What to Aim for? The Choice of an Inflation Objective when Openness Matters

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Abstract:
Inflation targeting countries generally define the inflation objective in terms of the consumer price index. Studies in the academic literature, however, reach conflicting conclusions concerning which measure of inflation a central bank should target in a small open economy. This paper examines the properties of domestic, CPI, and real-exchange- rate-adjusted (REX) inflation targeting. In one class of open economy New Keynesian models there is an isomorphism between optimal policy in an open versus closed economy. In the type of model we consider, where the real exchange rate appears in the Phillips curve, this isomorphism breaks down; openness matters. REX inflation targeting restores the isomorphism but this may not be desirable. Instead, under domestic and CPI inflation targeting the exchange rate channel can be exploited to enhance the effects of monetary policy. Our results indicate that CPI inflation targeting delivers price stability across the three inflation objectives and will be desirable to a central bank with a high aversion to inflation instability. CPI inflation targeting also does a better job of stabilizing the real exchange rate and interest rate which is an advantage from the standpoint of financial stability. REX inflation targeting does well in achieving output stability and has an advantage if demand shocks are predominant. In general, the choice of the inflation objective affects the trade-offs between policy goals and thus policy choices and outcomes.

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By 2006 twenty-five countries mostly small or mid-size open economies had adopted inflation targeting as a monetary policy strategy. In the wake of the 2007-09 financial crisis and deep recession, as Svennson (2011) has noted, "no country has so far abandoned inflation targeting … or even expressed regrets." Inflation targeting requires the choice of a specific inflation objective. Inflation targeting countries define the objective in terms of the headline consumer price index or a modified "core" consumer price index [Svensson (2011)]. This choice is not surprising as inflation targeting countries tend to be economies where import inflation is a concern. Performance is typically measured by the central bank's ability to keep CPI inflation within a target band or close to a numerical target.[1]

The academic literature on monetary policy acknowledges that the choice of which measure of inflation to target is important (Woodford (2011)). Existing studies, however, even abstracting from the experience of the post-2007 financial and general economic instability, reached conflicting conclusions about the appropriate target criterion for inflation in a small open economy. Allsopp, Kara, and Nelson (2006) favor CPI inflation targeting in a New Keynesian model where exchange rate changes act like supply shocks. In contrast, a number of influential contributions to the New Keynesian literature (Aoki (2001), Clarida, Gali, and Gertler (1999, 2001, 2002), Gali and Monacelli (2005), Kirsanova, Leith, and Wren-Lewis (KLWL) (2006), De Paoli (2009) and others) advocate the stabilization of domestic rather than CPI inflation.

Models such as Clarida, Gali, and Gertler (1999, 2001, 2002) and Gali and Monacelli (2005) have the strong implication that optimal policy in an open economy is isomorphic to policy in a closed economy. This view is reflected in a target rule in an open economy which is the same as in a closed economy except that the weight on domestic inflation is now affected by the degree of openness. This isomorphism is a distinctive feature of models where the output gap is the sole conduit through which monetary policy affects the Phillips curve.

The isomorphism result in an open economy New Keynesian framework has not gone unchallenged. KLWL (2006) add a terms of trade gap to the objective function of the central bank after allowing for a wider range of plausible values for the intertemporal elasticity of consumption and the elasticity of demand. Exchange rate related frictions and an imported input in production also result in the failure of the isomorphism result. Monacelli (2005) describes how incomplete-exchange rate pass-through alters the Phillips curve in an open economy. Domestic inflation is affected by the wedge between the world price (in domestic

1 For a survey, see Walsh (2009).

currency) and the home currency price set by importers of the consumption good. In Monacelli (2013) the existence of an imported intermediate input calls for both real marginal cost (the inverse of the mark-up) and the terms of trade to be variable.[2] Corsetti, Dedola and Leduc (2011), Engel (2010), Benigno and Benigno (2006), and Clarida, Gali and Gertler (2002) analyze target rules in a two-country framework where the definition of the central bank's objective function depends on factors such as: the values of deep parameters, local versus producer currency pricing, and cooperative versus non-cooperative policymakers.[3]

While, as noted above, no central bank has abandoned inflation targeting in the wake of the financial crisis, there has been an extensive re-examination of the strategy in the academic literature. One issue is whether consideration of financial stability calls for adding new objectives to the central bank's objective function in a flexible inflation targeting regime.[4] In small open economies there is now broader awareness of the threat sudden capital flow reversals – triggered by external events such as the "lift-off" of US interest rates - pose for the exchange rate and domestic interest rates. Financial stability in open economies depends in large degree, though not exclusively, on the volatility of the real exchange rate and interest rates. An important additional factor that weighs on financial stability is the choice of the inflation target proper. This is because the inflation objective influences directly the extent to which the central bank takes account of exchange rate movements and use of its instrument in implementing monetary policy.

This paper examines the implications of a central bank's choice of a specific inflation objective within a flexible inflation targeting strategy. We show that the breakdown or survival of the isomorphism result hinges on the choice of the inflation objective in the central bank's targeting strategy. The choice of the inflation objective affects the form of the optimal target rule and thus trade-offs between policy goals that confront the policymaker.

Our analysis is conducted within a model with a foundation for an exchange rate channel in the Phillips curve which does not rely on a particular currency misalignment such as incomplete exchange rate pass-through or on imports of intermediate inputs. Our Phillips curve is derived from a setting where domestic firms produce goods for the home market and exports. Its theoretical basis is an optimizing framework where domestic firms are concerned, amongst other things, about their competitiveness vis-à-vis foreign firms. As a result, prices

2 Monacelli (2013) argues that consumption openness (under perfect exchange rate pass-through) also accounts for the breakdown of the isomorphism result.
3 Using a symmetric two-country framework, Bodenstein, Guerrieri, and Kilian (2012) analyze optimal interest rate responses to headline versus core inflation with endogenous energy prices.
4 See, for examples: Woodford (2012), Smets (2014), Vredin (2015) and Leeper and Nason (2015).

set by domestic firms respond to exchange rate fluctuations and changes in the prices charged by competing foreign firms. If, at the firm level, the pricing is sensitive to movements in the exchange rate and competitive price pressure from abroad, then, at the aggregate level, such behavior results in a Phillips curve which features a direct real exchange rate channel. The standard inflation expectations and the output gap channels are complemented by this real exchange rate channel.

Following Ball (1999) and Svensson (2000), we trace the implications for monetary policy of the existence of a real exchange rate channel in the Phillips curve, albeit in a different modeling framework.[5] Our approach to investigate inflation targeting in open economies is similar in spirit to Svensson. Yet, the current paper emphasizes different aspects of policymaking in open economies, offering a broader discussion of the factors which affect the choice of potential inflation targets and giving greater attention to financial stability concerns. A novel feature of our paper is that it presents *tractable* optimal target rules that clearly pin down the role and underscore the importance (relative to the rate of inflation and the output gap) of the real exchange rate in setting monetary policy. In addition, we analyze the output-inflation tradeoff under different flexible inflation targeting strategies. Lastly, there is a more expanded discussion of flexible inflation targeting strategies and the extent to which their performance is influenced by the central bank's relative aversion to inflation variability and the sources of uncertainty.

We examine three flexible inflation targeting strategies: domestic inflation targeting, CPI inflation targeting, and real-exchange rate-adjusted (REX) inflation targeting. REX inflation is defined as domestic inflation purged of the effects of real exchange rate changes.[6] For each of these strategies we derive the optimal target rule and analyze the ways in which the rule differs from the rule in the canonical closed-economy New Keynesian model.

For CPI or domestic inflation targeting, our analysis leads to several conclusions. First, the real exchange rate plays a much more important role in the design of target rules than in

5 Ball's model is completely backward-looking while Svensson's features both backward-and forward-looking elements. In Svensson's framework domestic inflation in the Phillips curve is pre-determined so as to allow for a two-period lag of the effect of monetary policy on domestic inflation. This lag pattern is absent in our modelling framework. The real exchange rate channel in Svensson's Phillips curve is more subdued than in our version of the Phillips curve. Domestic inflation in period *t+2* is affected by the expected change in the real exchange rate from period *t+1* to period *t+2*. This expectation is formed in period *t*.

6 The definition of REX inflation differs from Ball's definition of long-run inflation in one important respect. Ball's measure relates the *level* of the *lagged* real exchange rate to overall inflation while our definition of REX inflation represents *domestic* inflation adjusted for the degree of supply openness and the *change* in the real exchange rate. Unlike Ball's, our definition thus has the natural advantage of being able to distinguish between the REX price level ($p_t^{REX} = p_t - bq_t$) and the REX inflation rate ($\pi_t^{REX} = \pi_t - b\Delta q_t$). Froyen and Guender (2014) provides a discussion of the importance of choosing a REX price level target in delegating the conduct of monetary policy to a conservative central banker in an open economy.

most previous frameworks. Second, the isomorphism result in the earlier literature breaks down if there is a separate exchange rate channel in the Phillips curve. Third, the exchange rate channel for policy improves the inflation- output tradeoff in the presence of cost-push shocks. As a consequence of this improved trade-off, more weight is put on inflation stabilization in the target rule.

REX inflation targeting restores the isomorphism to policy in the closed economy. It becomes more desirable as the consequences of openness just set out become undesirable. As the incidence of demand-side shocks increases relative to cost push shocks, for example, the ease with which these shocks are offset in the closed economy favors REX inflation targeting. REX inflation targeting also becomes more desirable if the central bank puts more weight on output stabilization in the objective function; openness, by improving the inflation-output-trade-off, raises the opportunity cost of gains in output stability.

A central bank's innate aversion to inflation relative to output variability plays a decisive role in the choice of which inflation rate to target. Even if demand-side shocks are substantially more volatile than cost-push shocks, an optimizing central bank that places greater emphasis on price stability chooses CPI inflation targeting over domestic or REX inflation targeting. One attractive feature of CPI inflation targeting is that it also ensures stability of domestic and REX inflation while the reverse does not hold. Additionally, CPI inflation targeting is superior from the standpoint of stabilizing the real exchange rate and domestic interest rate, an advantage for the maintenance of financial stability.

The paper is organized as follows. In Section 2 we derive an open-economy Phillips curve and incorporate it into a small open-economy New Keynesian model. Section 3 discusses the three flexible inflation targeting strategies. A performance analysis is carried out and commented on in Section 4. Section 5 concludes.

2. The Building Blocks of the Model

A. An Open Economy Phillips Curve

The central building block for our open economy Phillips curve is the firm's pricing equation. Recent evidence from surveys [Greenslade and Parker (2012) and Parker (2012)] as well as from micro data [Bunn and Ellis (2012a), (2012b)] indicates wide divergence in pricing behavior within and across sectors of the economy. These studies cast doubt on whether any one theory can adequately capture all the important features of firm pricing. In particular the popular specification of Calvo (1983) pricing supplemented by "rule of thumb"

indexation appears to describe actual pricing behavior of only a small minority of firms. Given the heterogeneity of firm pricing behavior, any aggregate price setting equation will be an approximation aimed at capturing some central features of the process.

The pricing framework here emphasizes three elements, each of which receives support from this survey evidence for the United Kingdom [Greenslade and Parker (2012)] and for New Zealand {Parker (2012)]. First, we assume firms follow mark-up pricing influenced by the benchmark prices of competing domestic firms. Second, we assume that there is price stickiness due to menu costs. Menu costs include not just the physical costs of price changes but are also the result of implicit and explicit contracts as well as coordination problems. Finally, in the open economy the firm is concerned with competitiveness at home and abroad. Thus the firm responds to exchange rate induced changes in the terms of trade.[7]

We model these elements of optimal price setting within an extension of Rotemberg's (1982) quadratic cost adjustment model of monopolistically competitive firms. In our open-economy version of the model an optimizing firm sets the price of output so that the overall cost function which consists of three separate components is minimized. The objective function of the typical firm *j* is:

$$min_{p(j)_t}\, \Omega(j)_t = E_t \sum_{i=0}^{\infty} \beta^i \left[\begin{array}{c} (p(j)_{t+i} - p(j)^*_{t+i})^2 + c(p(j)_{t+i} - p(j)_{t+i-1})^2 + \\ a(q(j)_{t+i} - q(j)_{t+i-1})^2 \end{array} \right] \tag{1}$$

where:

$\Omega(j)_t$ = the total cost of firm *j* at time *t*

$p(j)_t$ = the price of the good produced by firm *j* at time *t*

$p(j)^*_t$ = the optimal mark-up price for firm *j*

$q(j)_t = p^f_t + s_t - p(j)_t$ = firm-specific terms of trade

p^f_t = the price of the foreign good in foreign currency

s_t = the nominal exchange rate (units of domestic currency per unit of foreign currency)

β = the constant discount factor

7 In New Zealand, competitors' price changes—both increases and decreases-- were deemed to be the most important factor in an exporting firm's decision to change price. Exchange rate changes were found to be an important or very important factor in determining price changes by more than 70 percent of exporters among the survey respondents in the United Kingdom. Support for the importance of exchange rate changes as an influence on price setting in the United Kingdom is also provided by Bunn and Ellis (2012a, 2012b).

c = the parameter that measures the costs of changing prices relative to the costs of deviating from the optimal mark-up price

a = the parameter that measures the costs of changes in the firm's terms of trade relative to the costs of deviating from the optimal mark-up price

E_t = the expectations operator conditional on information available at time *t*.

The first term within the brackets is the cost of being away from the optimal mark-up on cost, the price that the firm would charge in the absence of menu costs and foreign competition. This price, the specification of which is explained below, is denoted $p(j)^*$. Menu costs are represented by the second term in brackets.

In an open economy, as explained previously, firms are concerned about competitiveness abroad as well as at home. Define the terms of trade (or real exchange rate) as the domestic currency price of foreign output relative to the price of domestic output. The firm-specific terms of trade measure a representative firm's price competitiveness vis-à-vis foreign competition. To avoid changes in its terms of trade caused by sudden exchange rate movements or foreign price movements both of which are beyond its control, the firm is required to alter its price. Menu costs make this costly.

The firm sets the price of its output in domestic currency. Taking the first-order condition and running the expectations operator through it, we can characterize the relationship between past, current, and future prices as well as the current and expected change in the terms of trade as:[8]

$$p(j)_t - p(j)_{t-1} = \beta E_t(p(j)_{t+1} - p(j)_t) - \frac{1}{c}(p(j)_t - p(j)_t^*) - \frac{\beta a}{c}(E_t q(j)_{t+1} - q(j)_t) + \frac{a}{c}(q(j)_t - q(j)_{t-1}) \quad (2)$$

From equation (2) it is evident that the current and the expected change in the firm-specific terms of trade matter in setting the price at time *t*. The greater *a* - the relative weight on the change in the terms of trade in the total cost function - compared to *c*, the relative weight on costly price changes, the more current and expected changes in the terms of trade factor in the decision to change the price in the current period.

Next, consider the formation of the firm's optimal mark-up price:

8 From the definition of the firm-specific terms of trade and the fact that the firm cannot influence the price set by foreign competitors or the nominal exchange rate it follows that $\frac{\partial q(j)_t}{\partial p(j)_t} = -1$.

$$p(j)_t^* = \hat{p}_t + \vartheta y(j)_t + \varsigma(j)_t \qquad \varsigma > 0 \qquad (3)$$

where all variables are as previously defined. In addition:

$\hat{p}_t$ = the price charged by competing firms at time *t*

$y(j)_t$ = output produced (relative to potential) by firm *j*

$\varsigma(j)_t$ = a stochastic disturbance.

Under imperfect competition, $p(j)_t^*$ is a mark-up over marginal cost. But marginal cost and real output are positively related.[9] Therefore we replace marginal cost with the output gap in (3). To capture the idea of a time-varying mark-up factor, we model it as a random element $\varsigma(j)_t$ that enters into the process of setting the optimal mark-up price. The other factor that influences the firm's optimal mark-up price is the benchmark price set by competing firms. This price, denoted by $\hat{p}_t$, equals the aggregate domestic price level p_t.

Substituting equation (3) into (2) and aggregating over all firms yields equation (4), an open-economy Phillips curve where, in addition to the output gap and expected domestic inflation, the current and expected change in the real exchange rate affect current domestic inflation.[10]

$$\pi_t = \beta E_t \pi_{t+1} + \kappa y_t + b(q_t - q_{t-1}) - \beta b(E_t q_{t+1} - q_t) + u_t \qquad (4)$$

where

$$\pi_t = p_t - p_{t-1} \qquad q_t = p_t^f + s_t - p_t$$

$$\kappa = \frac{\vartheta}{c} \qquad b = \frac{a}{c} \qquad u_t = \frac{1}{c}\varsigma_t.$$

Compared to the standard closed-economy Phillips curve, the open-economy representation features a more expansive expectations channel that operates through expected changes in the real exchange rate. In addition, the current period change in the real exchange rate exerts a direct effect on domestic inflation.

9 Equation (3) is the same as the one proposed by Roberts (1995). Within a general equilibrium framework, the co-movement between marginal cost and economic activity can be established by combining the labor supply and demand relations with the market clearing condition in the goods market. On this point see Clarida, Gali, and Gertler (2001, 2002) or Gali and Monacelli (2005).

10 For simplicity there is no distinction between the terms of trade and the real exchange rate.

B. Model for a Small Open Economy

The complete model for a small open economy consists of four equations:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa y_t + b(q_t - q_{t-1}) - \beta b(E_t q_{t+1} - q_t) + u_t \quad (4)$$

$$y_t = E_t y_{t+1} - a_1(R_t - E_t \pi_{t+1}^{CPI}) + a_2(q_t - E_t q_{t+1}) + a_3(y_t^f - E_t y_{t+1}^f) + v_t \quad (5)$$

$$R_t - E_t \pi_{t+1} = R_t^f - E_t \pi_{t+1}^f + E_t q_{t+1} - q_t + \varepsilon_t \quad (6)$$

$$\pi_t^{CPI} = \pi_t + \gamma \Delta q_t \quad (7)$$

$\pi_t =$ the rate of domestic inflation

$E_t \pi_{t+1}^{CPI} =$ the expected rate of CPI inflation

$q_t =$ the real exchange rate

$y_t =$ the output gap

$R_t =$ the nominal rate of interest (policy instrument)

$R_t^f =$ the foreign nominal rate of interest

$E_t \pi_{t+1}^f =$ the expected foreign rate of inflation

$y_t^f =$ the foreign output gap

Lower case variables represent logarithms. All parameters are positive. The discount factor β is less than or equal to one.

Equation (4) is the open-economy Phillips curve. Equation (5) is the open economy IS relation that features a real interest rate and real exchange rate channel. A foreign output shock and an idiosyncratic shock affect demand for domestic output.[11] Equation (6) is the linearized uncovered interest rate parity (UIP) condition: apart from a stochastic risk premium (ε_t) agents are assumed to trade in a frictionless international bond market. More formally, the stochastic disturbances are modeled as follows: [12]

$u_t \sim N(0, \sigma_u^2)$ $\quad v_t \sim N(0, \sigma_v^2)$ $\quad \varepsilon_t \sim N(0, \sigma_\epsilon^2)$

$R_t^f \sim N(0, \sigma_{Rf}^2)$ $\quad \pi_t^f \sim N(0, \sigma_{\pi f}^2)$ $\quad y_t^f \sim N(0, \sigma_{yf}^2)$

We treat all foreign variables as exogenous random variables that are independent of each other. Finally, equation (7) describes the relationship between the CPI inflation rate, the

11 The derivation of the forward-looking IS relation from microeconomic foundations is explained in Guender (2006). A separate appendix, available from the authors, shows how the shocks that appear in the IS relation can be motivated.

12 The property that all shocks are white noise follows Woodford (1999a). Its purpose is to show that gradual adjustment of the output gap, the rate of inflation, etc. are not exclusively tied to the presence of autocorrelated disturbances in the model.

domestic inflation rate, the real exchange rate, and consumption openness (γ) under perfect exchange rate pass-through.

3. Targeting Different Measures of Inflation

Woodford (2011, p.802) recognizes that "the question as to which measure of inflation should be targeted by a central bank is an important practical question for the theory of monetary policy." We conceive of this question of a particular inflation target being confronted by the central bank (or government) of an open economy such as Australia, New Zealand or Switzerland. What criteria should guide this choice and, more generally, that of an inflation targeting regime? The literature distinguishes two approaches. One emphasizes a welfare-theoretic approach to determine the central bank's target criterion while the other is a "simple representation of conventional central bank objectives (Woodford (2011, p.728)."

Under the welfare-theoretic target criterion, the central bank minimizes a loss (objective) function given by an approximation to a representative household's utility function. A welfare-based criterion has a strong claim to legitimacy in the optimal policy literature. Such a loss function is, however, model-specific and depends critically on the specification of the consumer's utility function and the values chosen for the elasticity of substitution, elasticity of demand, and other factors.[13,14]

We adopt the less formal approach in which the central bank decides on (or is assigned) a menu of flexible inflation targeting strategies, each containing the output gap as well as an inflation measure to target. Within the model we have set out, the central bank traces out the implications of adopting the alternative inflation targets. This approach allows us to focus on the implications of the choice of an inflation target for: the optimal target rule, the output-inflation variability trade-off, and the effects of various shocks in the model.

How far does this take us away from a welfare-based measure? Woodford (2011, p.776) concludes "in a broad range of models" maximizing the expected utility of a representative household is consistent with a central bank's objective of minimizing fluctuations in *some* measure of inflation and the output gap. Thus the welfare theoretic approach and the more pragmatic representation of conventional central bank objectives are broadly consistent in many contexts. Also relevant is Woodford's view that "[a]s a practical

13 Kirsanova et al (2006) show that relaxing the assumptions of unitary elasticity of demand and intertemporal substitution results in a far more complex welfare criterion than proposed by Gali and Monacelli (2005).
14 Exclusive reliance on utility-based welfare metrics has drawn some criticism. Clarida, Gali and Gertler (1999, p.1688) conclude that the micro-founded DSGE New Keynesian approach "could be misleading as a guide to welfare analysis because of its highly stylized microeconomic underpinnings." Sims (2012) echoes their concerns citing the implausibility of the microeconomic foundations of these DSGE models.

matter, then, it is important to formulate recommendations for relatively simple target criteria, that while not expected to be fully optimal, it is nonetheless an approximate optimal policy to a reasonable extent (2011, p. 822)."

A final point to consider before proceeding to the policy regimes we examine is whether in light of the financial crisis a financial stability objective should be included in the central bank objective function. There are different views on the question as explained, for example, in Smets (2014). Woodford (2012) argues that a flexible inflation targeting regime should be expanded to include a financial stability objective which is then included in the optimal target rule for monetary policy. Curdia and Woodford (2011) develop a model that supports such an expansion based on the presence of frictions in the financial intermediation process. Smets (2014, p. 263) argues for a less direct linkage where the objective function is not modified but where the "monetary policy authorities should also keep an eye on financial stability."

As noted in the introduction, for small open economies the real exchange rate and the interest rate are important transmission channels for financial instability. Thus the question of expanding an inflation targeting framework to incorporate financial instability brings us to the question of whether these variables should enter the central bank loss function and targeting rules. Blanchard et. al. (2010), for example, suggest that "central banks in small open economies should openly recognize that exchange rate stability is part of their objective function." The question addressed here is the choice of an inflation target. Rather than specify a weight for exchange rate stability in the loss function, we take the approach suggested by Smets (2014) and assume that while the targeting regime consists of only squared deviations of the inflation measure and the output gap, the policymaker monitors the behavior of the real exchange rate and interest rate. The volatility of these variables is shown to depend on the choice of the inflation measure to target. It will also be seen that even if the real exchange rate is not incorporated into the central bank loss function, it will appear in the optimal target rule for two of our inflation measures.

Thus, in what follows we consider three flexible targeting regimes. As just explained, in the simple version used here flexible inflation targeting is where the objective function consists of squared deviations of the output gap and the rate of inflation the central bank targets. The three inflation targets are: domestic inflation, exchange-rate adjusted inflation, and CPI inflation. At the core of each regime is a tractable optimal target rule that prescribes how the target variables and other relevant endogenous variables interact to ensure that the objective function is minimized. The central bank uses discretion in setting optimal policy.

A. Targeting Domestic Inflation

In the first strategy inflation is defined in terms of changes in the level of domestic prices. The explicit objective function that the central bank minimizes is given by:

$$E_t \sum_{i=0}^{\infty} \beta^i [y_{t+i}^2 + \mu \pi_{t+i}^2] \qquad (8)$$

β is the discount rate and μ represents the relative weight the policymaker attaches to the squared deviations of the rate of domestic inflation from target.[15]

To illustrate how optimal policy in the open economy is determined, it is helpful at the outset to reduce the dimension of the problem to one involving only two constraints. Two steps need to be taken. First, substitute for the rate of CPI inflation in equation (5). Second, substitute the UIP condition into the IS equation. The problem can then be expressed as:

$$\min_{\pi_t, y_t, q_t} E_t \sum_{i=0}^{\infty} \beta^i [y_{t+i}^2 + \mu \pi_{t+i}^2]$$

s. t

$$\pi_t = \beta E_t \pi_{t+1} + \kappa y_t + b(q_t - q_{t-1}) - \beta b(E_t q_{t+1} - q_t) + u_t \quad (9)$$

and

$$y_t = E_t y_{t+1} - a_1\left(R_t^f - E_t \pi_{t+1}^f + \epsilon_t\right) + (a_1(\gamma - 1) - a_2)(E_t q_{t+1} - q_t) + a_3\left(y_t^f - E_t y_{t+1}^f\right) + v_t$$

The resulting target rule under flexible domestic inflation targeting is:[16]

$$y_t + \mu[\pi_t \left(\kappa + \frac{c_1}{c_2}\right) - \frac{\beta b}{c_2} w_\pi q_t] = 0 \qquad (10)$$

$$c_1 = \beta(w_\pi - b(w_q - 1)) + b \qquad c_2 = w_y - (a_1(1 - \gamma) + a_2)(w_q - 1)$$

The open economy target rule is more complex than in the canonical closed-economy New Keynesian model. First, even though it does not appear in the objective function, the real exchange rate appears in the target rule alongside the target variables π_t and y_t. The real exchange rate provides essential information. Second, both Phillips curve and IS parameters as well as the discount factor determine the relative weights on the rate of domestic inflation

15 The target for the output gap and the rate of inflation is zero, respectively.

16 A step-by-step derivation of all target rules and an explanation of the solution technique employed to determine the forward-looking expectations of inflation, output, and the real exchange rate appear in the appendix which is available upon request from the authors. The coefficients w_π, w_q, w_y are the respective coefficient on the lagged real exchange rate in the putative solution for π_t, q_t, and y_t.

and the real exchange rate. The size of these weights depends on the strength of the (expected) real interest rate and exchange rate channel on the demand side and the sensitivity of domestic inflation to the output gap and changes in the real exchange rate on the supply side. The difference between the target rule in a closed economy and the target rule in an open economy is due to the existence of the exchange rate channel in the Phillips curve. If *b = 0*, then $w_\pi = 0 = c_1$ and the open-economy target rule reverts to its closed-economy counterpart. Equation (10) can be combined with the Phillips curve, the IS relation and the UIP condition to generate solutions for the endogenous variables and their variances.

B. Targeting "R(eal)-EX(change)-Rate-Adjusted" Inflation

As mentioned in the introduction, several contributions to the literature argue that optimal policy in an open economy is isomorphic to policy in a closed economy. Our aim in this section is to show that by choosing an alternative target variable for inflation an open-economy target rule can be made to look exactly like its closed-economy counterpart. This alternative target variable is domestic inflation stripped of the effects of changes in the real exchange rate.

The preceding section showed that the existence of a real exchange rate channel in the Phillips curve is instrumental in shaping the target rule for an open economy. Both the current and expected change in the real exchange rate appear on the right-hand side of the Phillips curve, which is shown again for convenience below.

$$\pi_t = \beta E_t \pi_{t+1} + \kappa y_t + b(q_t - q_{t-1}) - \beta b(E_t q_{t+1} - q_t) + u_t \quad (4)$$

The Phillips curve can be rewritten as

$$\pi_t - b(q_t - q_{t-1}) = \beta(E_t \pi_{t+1} - b(E_t q_{t+1} - q_t)) + \kappa y_t + u_t$$

Defining

$$\pi_t^{REX} = \pi_t - b(q_t - q_{t-1}) \quad (11)$$

as the domestic rate of inflation purged of the real exchange rate effect allows us to rewrite the original open-economy Phillips curve as

$$\pi_t^{REX} = \beta E_t \pi_{t+1}^{REX} + \kappa y_t + u_t \quad (12)$$

Written in this form, equation (12) looks like the original Phillips curve. The only difference between equation (4) and equation (12) pertains to the definition of the rate inflation.

The remaining two equations of the model can be rewritten in terms of the real-exchange-rate-adjusted rate of inflation:

$$y_t = E_t y_{t+1} - a_1(R_t - E_t \pi_{t+1}^{REX}) + (a_1(b+\gamma) - a_2)(E_t q_{t+1} - q_t) + a_3(y_t^f - E_t y_{t+1}^f) + v_t \quad (13)$$

$$R_t - E_t \pi_{t+1}^{REX} = R_t^f - E_t \pi_{t+1}^f + (1+b)(E_t q_{t+1} - q_t) + \varepsilon_t \quad (14)$$

The last change is a modification of the objective function of the policymaker. The target variable for inflation is now the real-exchange-rate-adjusted rate of inflation.

After substitution of equation (14) into equation (13) to eliminate the real exchange rate, the optimization problem of the policymaker can be stated as:

$$\min_{y_t, \pi_t^{REX}, R_t} \frac{1}{2} E_t [\sum_{i=0}^{\infty} \beta^i [\, y_{t+i}^2 + \mu \pi^{REX\,2}_{t+i} \,]] \quad (15)$$

s. t.

$$\pi_t^{REX} = \beta E_t \pi_{t+1}^{REX} + \kappa y_t + u_t$$

and

$$y_t = E_t y_{t+1} - a_1(R_t - E_t \pi_{t+1}^{REX}) + \frac{(a_1(b+\gamma) - a_2)}{1+b}(R_t - E_t \pi_{t+1}^{REX} - R_t^f + E_t \pi_{t+1}^f - \varepsilon_t) + a_3(y_t^f - E_t y_{t+1}^f) + v_t$$

Solving the optimization problem yields the target rule under REX inflation targeting:

$$y_t + \mu \kappa \pi_t^{REX} = 0 \quad (16)$$

As in the closed-economy model, only the Phillips curve parameter κ appears in the target rule. Demand-side parameters have no role to play. Combining equation (16) with equations (12) – (14) yields the solutions for the endogenous variables and the policy instrument.

C. Targeting CPI Inflation

If the focus of policy rests on CPI inflation, then the policymaker minimizes

$$\frac{1}{2} E_t [\sum_{i=0}^{\infty} \beta^i [\, y_{t+i}^2 + \mu \pi^{CPI\,2}_{t+i} \,]] \quad (17)$$

subject to the constraint represented by the model economy. After rewriting the structure of the economy in terms of the CPI inflation rate, we can restate the policy objective as:

$$\min_{y_t, \pi_t^{CPI}, q_t} \frac{1}{2} E_t [\sum_{i=0}^{\infty} \beta^i [\, y_{t+i}^2 + \mu \pi^{CPI\,2}_{t+i} \,]]$$

subject to (18)

$$\pi_t^{CPI} = \beta E_t \pi_{t+1}^{CPI} + \kappa y_t + (1+\beta)(\gamma+b) q_t - (\gamma+b) q_{t-1} - \beta(\gamma+b) E_t q_{t+1} + u_t$$

and

$$y_t = E_t y_{t+1} - a_1(R_t^f - E_t\pi_{t+1}^f + \varepsilon_t) - (a_1(1-\gamma) + a_2)(E_t q_{t+1} - q_t) + a_3(y_t^f - E_t y_{t+1}^f) + v_t \quad (19)$$

Combining the first-order conditions of the optimization problem leads to the following target rule:[17]

$$y_t + \mu[\left(\kappa + \frac{f_1}{f_2}\right)\pi_t^{CPI} - \frac{\beta(\gamma+b)\phi_\pi}{f_2} q_t] = 0 \quad (20)$$

$$f_1 = \beta\phi_\pi + (\gamma + b)\big(1 + \beta(1 - \phi_q)\big) \qquad f_2 = \phi_y - (a_1(1-\gamma) + a_2)\big(\phi_q - 1\big)$$

As with the target rule under domestic inflation targeting, the real exchange rate appears in the target rule in addition to the target variables proper. Again, the level of the real exchange rate provides essential information that is contained neither in the rate of CPI inflation nor the output gap. Although the target rule under CPI inflation targeting looks similar to the target rule under domestic inflation targeting, there is one fundamental difference between the two rules. Even if the real exchange rate channel in the Phillips curve is shut off, i.e. *b = 0*, the target rule under CPI inflation targeting does not revert to the closed-economy target rule in the canonical New Keynesian model. Setting *b = 0* results neither in $f_1 = 0$ nor in reducing the coefficient on the real exchange rate to zero. The relative weight on the CPI inflation rate and the real exchange rate, respectively, merely decreases in size. By definition, the CPI inflation rate depends in part on the degree of openness multiplied by a change in the real exchange rate. Thus, if the policymaker changes the policy instrument in response to a demand-side shock, the real exchange rate changes, which in turn filters through to the CPI inflation rate. Attempting to prevent the output gap from changing does not work in the present case because the rate of CPI inflation is directly affected by changes in the real exchange rate.

Solutions for the endogenous variables and the policy instrument and their variances are obtained by combining equation (20) with equations (18) and (19).

4. Assessing the Performance of the Flexible Inflation Targeting Strategies

The previous section establishes that, depending on the choice of an inflation objective, optimal monetary policy in an open economy can but need not be isomorphic to that of a closed economy. While informative, the isomorphism result by itself says very little about the

17 The coefficients ϕ_π, ϕ_q, ϕ_y are the respective coefficient on the lagged real exchange rate in the putative solution for π_t^{CPI}, q_t, and y_t.

relative merits of flexible domestic, CPI, and REX inflation targeting. This section therefore carries out two tests to evaluate the performance of the three monetary policy strategies. The first test assesses the role of a central bank's innate aversion to inflation variability in ranking the flexible inflation targeting regimes by loss score. It further compares the variability of the output gap across the different inflation targeting regimes and examines the extent to which a particular choice for the inflation objective achieves price stability across the board.[18] Consideration is also given to the behavior of the real exchange rate and the policy instrument. The second test assesses the inflation-output gap tradeoffs under each of the three flexible inflation targeting regimes. Prior to these assessments we examine the target rules underlying the three inflation targeting strategies. A comparison of the target rules allows us to make conjectures about the extent to which the output gap and the real exchange rate fluctuate across the flexible inflation targeting regimes, conjectures that receive strong support in the numerical assessments that follow.

A. The Three Target Rules

A central focus of the current paper is to highlight the differences among regime-specific target rules. Table *1A* presents the target rule for each of the three flexible inflation targeting strategies. Consider the weights the central bank attaches to the inflation rate and the real exchange rate relative to the output gap under domestic and CPI inflation targeting. The coefficients $c_1, c_2, f_1,$ and f_2 play an important role in determining the size of these weights. The four coefficients describe the potency of the monetary transmission channels in the Phillips curve (c_1, f_1) and the IS relation (c_2, f_2) under the two monetary policy strategies.

Both consumption openness (γ) and supply-side openness (b) matter for the size of $f_1$while only the latter directly affects the size of c_1. As a result $f_1 > c_1$: the real exchange rate channel in the Phillips curve is more potent under CPI than under domestic inflation targeting. At the same time $f_2 = c_2$, which suggests that the choice of inflation objective has no implications for the strength of the monetary transmission channels on the demand side.[19]

18 Arguably, price stability goes beyond keeping a given measure of inflation low and stable. In New Zealand, for instance, price stability is defined not solely in terms of CPI inflation but in terms of changes in the *general* level of prices. This clearly indicates that changes in other price indices figure in the overall assessment of flexible CPI inflation targeting (*Monetary Policy and the New Zealand Financial System (1992)*, p. 35).
19 As analytical solutions do not exist under domestic and CPI inflation targeting these results are established by solving the models numerically. The numerical solutions establish, for instance, that $|\phi_\pi| > |w_\pi|$. The effect of the current real exchange rate on expected CPI inflation is greater than on expected domestic inflation. More details on the numerical solution procedure are given in the appendix.

With $f_1 > c_1$ the relative weight on inflation under CPI inflation targeting is greater than the relative weight on inflation under domestic inflation targeting. Also, the relative weight on the real exchange rate in the CPI inflation target rule is greater than its counterpart in the domestic inflation target rule. Both consumption and supply openness affect the size of the numerator of the coefficient on q_t in the CPI inflation target rule but not in the domestic inflation target rule where only supply openness matters.

In general, the size of the relative weight on inflation and the real exchange rate in the respective target rule reflects the importance of these two variables vis-à-vis the output gap in the setting of policy under the three regimes. In the case of flexible inflation targeting where both the inflation and the output gap objective are deemed important, the size of the relative weights in the target rules should convey information about the variability of those variables that explicitly or implicitly figure in *all* three target rules.[20] According to Table *1A*, the relative weights on inflation and the real exchange rate are largest under CPI inflation targeting but smallest under REX inflation targeting. This suggests the following conjectures:

Conjecture 1:

The output gap is most stable under REX inflation targeting.

Conjecture 2:

Fluctuations in the real exchange rate should be lowest under CPI inflation targeting but most pronounced under REX inflation targeting where the relative weight on the real exchange rate is zero.

To assess the plausibility of these conjectures, we use a numerical solution procedure with the following plausible parameter values: $a_1 = 0.45, a_2 = 0.195, a_3 = 0.27, b = 0.1, \kappa = 0.1, \beta = 1$. The choice of parameter values is explained in the note below Table *1*. For the computation of the variances of endogenous variables in Section *B* we assume that all disturbances are independent white noise processes with unit variance.

Using the above parameter values, we calculate the relative weights on the respective rate of inflation and the real exchange rate in the three target rules. These relative weights appear in Table *1B*. Each horizontal line is based on a different value of the relative inflation aversion parameter μ.The entries confirm that the relative weight on inflation is largest under CPI inflation targeting and smallest under REX inflation targeting. One feature of flexible CPI inflation targeting is that the relative weight the central bank attaches to the CPI inflation rate in the target rule roughly corresponds to its relative aversion to inflation variability in the

20 To give precise meaning to the concept of "importance", we let μ take on values *1*, *4*, and *8*.

objective function. Also, under flexible CPI inflation targeting, the relative weight on the real exchange rate is considerably higher than under domestic inflation targeting.

B. Variability of the Model Variables Across the Three Regimes

The results of the comparison of the three targeting strategies are presented in Tables *2*, *3*, and *4*. Table *2* shows the results for the case when the policymaker is equally concerned about inflation variability and output gap variability ($\mu = 1$) while Tables *3* and *4* report the results for the case where the policymaker's concern about inflation variability increasingly outweighs the concern about output gap variability, i.e. $\mu = 4$ and $\mu = 8$, respectively.

Let us begin by considering the information contained in section A of Tables *2* and *3*. The loss scores for the three inflation targeting regimes appear in bold-face as diagonal entries. Off-diagonal entries show how losses change if the variance of one of the two alternative measures of inflation takes the place of the variance of the inflation rate being targeted in the loss function. Inspection of the diagonal elements of the two tables reveals a striking contrast. The ranking of the three inflation targeting strategies by loss score is reversed as the central bank's emphasis shifts from equal concern about inflation and output gap variability towards greater concern about inflation stability. Placing greater emphasis on inflation stability clearly favors CPI targeting over domestic and particularly REX inflation targeting which dominates the other two strategies for $\mu = 1$. Losses under CPI inflation targeting are also fairly compact but far less so for domestic and REX inflation targeting as the variance of CPI inflation increases markedly under both regimes.

A second result is that a CPI inflation target produces the lowest variance for all three inflation measures. Indeed the variance of REX inflation is smaller than the variance of CPI inflation itself if $\mu = 1$ and the central bank chooses a CPI inflation objective; the variability of domestic inflation is only slightly above that of CPI inflation. In contrast, domestic and especially REX inflation targeting results in substantial variability of CPI inflation. Putting greater emphasis on inflation control in the objective function ($\mu = 4$) leads to a massive drop in the variance of CPI inflation under CPI inflation targeting – more than threefold- but only moderate (domestic inflation targeting) or slight (REX inflation) decreases in the variance of the chosen target under the alternative targeting strategies.

CPI inflation targeting has the drawback that it leads to pronounced fluctuations in the output gap compared to the other two strategies. This is evidenced by the low variability of the output gap under domestic inflation targeting *(0.064*) and particularly under REX

inflation targeting (*0.0098)* relative to CPI inflation targeting (*0.6149)* in the case where $\mu = 1$ (Confirmation of conjecture 1). With a relatively low relative weight on the inflation rate (μ=1), the central bank's concern with stabilization of the output gap makes REX inflation targeting the preferred strategy. Moreover, REX inflation targeting has the advantage that the output gap and REX inflation are sensitive only to cost-push disturbances. Demand-side disturbances can be completely offset by manipulating the policy instrument.

Financial stability concerns are important in assessing the stance of monetary policy. Central banks wish to avoid contributing to erratic swings in asset prices that have the potential to cause upheaval in financial markets and the wider economy. How do the three inflation targeting regimes affect the variability of the real exchange rate and the policy instrument? Inspection of the lower right half of Tables *2* and *3* confirms conjecture *2*: CPI inflation targeting stabilizes the real exchange rate much better than the alternative targeting strategies. CPI inflation targeting also makes for less variation of the nominal interest rate.

The results described above do not change markedly if the central bank places even greater relative emphasis on inflation stability($\mu = 8$). According to Table *4*, only two minor modifications must be made to our assessment of the targeting strategies. Both changes concern the relative standing of domestic inflation targeting: of the three strategies it is now best at controlling the variability of domestic inflation but worst at managing the variability of the real exchange rate.[21]

C. Policy Frontiers and Inflation-Output Variability Tradeoffs

Additional evidence on the performance of the three flexible inflation targeting strategies can be gleaned by considering the shape and location of policy frontiers which describe the inflation-output variability tradeoffs under each regime. Figure *1* shows the policy frontiers under CPI inflation, domestic, and REX inflation targeting.[22] In addition to the policy frontier for the targeted inflation measure, each segment of the figure shows the frontier for the non-targeted inflation measures. This reflects our interest in the degree to which each strategy provides general price stability.

It is apparent that the three targeting strategies produce vastly different inflation-output variability tradeoffs. In Figure *1C*, under REX inflation targeting, the inflation-output

21 The ranking of policy regimes under discretion is not altered by considering optimal policy under commitment from a timeless perspective as in Woodford (1999a). In general, the output gap becomes more variable and each rate of inflation less variable under commitment.

22 For each strategy, the inflation-output variability frontier is constructed by varying the relative weight on the rate of inflation in the objective function. μ takes on values *1*, *4*, and *8*.

variability tradeoffs are compact. There is not much variation in fluctuations of the output gap and the rate of inflation (no matter how inflation is measured). There are, however, dramatic differences in the loci of the variability tradeoffs. The policy frontier along which CPI inflation variability is traded off for output gap variability under REX inflation targeting is a considerable distance to the right of (and hence inferior to) the policy frontiers that govern the tradeoff between output gap and REX inflation variability and the tradeoff between output gap and domestic inflation variability. Figures *1A* and *1B* illustrate that CPI inflation and especially domestic inflation targeting give rise to far wider inflation-output variability tradeoffs. These observations admit a simple interpretation: the central bank's relative aversion to inflation variability is of less consequence for the variability of the output gap and all three measures of inflation if it targets REX inflation.

In two of the three cases considered the inflation rate targeted traces out the most preferred policy frontier, i.e. the one closest to the origin. Figure *1A* depicts the three policy frontiers under CPI targeting. The one which describes the tradeoff between the variability of CPI inflation and the output gap lies to the left of those based on REX or domestic inflation. In Figure *1B* we find a similar result: under domestic inflation targeting, the tradeoff between domestic inflation variability and output gap variability occurs to the left of the policy frontiers based on REX inflation or CPI inflation. Figure *1C* illustrates a contrary example. When price stability is of great or medium concern, REX inflation targeting produces a variability tradeoff between itself and the output gap that lies above the variability tradeoff between domestic inflation and the output gap.

A striking feature that can be seen from comparing the three segments of Figure 1 is that CPI inflation targeting provides relatively low inflation variability across all three inflation measures. Each of the other strategies produces relatively poor performance for CPI inflation. This results from the fact that these other strategies produce very high variance in the real exchange rate with adverse effects on the variance of CPI inflation.

Figure 1D provides more information on the behavior of the real exchange rate as well as that of the policy instrument under the three targeting strategies. In general, greater emphasis on inflation leads to greater variability in both the real exchange rate and the policy instrument as optimal policy becomes more aggressive. From the standpoint of financial stability, however, it can be seen from the figure that both are least volatile under CPI inflation targeting for all levels of inflation aversion.

D. How Sensitive is the Ranking to the Sources of Shocks?

A central result of Clarida, Gali and Gertler's (1999) analysis of monetary policy in the closed economy is that "[t]he optimal policy calls for adjusting the interest rate to perfectly offset demand shocks ….Demand shocks do not force a short-run trade-off between output and inflation." This result does not necessarily carry over to the type of open-economy model considered here but depends on the central bank's inflation objective. As in Poole (1970), the ranking of alternative strategies in the model will depend on the relative variability of the shocks faced by the policymaker. Under domestic or CPI inflation targeting, the policymaker confronted with demand-side shocks faces a tradeoff between stabilizing inflation and the output gap. The isomorphism between optimal monetary policy in the open and closed economy breaks down. REX inflation targeting restores the isomorphism. The Clarida, Gali and Gertler (1999) result for demand-side shocks holds under this targeting procedure.

To see how the origin and variability of shocks affects the ranking of the three targeting procedures, we modify the original set-up by increasing the variance of each demand-side disturbance from one to four while the variance of the cost-push shock is kept at one. Table *5* presents the findings with this modification when the central bank is equally concerned about inflation and output gap variability ($\mu=1$). Table *6* shows findings for substantially greater aversion to inflation variability ($\mu=8$).

First, compare the loss scores in the top panels of Tables *5* and *6* to those in Tables *2* and *4*. From a loss minimizing perspective, a central bank with a relatively low aversion to inflation variability ($\mu=1$) does best under REX inflation targeting. The advantage of this strategy increases if shocks to the demand side of the economy are far more variable than the cost-push shock (Table *5* compared to Table *2*). As the demand-side shocks become more variable, the loss score for REX inflation targeting is unchanged while the loss score for the other two strategies rises. Comparison of Tables *4* and *6* shows, however, that a highly inflation-averse central bank ($\mu=8$) would still choose CPI inflation targeting with highly variable demand-side shocks albeit by a smaller margin.

Thus, as expected, more variability of demand-side shocks favors REX inflation targeting; under this strategy these shocks are perfectly offset by adjusting the interest rate. CPI inflation targeting is still attractive as can be seen from the rankings of the three strategies if performance is measured by minimizing the variances of each of the inflation measures we consider. Moreover, while the variance of the real exchange rate and nominal

interest rate increase for all strategies as demand shocks become more variable, CPI inflation targeting still produces the lowest variance for both. These results hold for either μ=1 or μ=8.

To summarize, an increase in the variability of demand-side shocks relative to cost-push shocks increases the desirability of REX inflation targeting relative to the other two strategies. Even so, CPI inflation targeting retains its advantage in providing low inflation variability by all measures and results in lower variability of the real exchange rate and policy instrument.[23]

5. Conclusion

This paper considers the choice of an inflation objective in a New Keynesian open economy model which has a direct exchange rate channel in the Phillips curve. In the model this channel results from the fact that producers care about the real exchange rate in setting prices. There are other rationales for such a real exchange rate channel in models such as those of Ball (1999), Svensson (2000) and Froyen and Guender (2007). With a direct exchange rate channel in the Phillips curve the transmission mechanism of monetary policy no longer works exclusively through the output gap. Instead it relies as well on the real exchange rate to bring about changes in the rate of inflation.

A more expansive transmission mechanism affects optimal central bank policy. If the CPI or domestic rate of inflation is the inflation objective, the current framework has policy implications that differ sharply from models such as those of Clarida, Gali and Gertler (2001, 2002) and Gali and Monacelli (2005) which do not provide for a direct exchange rate channel in the Phillips curve. In their open-economy models optimal monetary policy is isomorphic to that in the closed-economy counterpart. With a direct exchange rate channel, the isomorphism breaks down. The difference in optimal policies is most easily seen in the specification of the target rules (Table*1*). With a direct exchange rate channel in the Phillips curve, the real exchange rate appears as an essential element in the target rule. In addition, characteristics of the demand-side of the economy influence the relative weights the central bank places on the components of the target rule. Demand-side disturbances can no longer be offset by a mere adjustment of the policy instrument; the response to *all* disturbances depends on the central bank's relative aversion to inflation variability.

23 We have also checked the sensitivity of the results reported to a change in the size of *b*, a key parameter. If supply side openness increases from *0.1* to *0.25*, domestic and CPI inflation targeting achieve lower inflation variability at the expense of higher output gap variability. Losses increase somewhat under domestic and CPI inflation targeting but remain invariant under REX inflation targeting. The inflation-output gap variability trade-off frontiers shift up and to the left but the general shape of the frontiers remains similar to those in Figure *1*.

We consider a real-exchange-rate-adjusted (REX) inflation targeting regime that restores the isomorphism with policy in a closed economy. This strategy closes down the real exchange rate channel in the (redefined) Phillips curve. The resulting target rule contains only REX inflation and the output gap. Its parameters do not depend on characteristics of the demand-side of the model and demand-side disturbances can again be offset without cost by adjustments in the policy instrument.

So what to aim for? With CPI or domestic inflation as the inflation objective, the real exchange rate channel enhances the inflation-output tradeoff. The direct effect of the exchange rate on the inflation rate in the Phillips curve complements the indirect effect through the output gap as the policymaker adjusts the interest rate. This is more pronounced for CPI inflation than domestic inflation because import prices are included in the CPI. Thus we find that a higher degree of aversion to inflation variability in general favors CPI inflation targeting (See Tables *4* and *6*.)

Among the three strategies REX inflation targeting gives the highest weight to the output gap in the target rule for a given inflation aversion. For all cases we consider, this results in REX inflation targeting producing the lowest variability of the output gap, often by a large margin. For a central bank with a relatively high weight on the output gap in the loss function, this makes REX inflation attractive (Tables *2* and *5*).

In countries such as New Zealand and the United Kingdom where the central bank's agreement with the government stipulates that monetary policy be implemented with price stability as the primary goal, CPI inflation targeting is likely to be dominant. CPI inflation targeting provides low variability of *all* three inflation measures, often the lowest for all three. Concern for financial stability strengthens the case for CPI inflation targeting which provides the lowest variability of the real exchange rate and interest rate.

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Table 1: The Target Rules Underlying Domestic, CPI, and REX Inflation Targeting

A. The Target Rules Compared

Rule under Domestic Inflation Targeting	**Rule under CPI Inflation Targeting**	**Rule under REX Inflation Targeting**
$y_t + \mu[\pi_t\left(\kappa + \frac{c_1}{c_2}\right) - \frac{\beta b}{c_2} w_\pi q_t] = 0$	$y_t + \mu[\left(\kappa + \frac{f_1}{f_2}\right)\pi_t^{CPI} - \frac{\beta(\gamma+b)\phi_\pi}{f_2} q_t] = 0$	$y_t + \mu\kappa\pi_t^{REX} = 0$
$c_1 = \beta\left(w_\pi - b\left(w_q - 1\right)\right) + b > 0$	$f_1 = \beta\phi_\pi + (\gamma + b)\left(1 + \beta(1 - \phi_q)\right) > 0$	
$c_2 = w_y - (a_1(1-\gamma) + a_2)\left(w_q - 1\right) > 0$	$f_2 = \phi_y - (a_1(1-\gamma) + a_2)\left(\phi_q - 1\right) > 0$	

B. The Relative Weights in the Target Rules Based on Parameter Values: $a_1 = 0.45, a_2 = 0.195, a_3 = 0.27, b = 0.1, \kappa = 0.1, \beta = 1$

	Domestic Inflation Targeting		CPI Inflation Targeting		REX Inflation Targeting	
	π_t	q_t	π_t^{CPI}	q_t	π_t^{REX}	q_t
$\mu = 1$	0.30	0.018	0.93	0.195	0.1	0
$\mu = 4$	1.27	0.057	3.97	0.395	0.4	0
$\mu = 8$	2.65	0.089	8.28	0.464	0.8	0

The parameter values for a_1, a_2, and a_3 depend on deep parameters such as the elasticity of demand, elasticity of substitution, etc. We are not aware of any reliable empirical estimates of *b*. A conservative value for *b* is chosen so as to not overemphasize the importance of a real exchange rate channel in the Phillips curve. Empirical estimates of κ typically fall within the [0.05, 0.4] range. See also the notes to Table 2.

Table 2: The Variances of the Endogenous Variables and the Policy Instrument under Different Inflation Targeting Strategies: Policymaker is Equally Concerned about Inflation Variability and Output Gap Variability (**Discretion with μ=1)**

A. The Loss Functions							
E(L)	*CPIT*	*DOMIT*	*REXIT*				
$\mu\ V(\pi^{CPI}) + V(y)$	***1.32***	*2.13*	*2.67*				
$\mu\ V(\pi) + V(y)$	*1.38*	***1.02***	*1.07*				
$\mu\ V(\pi^{REX}) + V(y)$	*1.28*	*1.88*	***0.99***				
B. Variances of Endogenous Variables							
Target Variables	*CPIT*	*DOMIT*	*REXIT*	Other Variables	*CPIT*	*DOMIT*	*REXIT*
V(y)	*0.6149*	*0.0864*	*0.0098*	*V(q)*	*2.26*	*5.0416*	*5.7197*
$V(\pi^{CPI})$	***0.7073***	*2.0465*	*2.6568*	*V(R)*	*1.9274*	*4.0915*	*5.0385*
$V(\pi)$	*0.757*	***0.933***	*1.0563*				
$V(\pi^{REX})$	*0.6673*	*0.944*	***0.9803***				

Note: i. All disturbances are distributed independently with a mean of zero and unit variance. The parameters of the IS relation are $a_1 = 0.45, a_2 = 0.195, a_3 = 0.27$. The parameters of the Phillips curve are $\beta = 1, b = 0.1, \kappa = 0.1$.

ii. The IS parameters depend on structural parameters: $a_1 = (1-\gamma)\sigma \quad a_2 = \gamma((1-\gamma)\eta + \gamma^f \eta^f) \quad a_3 = \gamma\zeta^f$

where $\gamma =$ degree of consumption openness = 0.3 $\quad \sigma =$ intertemporal elasticity of substitution $= 0.64$.

η = elasticity of substitution between domestic and foreign good = 0.765 $\quad \eta^f$ = foreign elasticity of substitution between foreign and domestic good = 0.77.

γ^f = degree of openness of foreign economy = 0.15 $\quad \zeta^f$ = share of foreign consumption in foreign output = 0.9.

For further details, see Guender (2006).

iii. The numerical results are based on an adapted GAUSS algorithm originally developed by Dennis (2001). Under domestic and CPI inflation targeting, the numerical solution procedure experienced problems achieving convergence. This problem is often encountered in the literature and is typically solved by adding an interest smoothing term to the objective function (See Svensson (2000). To achieve convergence, we instead adjusted by a factor of 0.005 two terms under domestic inflation and CPI inflation targeting, respectively: $\beta b = 0.095\ instead\ of\ 0.1\ and\ 2(b+\gamma) = 0.795\ instead\ of\ 0.8$.

iv. *CPIT* = CPI Inflation Targeting, *DOMIT* = Domestic Inflation Targeting, *REXIT* = Real-Exchange-Rate-Adjusted Inflation Targeting.

Table 3: The Variances of the Endogenous Variables and the Policy Instrument under Different Inflation Targeting Strategies: Policymaker is More Concerned about Inflation Variability Than Output Gap Variability (**Discretion with μ=4)**

A. The Loss Functions							
E(L)	*CPIT*	*DOMIT*	*REXIT*				
$\mu\ V(\pi^{CPI})+ V(y)$	***2.29***	*5.54*	*9.53*				
$\mu\ V(\pi) + V(y)$	*3.67*	***3.23***	*3.77*				
$\mu\ V(\pi^{REX}) + V(y)$	*3.31*	*4.07*	***3.85***				
B. Variances of Endogenous Variables							
Target Variables	*CPIT*	*DOMIT*	*REXIT*	Other Variables	*CPIT*	*DOMIT*	*REXIT*
V(y)	*1.57*	*0.8416*	*0.1479*	*V(q)*	*3.1608*	*5.9996*	*6.2508*
$V(\pi^{CPI})$	***0.179***	*1.1739*	*2.3447*	*V(R)*	*2.234*	*4.5738*	*5.681*
$V(\pi)$	*0.5253*	***0.5982***	*0.9045*				
$V(\pi^{REX})$	*0.4346*	*0.8074*	***0.9246***				

Notes: see Table 2.

Table 4: The Variances of the Endogenous Variables and the Policy Instrument under Different Inflation Targeting Strategies: Policymaker is Far More Concerned about Inflation Variability Than Output Gap Variability (**Discretion with μ=8)**

A. The Loss Functions							
E(L)	*CPIT*	*DOMIT*	*REXIT*				
$\mu\ V(\pi^{CPI}) + V(y)$	***2.61***	*10.67*	*18.74*				
$\mu\ V(\pi) + V(y)$	*5.54*	***5.00***	*6.50*				
$\mu\ V(\pi^{REX}) + V(y)$	*5.43*	*7.48*	***7.41***				
B. Variances of Endogenous Variables							
Target Variables	*CPIT*	*DOMIT*	*REXIT*	Other Variables	*CPIT*	*DOMIT*	*REXIT*
V(y)	*2.066*	*2.0424*	*0.5487*	*V(q)*	*4.2675*	*9.1445*	*7.7916*
$V(\pi^{CPI})$	***0.0678***	*1.0784*	*2.2748*	*V(R)*	*2.2764*	*6.1642*	*7.5455*
$V(\pi)$	*0.4343*	***0.3699***	*0.7442*				
$V(\pi^{REX})$	*0.4202*	*0.68*	***0.8573***				

Notes: see Table 2.

Table 5: The Variances of the Endogenous Variables and the Policy Instrument under Different Inflation Targeting Strategies: Demand-Side Variances are Four Times as Large as the Variance of Cost-Push Shock (**Discretion, μ=1, σ_i^2=4, $i = v, \epsilon, r^f, y^f, \pi^f$ and $\sigma_u^2 = 1$**).

A. The Loss Functions							
E(L)	*CPIT*	*DOMIT*	*REXIT*				
μ V(π^{CPI})+ V(y)	***3.42***	*NA*	*NA*				
μ V(π) + V(y)	*NA*	***1.32***	*NA*				
μ V(π^{REX}) + V(y)	*NA*	*NA*	***0.99***				
B. Variances of Endogenous Variables							
Target Variables	*CPIT*	*DOMIT*	*REXIT*	Other Variables	*CPIT*	*DOMIT*	*REXIT*
V(y)	*1.8893*	*0.1291*	*0.0098*	*V(q)*	*6.8465*	*19.334*	*22.766*
V(π^{CPI})	***1.5350***	*6.3300*	*8.1116*	*V(R)*	*6.5663*	*15.467*	*20.018*
V(π)	*0.7834*	***1.1915***	*1.3972*				
V(π^{REX})	*0.8123*	*0.9441*	***0.9803***				

Notes: The off-diagonal scores in part A of the table have been omitted as they do not provide additional useful information not already contained in Table 2. See also Table 2.

Table 6: The Variances of the Endogenous Variables and the Policy Instrument under Different Inflation Targeting Strategies: Policymaker is Far More Concerned about Inflation Variability than Output Gap Variability and Variances of Demand-Side Shocks are Fourfold the Variance of Cost-Push Shock (**Discretion, μ=8, σ_i^2=4, $i = v, \epsilon, r^f, y^f, \pi^f$ and $\sigma_u^2 = 1$**).

A. The Loss Functions							
E(L)	*CPIT*	*DOMIT*	*REXIT*				
μ V(π^{CPI})+ V(y)	***5.97***	*NA*	*NA*				
μ V(π) + V(y)	*NA*	***6.34***	*NA*				
μ V(π^{REX}) + V(y)	*NA*	*NA*	***7.41***				
B. Variances of Endogenous Variables							
Target Variables	*CPIT*	*DOMIT*	*REXIT*	Other Variables	*CPIT*	*DOMIT*	*REXIT*
V(y)	*5.1601*	*2.8186*	*0.5487*	*V(q)*	*5.1372*	*16.0047*	*24.8377*
V(π^{CPI})	***0.1015***	*2.5808*	*7.7295*	*V(R)*	*7.7441*	*11.3731*	*22.5243*
V(π)	*0.4379*	***0.4407***	*1.0851*				
V(π^{REX})	*0.4559*	*0.6833*	***0.8573***				

Notes: see Tables 2 and 5.

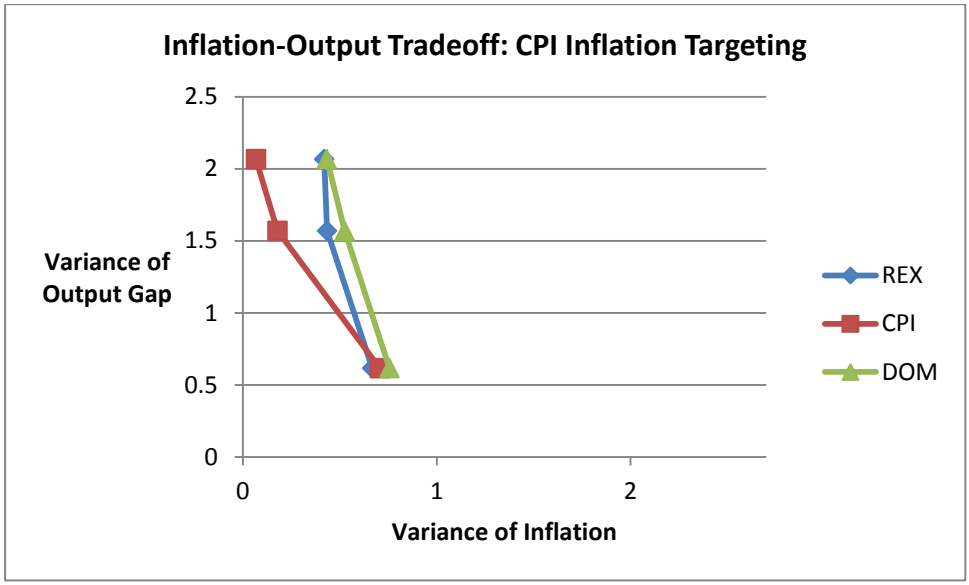

Figure 1A

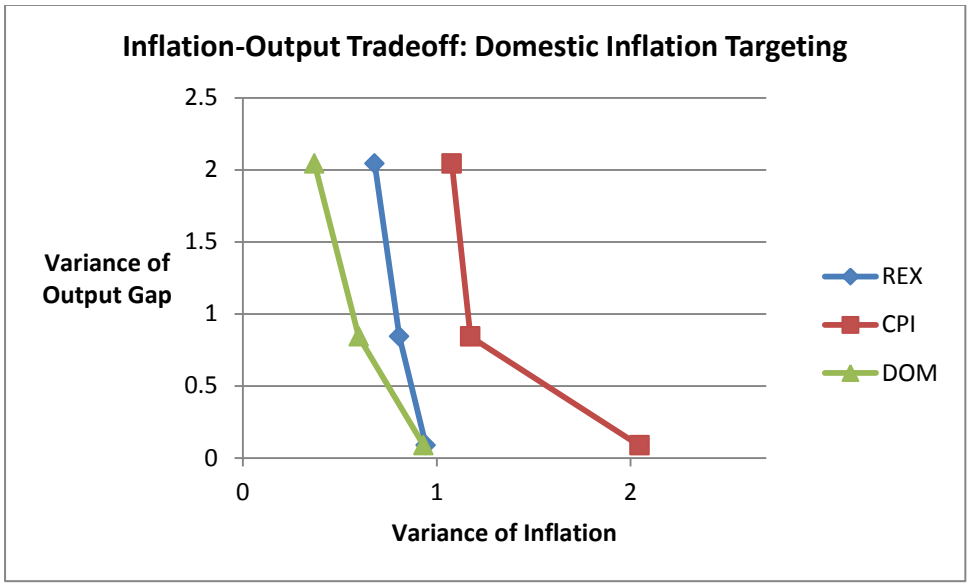

Figure 1B

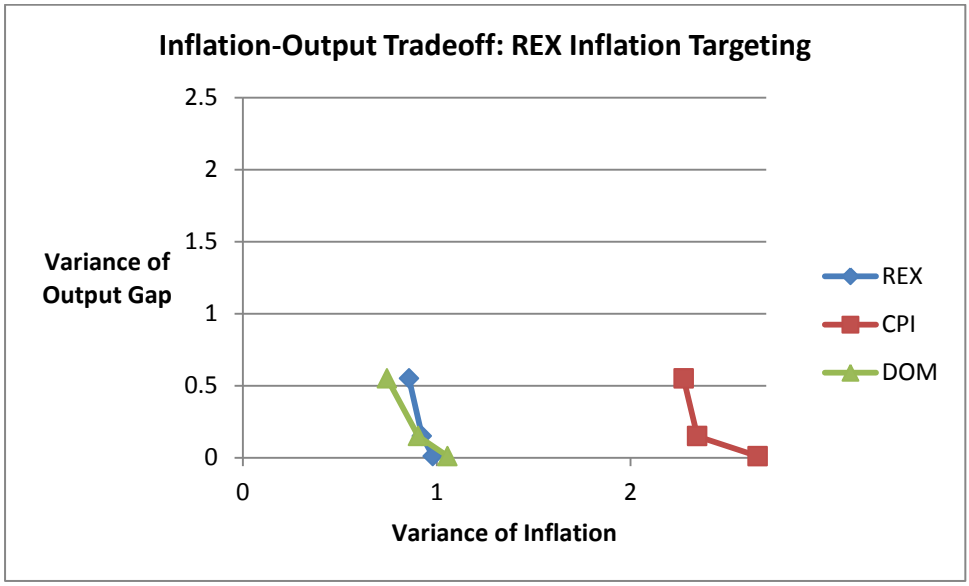

Figure 1C

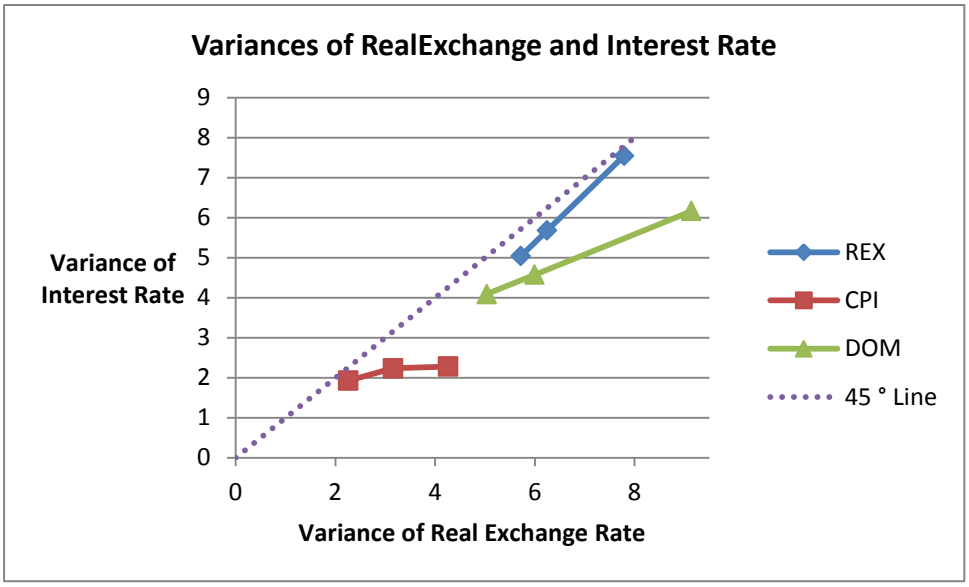
Variances of RealExchange and Interest Rate
Variance of Interest Rate
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
Variance of Real Exchange Rate
REX
CPI
DOM
45 ° Line

Figure 1D