exchange rates.

3.3 Efficient Coefficients for the Rule

The coefficients in the policy rule (7) depend on the constants m and n, which are not yet determined. The next step is to derive the efficient combinations of m and n – the combinations that put the economy on the output variance/inflation variance frontier. As discussed in Appendix B, the set of efficient policies depends on the coefficients in Equations (1) – (3) but not on the variances of the three shocks (although these variances determine the absolute position of the frontier). For base parameter values, I compute the variances of output and inflation for a given m and n and then search for combinations that define the frontier.

Figure 1 presents the results in a graph. The Figure shows the output variance/inflation variance frontier when the variance of each shock is one. For selected points on the frontier, the graph shows the policy-rule coefficients that put the economy at that point. It also shows the weights on output variance and inflation variance that make each policy optimal.

Figure 1: The Output Variance/Inflation Variance Frontier



Note: Objective function = Var(y) + μVar(π)

Two results are noteworthy. The first concerns the weights on *r* and *e* in the Monetary Conditions Index. There is currently a debate among economists about the appropriate weights. Some argue that the weights should be proportional to the coefficients on *e* and *r* in the IS equation (for example, Freedman 1994). For my base parameters, this implies *w*=0.75, i.e. weights of 0.75 on *r* and 0.25 on *e*. Others suggest a larger weight on *e* to reflect the direct effect of the exchange rate on inflation (see Gerlach and Smets 1996). In my model, the optimal weight on *e* is larger than 0.25, but by a small amount. For example, if the policy-makers objective function has equal weights on output and inflation variances, the MCI weight on *e* is 0.30. The weight on *e* is much smaller than its relative short-run effect on inflation.

The only exceptions occur when policy-makers objectives have very little weight on output variance.[3]

The second result concerns the coefficients on y and p^*, and how they compare to the optimal coefficients on y and p in a closed economy. Note that a one-point rise in the interest rate, which also raises the exchange rate, raises the MCI by a total of $w+q(1-w)$. Dividing the coefficients on y and p^* by this expression yields the responses of r to y and p^* – the analogues of Taylor-rule coefficients in a closed economy. For equal weights in policy-makers objective functions, the interest-rate response to output is 1.04 and the response to p^* is 0.82. Assuming the same objective function, the corresponding responses in a closed economy are 1.13 for output and 0.82 for inflation (Ball 1997). Thus the sizes of interest-rate movements are similar in the two cases.

4. Other Instrument Rules

This paper is part of a project to evaluate policy rules in alternative macroeconomic models. As part of the project, all authors are evaluating a list of six rules to see whether any performs well across a variety of models. Each of the rules has the general form:

$$r = \mathrm{a}p + by + cr_{-1} \tag{8}$$

where a, b, and c are constants. Table 1 gives the values of the constants in the six rules.

All of these rules are inefficient in the current model. There are two separate problems. First, the rules are designed for closed economies, and therefore do not make the adjustments for exchange-rate effects discussed in the last section. Second, even if the economy were closed, the coefficients in most of the rules

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[3] One measure of the overall effect of e on inflation is the effect through appreciation in one period plus the effect through the Phillips curve in two periods. This sum is $g + da = 0.28$. The corresponding effect of r on inflation is $ba = 0.24$. The MCI would put more weight on e than on r if it were based on these inflation effects.

would be inefficient. To distinguish between these problems, I evaluate the rules in two versions of my model: the open-economy case considered above, and a closed-economy case obtained by setting d and g to zero. The latter is identical to the model in Ball (1997).[4]

Table 1: Alternative Policy Rules

	Rule 1	Rule 2	Rule 3	Rule 4	Rule 5	Rule 6
a	2.0	0.2	0.5	0.5	0.2	0.3
b	0.8	1.0	0.5	1.0	0.06	0.08
c	1.0	1.0	0.0	0.0	2.86	2.86
						∞
Base case						
Var (y)	531.59	4.42	2.62	1.86	∞	∞
Var (π)	5.18	6.55	3.43	4.05	∞	∞
Closed economy						
Var (y)	∞	6.53	2.77	1.81	∞	∞
Var (π)	∞	7.59	3.91	4.22	∞	∞

Table 1 presents the variances of output and inflation for the six rules. For comparison, I also include variances for some of the efficient rules in the last section. The six new rules fall into two categories. The first are those with *c*, the coefficient on lagged *r*, that are equal to or greater than one (rules 1, 2, 5 and 6). For these rules, the output and inflation variances range from large to infinite, both in closed and open economies. This result reflects the fact that efficient rules in either case do not include the lagged interest rate. Including this variable leads to inefficient oscillations in output and inflation.

The other rules, numbers 3 and 4, omit the lagged interest rate ($c = 0$). These rules perform well in a closed economy. Indeed, rule 4 is fully efficient in that case; rule 3 is not quite efficient, but it puts the economy close to the frontier (see Ball 1997). In an open economy, however, rules 3 and 4 are inefficient because they ignore the exchange rate. Rule 4, for example, produces an output variance of 1.86 and an

[4] In the closed-economy case, I continue to assume $b + dq = 1$. Therefore, since d is zero, b is raised to one.

inflation variance of 4.05. Using an efficient rule, policy can achieve the same output variance with an inflation variance of 3.54.

Recall that the set of efficient rules does not depend on the variances of the model's three shocks. In contrast, the losses from using an inefficient rule generally do depend on these variances. For rules 3 and 4, the losses are moderate when demand and inflation shocks are most important, but larger when the exchange-rate shock is most important. That is, using *r* as the policy instrument is most inefficient if there are large shocks to the *r/e* relation. In this case, *r* is an unreliable measure of the overall policy stance.

5. The Perils of Inflation Targeting

This section turns from instrument rules to target rules, specifically inflation targets. In the closed-economy Svensson-Ball model, inflation targeting has good properties. In particular, the set of efficient Taylor rules is equivalent to the set of inflation-target polices with different speeds of adjustment. In an open economy, however, inflation targeting can be dangerous.

5.1 Strict Inflation Targets

As in Ball (1997), strict inflation targeting is defined as the policy that minimises the variance of inflation. When inflation deviates from its target, strict targeting eliminates the deviation as quickly as possible. I first evaluate this policy and then consider variations that allow slower adjustment.

Trivially, strict inflation targeting is an efficient policy: it minimises the weighted sum of output and inflation variances when the output weight is zero. Strict targeting puts the economy at the Northwest end of the variance frontier. In Figure 1, the frontier is cut off when the output variance reaches 15; when the frontier is extended, the end is found at an output variance of 25.8 and inflation variance of 1.0. Choosing this point implies a huge sacrifice in output stability for a small gain in inflation stability. Moving down the frontier, the output variance could be reduced to 9.7 if the inflation variance were raised to 1.1, or to 4.1 if the inflation variance were raised to 1.6. Strict inflation targeting is highly suboptimal if policy-makers put a non-negligible weight on output.

The output variance of 25.8 compares to a variance of 8.3 under strict inflation targeting in the closed-economy case. This difference arises from the different channels from policy to inflation. In a closed economy, the only channel is the one through output, which takes two periods (it takes a period for r to affect y and another period for y to affect p). With these lags, strict inflation targeting implies that policy sets expected inflation in two periods to zero. In an open economy, by contrast, policy can affect inflation in one period through the direct exchange-rate channel. When policy-makers minimise the variance of inflation, they set next period's expected inflation to zero:

$$Ep_{+1} = 0 \tag{9}$$

Equation (9) implies large fluctuations in the exchange rate, because next period's inflation can be controlled only by this variable. Intuitively, inflation in domestic-goods prices cannot be influenced in one period, so large shifts in import prices are needed to move the average price level. (Appendix A formalises this interpretation.) The large shifts in exchange rates cause large output fluctuations through the IS curve.

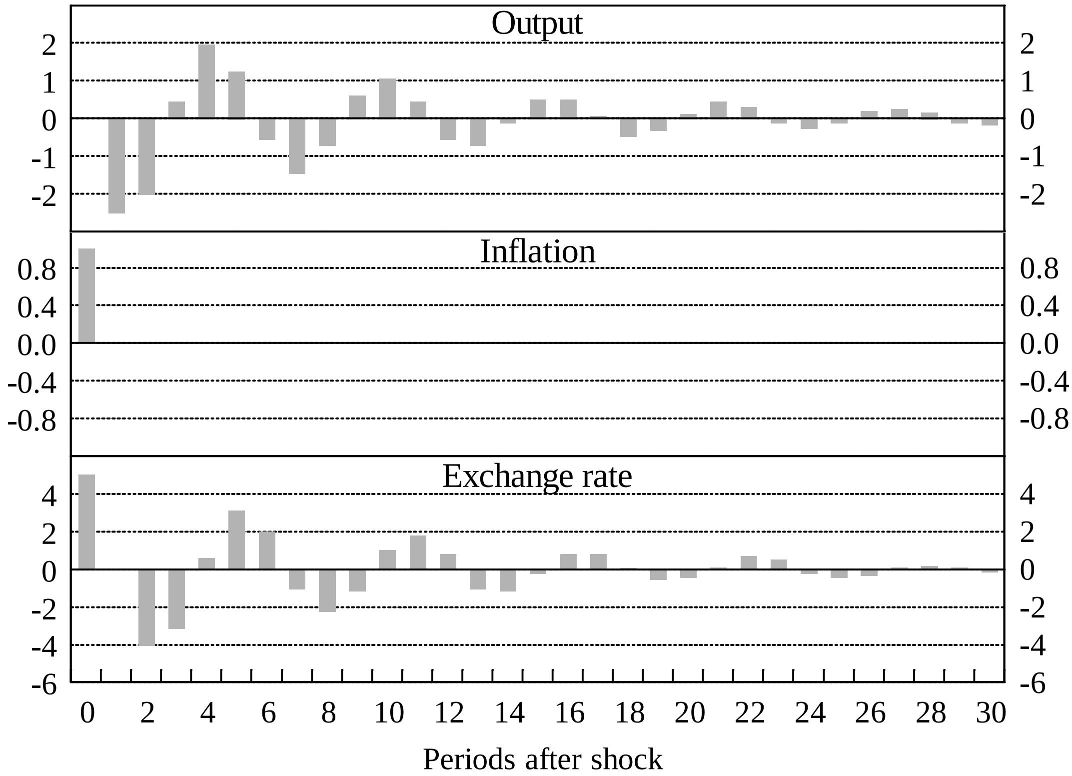
This point can be illustrated with impulse response functions. Substituting Equations (5) into (9) yields the instrument rule implied by strict inflation targeting:

$$e = (a / g)y + (1/ g)(p + ge_{-1}) \tag{10}$$

(Note this is a limiting case of Equation (7) in which the MCI equals the exchange rate.) Using Equations (4), (5) and (10), I derive the dynamic effects of a unit shock to the Phillips curve. Figure 2 presents the results. Inflation returns to target after one period, but the shock triggers oscillations in the exchange rate and output. The oscillations arise because the exchange rate must be shifted each period to offset the inflationary or deflationary effects of previous shifts. These results contrast to strict inflation targeting in a closed economy, where an inflationary shock produces only a one-time output loss.[5]

[5] Black, Macklem and Rose (1997) find that strict inflation targeting produces a large output variance in simulations of the Bank of Canada's model. Their interpretation of this result is similar to mine.

Figure 2: Strict Inflation Targets – Responses to an Inflation Shock



5.2 The Case of New Zealand

These results appear to capture real-world experiences with inflation targeting, particulary New Zealand's pioneering policy in the early 1990s. During that period, observers criticised the Reserve Bank of New Zealand for moving the exchange rate too aggressively to control inflation. For example, Dickens (1996) argues that 'whiplashing' of the exchange rate produced instability in output. He shows that aggregate inflation was steady because movements in import inflation offset movements in domestic-goods inflation. These outcomes are similar to the effects of inflation targeting in my model.

Recently, the Reserve Bank of New Zealand has acknowledged problems with strict inflation targeting:

> If the focus of policy is limited to a fairly short horizon of around six to twelve months, the setting of the policy stance will tend to be dominated by the relatively rapid-acting direct effects of exchange rate and interest rate changes on inflation. In the early years of inflation targeting, this was, in fact, more or less the way in which policy was run…

> Basing the stance of policy solely on its direct impact on inflation, however, is hazardous…[I]t is possible that in some situations actions aimed at maintaining price stability in the short term could prove destabilising to activity and inflation in the medium term.
>
> [Reserve Bank of New Zealand, 1996, pp. 28–29]

The Reserve Bank of New Zealand's story is similar to mine: moving inflation to target quickly requires strong reliance on the direct exchange-rate channel, which has adverse side-effects on output.[6]

5.3 Gradual Adjustment?

The problems with strict inflation targeting have led observers to suggest a modification: policy should move inflation to its target more slowly. The Reserve Bank of New Zealand has accepted this idea; it reports that 'in recent years the Bank's policy horizon has lengthened further into the future' and that this means it relies more heavily on the output channel to control inflation (p. 29).

In the current model, however, it is not obvious what policy rule captures the goal of 'lengthening the policy horizon'. One natural idea (suggested by several readers) is to target inflation two periods ahead rather than one period:

$$Ep_{+2} = 0 \tag{11}$$

This condition is the one implied by strict inflation targeting in the closed-economy model. In that model, the condition does not produce oscillations in output.

In the current model, however, Equation (11) does not determine a unique policy rule. Since policy can control inflation period-by-period, there are multiple paths to zero inflation in two periods. By the law of iterated expectations, $Ep_{+1} = 0$ in all periods impies $Ep_{+2} = 0$ in all periods. Thus a strict inflation target is one policy

6 The Reserve Bank discusses direct inflation effects of interest rates as well as exchange rates because mortgage payments enter New Zealand's CPI.

that satisfies Equation (11). But there are other policies that return inflation to zero in two periods but not one period.[7]

The same point applies to various modifications of Equation (11). For example, in the closed-economy model, any efficient policy can be written as an inflation target with slow adjustment: $Ep_{+2} = qEp_{+1}, 0 \leq q \leq 1$. This condition is also consistent with multiple policies in the current model. There does not appear to be any simple restriction on inflation that implies a unique policy with desirable properties. Policy-makers who wish to return inflation to target over the 'medium term' need some additional criterion to define their rule.[8]

6. Long-run Inflation Targets

This section presents the good news about inflation targets. The problems described in the previous section can be overcome by modifying the target variable. In light of earlier results, a natural modification is to target long-run inflation, p^*.

6.1 The Policies

Strict long-run inflation targeting is defined as the policy that minimises the variance of $p^* = p + ge_{-1}$. To see its implications, note that Equation (2) can be rewritten as:

$$p^* = p^*_{-1} + ay_{-1} + h \tag{12}$$

This equation is the same as a closed-economy Phillips curve, except that p^* replaces p. The exchange rate is eliminated, so policy affects p^* only through the

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[7] An example is a rule in which policy makes no contemporaneous response to shocks, but the exchange rate is adjusted after one period to return inflation to target in two periods.

[8] Another possible rule is partial adjustment in one period: $Ep_{+1} = qp$. This condition defines a unique policy, but the variance of output is large. The condition implies the same responses to demand and exchange-rate shocks as does strict inflation targeting. These shocks have no contemporaneous effects on inflation, so policy must fully eliminate their effects in the next period, even for $q > 0$.

output channel. Thus policy affects p^* with a two-period lag, and strict targeting implies:

$$Ep^*_{+2} \;=\; 0 \tag{13}$$

In contrast to a two-period-ahead target for total inflation, Equation (13) defines a unique policy.

There are two related motivations for targeting p^* rather than p. First, since p^* is not influenced by the exchange rate, policy uses only the output channel to control inflation. This avoids the exchange-rate 'whiplashing' discussed in the previous section. Second, as discussed in Section 3, p^* gives the level of inflation with transitory exchange-rate effects removed. p^* targeting keeps underlying inflation on track.

In addition to strict p^* targeting, I consider gradual adjustment of p^*:

$$Ep^*_{+2} \;=\; qEp^*_{+1}, \quad 0 \le q \le 1 \tag{14}$$

This rule is the similar to the gradual-adjustment rule that is optimal in a closed economy. Policy adjusts Ep^*_{+2} part of the way to the target from Ep^*_{+1}, which it takes as given. The motivation for adjusting slowly is to smooth the path of output.

In practice, countries with inflation targets do not formally adjust for exchange rates in the way suggested here. However, adjustments may occur implicitly. For example, a central-bank economist once told me that inflation was below his country's target, but that this was desirable because the currency was temporarily strong, and policy needed to 'leave room' for the effects of depreciation. Keeping inflation below its official target when the exchange rate is strong is similar to targeting p^*.

6.2 Results

To examine *p** targets formally, I substitute Equations (12) and (1) into condition Equation (14). This leads to the instrument rule implied by *p** targets:

$$w'r + (1 - w')e \quad = \quad \mathrm{a}'y + b'p\,* \tag{15}$$

where $w' = (b\,/\,(b + d)$, $\quad \mathrm{a}' = (1 - q + l)\,/\,(b + d)$, $b' = (1 - q)\,/\,[a\,(b + d)]$

This equation includes the same variables as the optimal rule in Section 3, but the coefficients are different. The MCI weights are given exactly by the relative sizes of *b* and *d*; for base parameters, *w*'=0.75. The coefficients on *y* and *p** depend on the adjustment speed *q*.

Appendix B calculates the variances of output and inflation under *p** targeting. Figure 3 plots the results for *q* between zero and one. The case of strict *p** targeting corresponds to the Northwest corner of the curve. For comparison, Figure 3 also plots the set of efficient policies from Figure 1.

The Figure shows that targeting *p** produces more stable output than targeting *p*. This is true even for strict *p** targets, which produce an output variance of 8.3, compared to 25.8 for *p* targets. Figure 4 shows the dynamic effects of an inflation shock under *p** targets, and confirms that this policy avoids oscillations in output. Strict *p** targeting is, however, moderately inefficient. There is an efficient instrument rule that produces an output variance of 8.3 and an inflation variance of 1.2. Strict *p** targets produce the same output variance with an inflation variance of 1.9.

As the parameter *q* is raised, so adjustment becomes slower, we move Southeast on the frontier defined by *p** targeting. This frontier quickly moves close to the efficient frontier. Thus, as long as policy-makers put a non-negligible weight on output variance, there is a version of *p** targeting that closely approximates the optimal policy. For example, for equal weights on inflation and output variances, the optimal policy has an MCI weight *w* of 0.70, and output and *p** coefficients of 1.35

Figure 3: p* Targeting

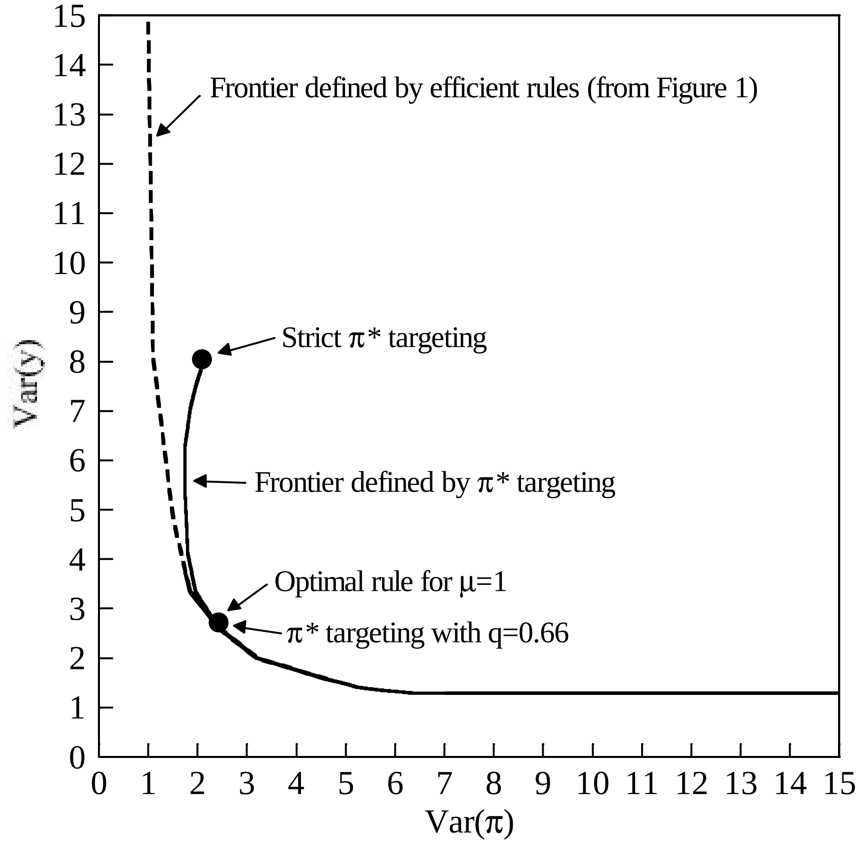
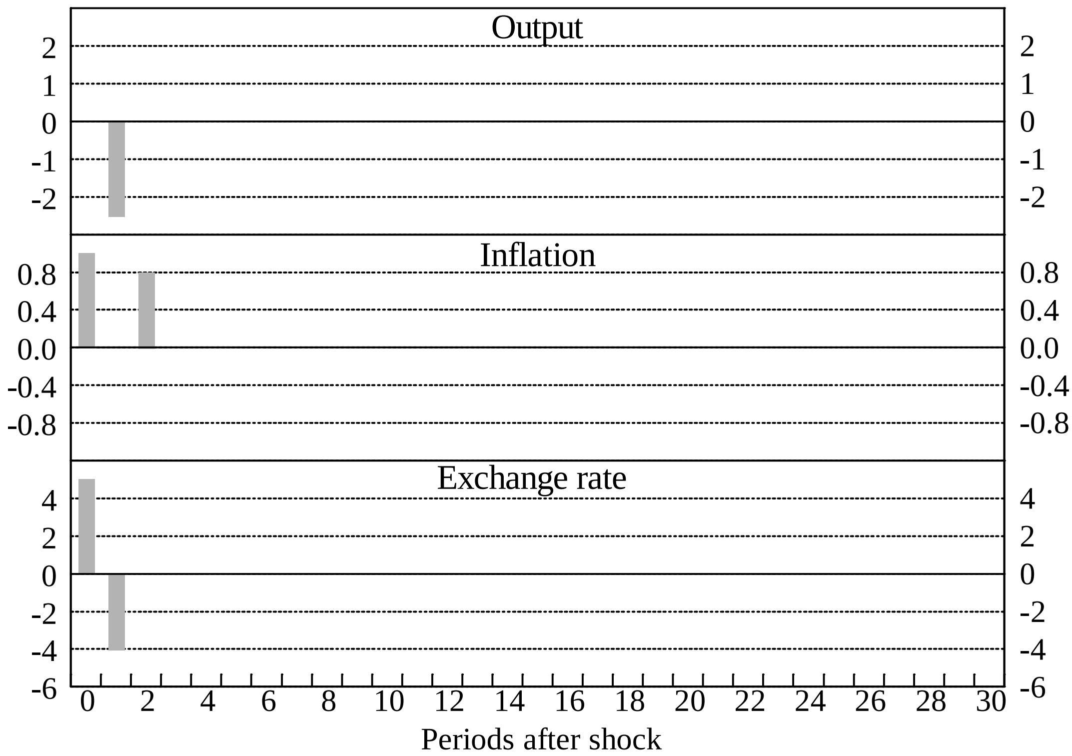


Figure 4: Strict p* Targets – Responses to an Inflation Shock



and 1.06. For a p^* target with $q = 0.66$, the corresponding numbers are 0.75, 1.43, and 1.08. The variances of output and inflation are 2.50 and 2.44 under the optimal policy and 2.48 and 2.48 under p^* targeting.

7. Conclusion

In a closed economy, inflation targeting is a good target rule and a Taylor rule is a good instrument rule. In an open economy, however, these policies perform poorly unless they are modified. The policy instrument should be a Monetary Conditions Index based on both the interest rate and the exchange rate. The weight on the exchange rate should be equal to or slightly greater than this variable's relative effect on spending. As a target variable, policy-makers should use 'long-run inflation' – an inflation variable purged of the transitory effects of exchange-rate fluctuations. This variable should also replace inflation on the right side of the instrument rule.

Several countries currently use an MCI as their policy instrument. In addition, some appear to have moved informally toward targeting long-run inflation, for example by keeping inflation below target when a depreciation is expected. It might be desirable, however, to make long-run inflation the formal target variable. In practice, this could be done by adding an adjustment to calculations of 'underlying' inflation: the effects of the exchange rate could be removed along with other transitory influences on inflation. At least one private firm in New Zealand already produces an underlying inflation series along these lines (Dickens 1996).

Appendix A: Domestic Goods and Imports

Here I derive the Phillips curve, Equation (2), from assumptions about inflation in the prices of domestic goods and imports. Domestic-goods inflation is given by:

$$p^{d} = p_{-1} + a' y_{-1} + h' \tag{A.1}$$

This equation is similar to a closed-economy Phillips curve: p^{d} is determined by lagged inflation and lagged output.

To determine import-price inflation, I assume that foreign firms desire constant real prices in their home currencies. This implies that their desired real prices in local currency are -*e*. However, they adjust their prices to changes in *e* with a one-period lag. Like domestic firms, they also adjust their prices based on lagged inflation. Thus import inflation is:

$$p^{m} = p_{-1} - (e_{-1} - e_{-2}) \tag{A.2}$$

Finally, aggregate inflation is the average of Equations (A.1) and (A.2) weighted by the shares of imports and domestic goods in the price index. If the import share is g this yields Equation (2) with $a = (1- g)a'$ and $h = (1- g)h'$.

Appendix B: The Variances of Output and Inflation

Here, I describe the computation of the variances of output and inflation under alternative policies. Consider first the rule given by Equations (6) and (7). Substituting Equations (4) and (5) into (6) yields an expression for the exchange rate in terms of lagged *e*, *p*, and *y*:

$$\begin{gathered} e = (lz + an)y_{-1} + np_{-1} - (b/q + d)ze_{-1} + gne_{-2} + ze + nh + bmv + bzv_{-1}, \\ z = lm + an \end{gathered} \tag{B.1}$$

This equation and Equations (4) and (5) define a vector process for *e*, *p*, and *y*:

$$C = F_1 C_{-1} + F_2 C_{-2} + E \tag{B.2}$$

where $C = [y\,p\,e]'$

The elements of *E* depend on the current and once-lagged values of white-noise shocks. Thus *E* follows a vector MA(1) process with parameters determined by the underlying parameters of the model. *X* follows an ARMA(2,1) process. For given parameter values and given values of the constants *m* and *n*, one can numerically derive the variance of *X* using standard formulas (see Hendry 1995, Section 11.3). To determine the set of efficient policies, I search over *m* and *n* to find combinations that minimise a weighted sum of the output and inflation variances.

To determine the variances of output and inflation under a *p** target, Equation (15), note that Equation (15) is equivalent to Equation (7) with *m* set to $q/(qd+b)$ and *n* set to $q(1-q)/[a(qd+b)]$. For a given *q*, the variances of output and inflation under Equation (15) are given by the variances for the equivalent version of Equation (7).

References

Ball, L. (1997), 'Efficient Rules for Monetary Policy', NBER Working Paper No. 5952.

Black, R., T. Macklem and D. Rose (1997), 'On Policy Rules for Price Stability', paper presented at the Bank of Canada conference, Price Stability, Inflation Targets and Monetary Policy, 3–4 May, Ottawa.

Dickens, R. (1996), 'Proposed Modifications to Monetary Policy', Ord Minnett New Zealand Research, May.

Duguay, P. (1994), 'Empirical Evidence on the Strength of the Monetary Transmission Mechanism in Canada: An Aggregate Approach', *Journal of Monetary Economics*, 33(1), pp. 39–61.

Freedman, C. (1994), 'The Use of Indicators and of the Monetary Conditions Index in Canada', in T.J.T. Balino and C. Cottarelli (eds), *Frameworks for Monetary Stability*, International Monetary Fund.

Gerlach, S. and F. Smets (1996), 'MCIs and Monetary Policy in Small Open Economies Under Floating Exchange Rates', Bank for International Settlements, November.

Gruen, D. and G. Shuetrim (1994), 'Internationalisation and the Macroeconomy', in P. Lowe and J. Dwyer (eds), *International Integration of the Australian Economy*, Proceedings of a Conference, Reserve Bank of Australia, Sydney, pp. 309–363.

Hendry, D.F. (1995), *Dynamic Econometrics*, Oxford University Press, Oxford.

Lafleche, T. (1996), 'The Impact of Exchange Rate Movements on Consumer Prices', Bank of Canada Review, pp. 21–32.

Longworth, D.J. and S.S. Poloz (1986), 'A Comparison of Alternative Monetary Policy Regimes in a Small Dynamic Open-Economy Simulation Model', Bank of Canada Technical Report No. 42.

Reserve Bank of New Zealand (1996), *Briefing on the Reserve Bank of New Zealand,* October.

Svensson, L.E.O. (1997a), 'Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets', *European Economic Review*, 41(6), pp. 1111–1146.

Svensson, L.E.O. (1997b), 'Open-Economy Inflation Targeting', Stockholm University, November.

Taylor, J.B. (1994), 'The Inflation/Output Variability Trade-off Revisited', in J.C. Fuhrer (ed.), *Goals, Guidelines, and Constraints Facing Monetary Policymakers*, Federal Reserve Bank of Boston.