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The results reported in this paper are based on research undertaken while the author was visiting the Bank of Finland. I wish to thank Richard Dennis of the Federal Reserve Bank of San Francisco for explaining to me the basic set-up of his solution algorithm. I also wish to acknowledge the valuable feedback that I have received from Seppo Honkapohja, Lauri Kajanoja, David Mayes, Jukka Railavo, Anssi Rantala, Tuomas Saarenheimo, Karsten Staehr, Juha Tarkka, and Jouko Vilmunen.

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Optimal discretionary monetary policy in the open economy: Choosing between CPI and domestic inflation as target variables

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Abstract

In open economy, a choice can be made between two measures of inflation for use as a target variable: CPI inflation or domestic inflation. This paper considers flexible and strict inflation targeting strategies and explores the circumstances under which a domestic inflation target is preferred to a CPI inflation target. This is done from the perspectives of the central bank and society as a whole.

The quantitative results of this paper indicate that under suitable conditions the temporal properties of stochastic disturbances are instrumental in determining which inflation target is preferred. The choice of target variable from society's viewpoint coincides almost perfectly with the choice of the central bank if the utility of the representative household serves as the welfare criterion for society.

If qualitative aspects matter in the choice inflation target, then the role of temporal properties of the stochastic disturbances becomes less prominent.

Policy conclusions are drawn with the help of a forward-looking model for a small open economy. This model has proper micro-foundations and exhibits two important features. First, the degree of openness affects the parameters of the IS relation and, second, under domestic inflation targeting, the existence of a direct exchange rate channel in the Phillips Curve impairs the perfect stabilising properties of monetary policy in the presence of demand-side disturbances.

Key words: monetary policy, inflation target

JEL classification numbers: E52, F41

Optimaalinen rahapolitiikka avoimessa taloudessa: kuluttajahinnat ja kotimainen inflaatio vaihtoehtoisina tavoitteina

Suomen Pankin keskustelualoitteita 12/2003

Alfred V. Guender
Tutkimusosasto

Tiivistelmä

Avoimessa kansantaloudessa voidaan valita kahdesta eri inflaation mittarista rahapolitiikan tavoitteena: kuluttajahinnoista tai kotimaisesta inflaatiosta. Tässä tutkimuksessa tarkastellaan sekä joustavan että tiukan inflaatiotavoitejärjestelmän toimintaa ja analysoidaan, missä tapauksissa kotimainen inflaatio on parempi rahapolitiikan tavoite kuin kuluttajahintainflaatio. Kysymystä tarkastellaan sekä keskuspankin että koko yhteiskunnan näkökulmasta. Tutkimuksen kvantitatiiviset tulokset osoittavat, että tietyissä tapauksissa taloudessa vaikuttavien satunnaishäiriöiden luonteesta riippuu, kumpi inflaatiotavoite on parempi. Yhteiskunnan valinta ja keskuspankin valinta eri vaihtoehtojen välillä ovat melkein täysin yhtenevät, jos yhteiskunnallisena valintakriteerinä käytetään edustavaa kotitalouden hyötytasoa. Talouspoliittisia johtopäätöksiä tehdään odotuksiin perustuvalla pienen avoimen talouden mallilla. Malli perustuu mikrotason käyttäytymiseen, ja sillä on kaksi tärkeää piirrettä: talouden avoimuus vaikuttaa kokonaiskysyntäfunktion parametreihin ja valuuttakurssi vaikuttaa inflaatioon myös suoraan Phillipsin käyrän kautta. Viimeksi mainitun seikan vuoksi rahapolitiikka ei tässä mallissa pysty täysin torjumaan kysyntähäiriöiden vaikutusta, kun noudatetaan inflaatiotavoitteeseen perustuvaa rahapolitiikan strategiaa.

Avainsanat: rahapolitiikka, inflaatiotavoite

JEL-luokittelu: E52, F41

Contents

1 Introduction

Few economists will take issue with the notion that by the end of the millennium inflation targeting had become the dominant monetary policy strategy. The countries that initiated the move towards inflation targeting in the late 1980s and early 1990s were typically small open economies.[1] Due to their relatively large trading sectors and the view that severe exchange rate fluctuations are disruptive to trade, these countries defined the target for inflation in terms of changes in a fairly broad price index, the Consumer Price Index (CPI). This index is broad in the sense that it includes the prices of selected domestic and foreign consumption goods. The extent to which the domestic currency prices of the latter are sensitive to changes in the exchange rate depends on the degree of exchange rate pass-through. If exchange rate pass-through is complete changes in the nominal exchange rate lead to one-for-one changes in the domestic currency price of imported goods. The overall effect of imported inflation on the CPI is then captured by changes in the real exchange rate and the degree of openness.

The case for CPI inflation targeting seems to be overwhelming in light of current practice. Indeed it appears to be so strong that there is no room for any *alternative* inflation targeting strategy. Yet in open economies, central banks have a choice between two measures of inflation as target variables: CPI inflation and domestic inflation. The issue of whether monetary policy ought to be based on a purely domestic measure of inflation in open economies has received some attention in the recent literature. Indeed, Sutherland (2000), Clarida, Gali, and Gertler (2001, 2002), and Aoki (2001) recommend that the policymaker target domestic inflation. Using an extension of the Obstfeld-Rogoff model (2000), Sutherland favors targeting domestic inflation as it helps stabilize wages in an economy that consists of a flexible and a fixed wage sector. With no changes in relative wages, the risk premium that workers in the fixed wage sector face is minimized and overall welfare is maximized. CPI inflation targeting also produces too little exchange rate volatility. Echoing Sutherland's view but employing a forward-looking New Keynesian framework, Clarida, Gali, and Gertler also advocate domestic inflation targeting. They favor domestic inflation targeting over CPI targeting as the latter impairs the adjustment of relative prices that is necessary to effect desirable changes in real quantities. The real exchange rate is to be accorded enough flexibility so that relative prices can change sufficiently to keep real output at its potential level. By focusing on domestic inflation only, the policymaker can bring about the desired flexibility in the real exchange rate. A similar conclusion is reached by Aoki who also employs a

[1] New Zealand, Canada, and Australia were among the first countries to adopt formal inflation targets.

forward-looking framework. In his view, policy is to focus on core inflation, ie inflation in the domestic sector, as it is the only source of friction in the model. Indeed stabilizing core inflation guarantees that the real exchange adjusts optimally as well. Again, welfare is maximized under domestic inflation targeting.

Other contributions de-emphasize the desirability of domestic inflation targeting. Svensson (2000) evaluates a number of different targeting strategies in a small open economy setting that features forward-looking behavior, persistence, and lags in the transmission mechanism of monetary policy. Strict and flexible domestic inflation targeting as well as strict and flexible CPI targeting are among the strategies compared. Svensson concludes that flexible CPI targeting is the most attractive strategy for monetary policy as it limits the variability of domestic inflation, CPI inflation, the output gap, the real exchange rate, and the policy instrument. A similar conclusion is reached by Adolfson (2001) who examines the implications of limited exchange rate pass-through for the conduct of monetary policy in a forward-looking framework.

This paper attempts to provide a comprehensive assessment of discretionary inflation targeting in the open economy from two different perspectives. The first perspective assumes that the policymaker is free to decide whether to pursue an inflation target that is defined in terms of domestic inflation or CPI inflation. We first consider a scenario where the policymaker cares equally about the variability of both real output and inflation in his objective function. We attempt to assess the implications of pursuing this *flexible* inflation targeting strategy analytically and with the help of a numerical solution technique. The analysis of flexible inflation targeting is complemented by the analysis of another form of optimal, albeit extreme form of inflation targeting, *strict* inflation targeting, where the policymaker faces a similar problem of choosing between domestic and CPI inflation as the target. The merits of the strict inflation targeting regime are also evaluated analytically and numerically.

It is safe to say that most central banks do not enjoy discretion in the choice of the rate of inflation that embodies the inflation target. In most, if not all instances, the decision of which rate of inflation to target is handed down to the central bank by government decree. Thus the second perspective is one where the central bank is given the mandate to target a particular rate of inflation. In this context the question that the policymaker must tackle is to decide between flexible or strict inflation targeting.

What are the possible factors that may influence the decision to target domestic instead of CPI inflation or pursue flexible instead of strict inflation targeting? We identify two factors: the degree of openness of the economy and the temporal properties of the stochastic disturbances of the model. The degree of openness is chosen because it affects the structural parameters of the IS equation. The distinction between white noise disturbances and persistent disturbances is deemed important because of the forward-looking nature of the New Keynesian framework. If shocks are persistent, then the effect of current shocks on current inflation and real output is augmented by forward-looking expectations. That is because the current expectations of future inflation and real output (and the real exchange rate) depend on these shocks.

Our examination yields a number of intriguing results. A critical factor that influences the decision of a central bank to target domestic or CPI inflation is the temporal property of the disturbances. We show that a flexible inflation targeting strategy where the rate of domestic inflation serves as the target dominates a flexible CPI inflation targeting strategy if all disturbances are white noise processes. In case the disturbances exhibit persistence, however, flexible CPI inflation targeting dominates flexible domestic inflation targeting. Under a regime of strict inflation targeting, the pattern is exactly reversed. Strict CPI inflation targeting is preferred to strict domestic inflation targeting in the event the disturbances are white noise and strict domestic inflation targeting turns out to be more attractive than strict CPI inflation targeting in case the disturbances are persistent. This intriguing pattern arises because the temporal property of the disturbances affects critically the ability of domestic and CPI inflation targeting to stabilize real output. The table below summarizes the findings of this exercise. The dominating inflation target appears in boldface.

Shocks	*Flexible inflation targeting*	*Strict inflation targeting*
White noise	**Domestic inflation**	**CPI inflation**
AR(1)	**CPI inflation**	**Domestic inflation**

We also address the issue of whether the choice of the inflation target by the central bank is consistent with the preferences of society. If the utility of the representative household serves as the welfare criterion for society, then the target variable for inflation chosen by the central bank matches the preferred choice of society.

Similarly interesting findings emerge from a scenario where the central bank is obliged to target either domestic or CPI inflation. In the event the central bank is instructed to target domestic inflation, our findings indicate that flexible inflation targeting is preferred to strict inflation targeting provided that the disturbances are white noise. For autocorrelated disturbances, the preferred choice depends on the degree of persistence in the disturbances. The greater the degree of persistence, the more attractive strict domestic inflation targeting becomes. These results are established both analytically and numerically for a zero domestic inflation target. A similar result arises in the case of a zero CPI inflation target: strict CPI inflation targeting is preferred to flexible CPI inflation targeting for highly persistent disturbances while flexible CPI inflation targeting dominates strict CPI inflation targeting in case of white noise disturbances. The conclusions drawn about CPI targeting are not quite as strong as they are based merely on results ground out by the numerical solution technique.

We complement the quantitative analysis with an alternative method that takes qualitative aspects of target choice into consideration. The qualitative method of performance evaluation finds the temporal properties of the stochastic disturbances to be less important in determining the appropriate variable for the inflation target.

All policy conclusions are drawn with the help of a model for a small open economy where the real exchange rate plays a prominent role in the transmission mechanism of monetary policy. In view of the importance of the real exchange rate, this paper offers a somewhat different definition of the "direct" exchange rate channel. In conventional models, the direct exchange rate channel is thought of as operating through the CPI. As the exchange rate forms part of this index, a change in the real exchange rate leads to a change in imported inflation and hence to a change in CPI inflation under the assumption of complete exchange rate pass through. Naturally this effect is also present in the current framework but it is not referred to as the "direct" exchange rate channel. Instead, in the current paper the "direct" exchange rate channel operates through the presence of the level of the real exchange rate in the Phillips Curve. The real exchange rate enters the Phillips Curve because domestic price setters take into consideration the domestic currency price of import-competing goods when setting their prices.

The existence of a direct exchange rate channel in the Phillips Curve has far-reaching implications for the conduct of optimal discretionary monetary policy in the open economy. First, the perfect stabilizing property of optimal discretionary monetary policy in the wake of demand-side disturbances and exchange rate disturbances under domestic inflation targeting disappears. Both domestic inflation and real output deviate from their respective target in the face of such disturbances. In conventional models such a response pattern occurs only if cost-push shocks hit the economy. These insights are based on analytical findings. Under CPI inflation targeting, the perfect stabilizing property fails to hold for all stochastic disturbances even if the direct exchange rate channel in the Phillips Curve is not operative.

The organization of the paper is as follows. In Section 2 we derive the forward-looking IS relation and the forward-looking Phillips Curve from an explicit optimization framework. Section 3 discusses the implications of choosing domestic inflation or CPI inflation as a target under flexible inflation targeting. In Section 4 we compare and contrast the advantages and disadvantages of adopting either rate of inflation as a target with the help of a numerical solution technique. The merits of pursuing a strict inflation targeting strategy are discussed in Section 5. Section 6 ties together the different strands of the quantitative analysis. It seeks to provide a rationale for the choice between a domestic and a CPI inflation target and examines the extent to which the target variable chosen by the central bank overlaps with the choice preferred by society. In Section 7 we analyze the choice of optimal policy from the standpoint of a central bank that is under instruction to target a particular rate of inflation. Section 8 considers qualitative aspects in the choice between a domestic and a CPI inflation target. Concluding comments appear in Section 9.

2 The building blocks of a small open economy model

The model proper consists of three equations: an IS relation that explains the behavior of aggregate demand in the open economy, a Phillips Curve that illustrates the price setting behavior of monopolistically competitive firms, and a standard uncovered interest rate parity condition. This section provides a step-by-step derivation of the open economy IS relation and the open economy Phillips Curve.[2]

The IS relation

Consumers maximize a lifetime utility function that depends on the consumption level of the domestically produced final good and an imported final good.

The period utility function takes the following form:

$$U(C_t^h, C_t^f) = \frac{C(C_t^h, C_t^f)^{1-\frac{1}{\sigma}} - 1}{1-\sigma} \tag{2.1}$$

where $\sigma > 0$ is the intertemporal elasticity of substitution and C measures aggregate consumption while C_t^h and C_t^f measures the quantity of the domestic and foreign consumption good, respectively.

From the standard *intertemporal* utility maximization problem, the following first-order condition obtains (lower case letter denotes deviation from steady state value):

[2] The contributions by McCallum and Nelson (1997), Gali and Monnacelli (1999), Svensson (2000), and Clarida, Gali, and Gertler (2001) represent earlier attempts to model optimizing behavior by economic agents in the open economy in ways that are directly comparable to the microfoundations established in this section. The derivation of the IS curve in the current model is in parts similar to that of Svensson (2000).

$$c_t = E_t c_{t+1} - \sigma(R_t - E_t \pi_{t+1}^{CPI}) \tag{2.2}$$

where c_t denotes aggregate consumption and $R_t - E_t \pi_{t+1}^{CPI}$ denotes the real rate of interest, defined as the difference between the nominal rate of interest and the CPI rate of inflation.

The *intratemporal* first-order condition yields the following relationship: the demand for the domestic consumption good is proportional to aggregate consumption and depends inversely on its relative price:

$$c_t^h = -\eta(p_t^h - p_t^{CPI}) + c_t \tag{2.3}$$

η measures the elasticity of substitution between the domestic and the foreign consumption good. p_t^{CPI} and p_t^h are defined as the consumer price index and the price of the domestic consumption good, respectively.

With η taken to equal unity, the consumer price index can be written as a weighted average of the price of the domestic and the imported foreign consumption good, respectively:

$$p_t^{CPI} = (1-\gamma)p_t^h + \gamma(p_t^f + s_t) \tag{2.4}$$

p_t^f represents the price of the foreign consumption good, s_t is the spot exchange rate at time t, defined as the units of domestic currency required to buy one unit of foreign currency, and γ denotes the weight of the price of the foreign good in the CPI.

Substituting (2.4) into (2.3) yields the following expression:

$$c_t^h = \eta\gamma q_t + c_t \tag{2.5}$$

where q_t represents the real exchange rate and is defined as $q_t = p_t^f + s_t - p_t^h$.

The next step consists of substituting (2.5) into (2.2):

$$c_t^h - \eta\gamma q_t = E_t c_{t+1}^h - \eta\gamma E_t q_{t+1} - \sigma(R_t - E_t \pi_{t+1}^{CPI}) \tag{2.6}$$

Expressing the resource constraint as a log-linearized equation around the steady state levels yields:

$$y_t = (1-\gamma)c_t^h + \gamma c_t^{hf} \tag{2.7}$$

where y_t is the real output gap and c_t^{hf} is foreign consumption of domestic goods, ie domestic exports.

Foreign demand for the domestic consumption good evolves in accordance with equation (2.8):

$$c_t^{hf} = c_t^f + \eta^f \gamma^f q_t \qquad (2.8)$$

Foreign consumption is proportional to foreign real output, ie $c_t^f = \beta^f y_t^f$. Hence (2.8) can be written as:

$$c_t^{hf} = \beta^f y_t^f + \eta^f \gamma^f q_t \qquad (2.9)$$

Updating and taking expectations of the resource constraint (Equation (2.7)) yields:

$$E_t y_{t+1} = (1-\gamma) E_t c_{t+1}^h + \gamma E_t c_{t+1}^{hf} \qquad (2.10)$$

After solving for $E_t c_{t+1}^h$, we can restate the above equation as follows:

$$\frac{E_t y_{t+1} - \gamma E_t c_{t+1}^{hf}}{1-\gamma} = E_t c_{t+1}^h \qquad (2.10')$$

Next, substitute (2.10') into (2.6):

$$c_t^h = \frac{E_t y_{t+1} - \gamma E_t c_{t+1}^{hf}}{1-\gamma} + \gamma\eta(q_t - E_t q_{t+1}) - \sigma(R_t - E_t \pi_{t+1}^{CPI}) \qquad (2.11)$$

Expression (2.11) can then be substituted back into expression (2.7):

$$y_t = E_t y_{t+1} + (1-\gamma)\left[\gamma\eta(q_t - E_t q_{t+1}) - \sigma(R_t - E_t \pi_{t+1}^{CPI})\right] + \gamma(c_t^{hf} - E_t c_{t+1}^{hf}) \qquad (2.12)$$

Making use of equation (2.9), we can restate equation (2.12) as written below:

$$y_t = E_t y_{t+1} + (1-\gamma)\left[\gamma\eta(q_t - E_t q_{t+1}) - \sigma(R_t - E_t \pi_{t+1}^{CPI})\right] + \gamma\beta^f(y_t^f - E_t y_{t+1}^f) \qquad (2.13)$$

or

$$y_t = E_t y_{t+1} - a_1(R_t - E_t \pi_{t+1}^{CPI}) + a_2(q_t - E_t q_{t+1}) + a_3(y_t^f - E_t y_{t+1}^f) \qquad (2.14)$$

where $a_1 = (1-\gamma)\sigma > 0$
$a_2 = \gamma[(1-\gamma)\eta + \eta^f\gamma^f] > 0$
$a_3 = \gamma\beta^f > 0$

Equation (2.14) represents the open economy IS relation. The forward-looking characteristic of aggregate demand is self-evident: current real output depends not only on the current real exchange rate and current foreign real output but also on their expected values next period. More specifically, the difference between real output in the current period and expected real output in the next period depends on the difference between the real exchange rate in the current period and the expected real exchange rate in the next period. Exactly the same pattern governs the response of real output to variations in foreign real output. The standard real interest rate channel is defined in terms of expected CPI inflation.

It is common to interpret as reflecting the degree of openness of the economy. All structural coefficients of the IS equation are thus very sensitive to the degree of openness of the economy.

Phillips curve

Monopolistically competitive firms aim to minimize menu costs weighed against the cost of being away from the optimal price they would charge in the absence of those menu costs. This optimal price is denoted p^{OPT}. As shown below, the price setting behavior in the open economy differs from the domestic context in one critical way: the optimal price that firms strive to attain responds to competitive pressure abroad. The objective function faced by the typical firm is:

$$\min_{P} \Omega_t = E_t \sum_{\tau=t}^{\infty} \delta^{\tau-t} \left[\left(p_\tau - p_\tau^{OPT}\right)^2 + c\left(p_\tau - p_{\tau-1}\right)^2 \right] \qquad (2.15)$$

where:[3]
Ω_t is the total cost at time t
p_t is the natural logarithm of the price of the domestic good at time t
p^{OPT} is the natural logarithm of the optimal price a firm charges.
δ is the constant discount factor
c is the parameter that measures the ratio of the costs of changing prices to the costs of being away from the optimal price
E_t is the expectations operator conditional on information available at time t.

[3] For convenience we drop the superscript ("h") on domestic prices.

After taking and rearranging the first-order condition for the above cost-minimization problem (where we have assumed δ to equal one for simplicity), we can characterize the relationship between past, current, and future price levels as:

$$p_t - p_{t-1} = E_t(p_{t+1} - p_t) - \frac{1}{c}\left(p_t - p_t^{OPT}\right) \tag{2.16}$$

Next we specify the optimal price p^{OPT} as

$$p_t^{OPT} = \hat{p}_t + \tau y_t + \varsigma_t \qquad \tau > 0 \tag{2.17}$$

where all variables are as previously defined. In addition:

$\hat{p}_t$ is the natural logarithm of the price charged by foreign firms at time t
ς_t is a stochastic disturbance.

The optimal price responds to changes in marginal cost. But marginal cost and real output are positively related.[4] Hence is innocuous to replace marginal cost with the output gap in (2.17).

So far our analysis of price-setting behavior has been very much in the spirit of the closed economy "New Keynesian Framework". In a small open economy, however, the price-setting behavior of domestic firms also takes into consideration developments abroad. Being a small player in world markets, the typical firm is guided in its pricing decision by the prevailing conditions in world markets. More specifically, there exists a benchmark price $\hat{p}_t$ that the firm faces in world markets. This benchmark price affects the optimal price charged by the firm. Indeed, the firm adjusts its optimal price in line with the domestic currency price of the final goods charged by its foreign competitors. Thus $\hat{p}_t$ becomes:

$$\hat{p}_t = p_t^f + s_t \tag{2.18}$$

where:
p_t^f is the natural logarithm of the price of the foreign good in foreign currency at time t

Using this specification for p_t^{OPT}, we can rewrite equation (2.16) as:

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[4] On this point see Clarida, Gali, and Gertler (2001). For the purpose at hand, there is no need to model explicitly the determinants of marginal cost. What is important is that real output moves proportionately with marginal cost.

$$p_t - p_{t-1} - E_t(p_{t+1} - p_t) = -\frac{1}{c}(p_t - p_t^f - s_t - \varsigma_t) + \frac{\tau}{c} y_t \tag{2.19a}$$

If aggregated over all firms, equation (2.19) represents a Phillips Curve relation for an open economy. The same equation can also expressed as:

$$\pi_t = E_t \pi_{t+1} + a y_t + b q_t + u_t \tag{2.19b}$$

where

$\pi_t = p_t - p_{t-1}$

$E_t \pi_{t+1} = E_t p_{t+1} - p_t$

$q_t = p_t^f + s_t - p_t$

$a = \frac{\tau}{c}$

$b = \frac{1}{c}$

$u_t = \frac{1}{c} \varsigma_t$.

Equation (2.19b) differs from the standard forward-looking Phillips Curve by allowing the real exchange rate to affect domestic inflation directly. In the wake of a depreciation of the domestic currency, domestically produced goods become cheaper. Hence domestic production is stepped up. In addition, the domestic currency price of the imported foreign consumption good rises. Both the rise in domestic production and in the price of the import-competing good cause the optimal price to increase. Facing an increase in the optimal price, firms raise the price of their output so as to minimize the deviation between the actual price charged and the optimal price. At the aggregate level, the increase in the domestic price level causes the rate of domestic inflation to rise. Thus we observe the positive link between the real exchange rate and the rate of domestic inflation.

The complete model

The model that will serve as the foundation for the analysis of the monetary policy issues in Sections 3–8 comprises the following three equations:

$$y_t = E_t y_{t+1} - a_1(R_t - E_t \pi_{t+1}^{CPI}) + a_2(q_t - E_t q_{t+1}) + a_3(y_t^f - E_t y_{t+1}^f) + v_t \tag{2.14}$$

$$\pi_t = E_t \pi_{t+1} + a y_t + b q_t + u_t \tag{2.19b}$$

$$R_t - E_t\pi_{t+1} = R^f_t - E_t\pi^f_{t+1} + E_t q_{t+1} - q_t + \varepsilon_t \tag{2.20}$$

Equation (2.20) represents the uncovered interest rate parity condition. Stochastic disturbances have been added to the three relations to reflect the existence of uncertainty in the economy.[5] The time series properties of these disturbances will play a central role in our assessment of the different targeting regimes. In the case of persistence in the disturbances, the degree of persistence is the same for all disturbances and fixed at ρ. More formally,

$$\begin{aligned}
u_t &= \rho u_{t-1} + \hat{u}_t & \hat{u}_t &\sim N(0,\sigma^2_{\hat{u}}) \\
v_t &= \rho v_{t-1} + \hat{v}_t & \hat{v}_t &\sim N(0,\sigma^2_{\hat{v}}) \\
\varepsilon_t &= \rho \varepsilon_{t-1} + \hat{\varepsilon}_t & \hat{\varepsilon}_t &\sim N(0,\sigma^2_{\hat{u}}) \\
R^f_t &= \rho R^f_{t-1} + \hat{R}^f_t & \hat{R}^f_t &\sim N(0,\sigma^2_{\hat{R}^f}) \\
\pi^f_t &= \rho \pi^f_{t-1} + \hat{\pi}^f_t & \hat{\pi}^f_t &\sim N(0,\sigma^2_{\hat{\pi}^f}) \\
y^f_t &= \rho y^f_{t-1} + \hat{y}^f_t & \hat{y}^f_t &\sim N(0,\sigma^2_{\hat{y}^f})
\end{aligned} \tag{2.21}$$

3 Optimal discretionary policy: the case of flexible inflation targeting

Central to any discussion of the properties of different monetary policy strategies is the specification of the objective function that the policymaker faces. In the literature it is standard practice to assume that society delegates its preferences to the policymaker in the form of an objective function. We shall not adopt this convention in the current paper.[6] Instead we will specify an objective function for the policymaker that varies in accordance with the chosen strategy for monetary policy and the target variable for inflation.[7]

Unlike in the closed economy, in the open economy there is some leeway in the choice of the appropriate inflation target. Either domestic inflation or CPI inflation can be designated as the target variable for inflation. We will approach the issue of choosing the appropriate target rate of inflation in the following way.

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[5] R^f_t, y^f_t, and π^f_t are considered to be exogenous stochastic variables. The home country is too small to affect prices, interest rates, and real output abroad. For simplicity, we also assume that all foreign shocks are independent of each other.

[6] Blinder (1998, p. 6) goes as far as arguing that central bankers "must – in a figurative, not literal sense – create their own social welfare function based on their legal mandate, their own value judgments, and perhaps their readings of the political will."

[7] The discussion of the objective function for society at large is deferred until Section 6.

Assume a scenario where the central bank is given a broad mandate by society to ensure stability in inflation without causing unnecessary fluctuations in real output. In the absence of explicit instructions the central bank is free to decide on the choice of the appropriate inflation target. The central bank can thus base its optimal monetary policy strategy on either domestic inflation or CPI inflation. In order to make an informed decision about which rate of inflation to target, the central bank must carry out a comparative analysis of the costs and benefits of targeting domestic as opposed to CPI inflation.

To complete the design of its monetary policy strategy, the central bank is required to state its preferences as regards inflation and output variability. We envisage an environment where the central bank practices flexible inflation targeting as both the real output gap and inflation enter its objective function. There is increasing evidence that what central banks do in practice is aptly described by flexible inflation targeting.[8]

In the remainder of this section, we will investigate the properties of discretionary stabilization policy under flexible domestic and CPI inflation targeting.

3.1 Domestic inflation as a target in the objective function

The policymaker faces a standard objective function consisting of squared deviations of the real output gap and the rate of inflation, respectively. The rate of inflation is defined in terms of changes in the level of domestic prices. The explicit objective function that he attempts to minimize is given by

$$\frac{1}{2}E_t\left[\sum_{i=0}^{\infty}\beta^i[y_{t+i}^2+\mu\pi_{t+i}^2]\right] \tag{3.1}$$

All variables are as previously defined. β is the discount rate and μ represents the relative weight the policymaker attaches to the squared deviations of the rate of domestic inflation. Equation (3.1) implies that the policymaker's sole concern

[8] Consider, for instance, the most recent policy agreement reached by the Minister of Finance and the Governor of the Reserve Bank of New Zealand. It stipulates that inflation is to be targeted over the business cycle. The new arrangement provides the bank with more flexibility in setting the course of monetary policy and allows the bank to pay greater attention to the state of the real economy. A similar targeting strategy has been successfully employed by the Reserve Bank of Australia and the Bank of England since the early 1990s.

rests with real output and domestic inflation. Fluctuations in the real exchange rate do not enter explicitly the loss function.[9,10]

To set the stage for illustrating how discretionary policymaking in the open economy is carried out, it is helpful at the outset to reduce the dimension of the optimization problem to one involving only one constraint. A few simple steps need to be taken. First, we solve the UIP condition for the real exchange rate and substitute it into both the IS equation and the Phillips curve relation. Next, after substituting for the rate of CPI inflation in Equation (2.14), we solve the IS relation for the expected real rate of interest $(R_t - E_t\pi_{t+1})$.[11] Following this, we insert the expression for expected real rate of interest into the Phillips curve relation. The following expression results:

$$\begin{aligned}\pi_t &= \left(a + \frac{b}{a_1 + a_2^*}\right) y_t + E_t\pi_{t+1} \\ &+ \frac{b}{a_1 + a_2^*}\left[a_1(R_t^f - E_t\pi_{t+1}^f + \varepsilon_t) - (E_t y_{t+1} + v_t) - a_3(y_t^f - E_t y_{t+1}^f)\right] + bE_t q_{t+1} + u_t\end{aligned} \tag{3.2}$$

where $a_2^* = a_2 - \gamma a_1$.

When setting policy with discretion, the policymaker takes the expectations of the endogenous variables y_t, π_t, q_t and the remaining terms as given.[12] Hence we can rewrite the above as

$$\pi_t = \left(a + \frac{b}{a_1 + a_2^*}\right) y_t + f_t \tag{3.2'}$$

where

[9] Adopting equation (3.1) as the welfare criterion ignores the effects on welfare of changes in the real exchange rate in the open economy framework. Including only real output and the rate of inflation in the loss function is rather typical in the literature and thus facilitates comparing the results of this paper to earlier contributions (eg Clarida, Gali, and Gertler (1999, 2001) or Svensson (2000)).

[10] The target level for real output is the potential level of output. The target for the rate of inflation is assumed to be zero.

[11] Update Equation (2.4) by one period and take conditional expectations. To obtain $E_t\pi_{t+1}^{CPI}$ in terms of expected domestic inflation and the expected change in the real exchange rate, simply subtract Equation (2.4) from its conditional expectation and use the definition of the real exchange rate. See also Equations (3.5) and (3.6).

[12] Here we adopt the convention of describing the conduct of discretionary policy along the lines of Clarida, Gali, and Gertler (1999).

$$f_t = E_t\pi_{t+1} + \frac{b}{a_1 + a_2^*}\left[a_1(R_t^f - E_t\pi_{t+1}^f + \varepsilon_t) - (E_t y_{t+1} + v_t) - a_3(y_t^f - E_t y_{t+1}^f)\right] + bE_t q_{t+1} + u_t$$

Notice further that the objective function can be neatly broken up into two separate components as future values of the endogenous variables are independent of today's policy action:[13]

$$\frac{1}{2}[y_t^2 + \mu\pi_t^2] + F_t \tag{3.1'}$$

where $F_t = \frac{1}{2}E_t\left[\sum_{i=1}^{\infty}\beta^i(y_{t+i}^2 + \mu\pi_{t+i}^2)\right]$

The problem of setting policy under discretion thus reduces to the following simple one-period optimization problem:

$$\underset{y_t,\pi_t}{\text{Min}}\ \tfrac{1}{2}[y_t^2 + \mu\pi_t^2] + F_t \tag{3.3}$$

subject to

$$\pi_t = \left(a + \frac{b}{a_1 + a_2^*}\right)y_t + f_t$$

Replacing a_2^* with $a_2 - \gamma a_1$ and combining the first-order conditions produces a systematic negative relationship between real output and the rate of inflation:

$$y_t = -\mu\left(a + \frac{b}{a_1(1-\gamma) + a_2}\right)\pi_t \tag{3.4}$$

The coefficient on the rate of inflation indicates the loss of output that the policymaker is prepared to sustain if the rate of inflation exceeds its zero target level.

What is striking about the above optimizing condition is the relationship between the degree of openness (γ) and the sensitivity of domestic inflation to the real exchange rate in the Phillips Curve (b). The degree of openness matters only to the extent that the direct exchange rate channel is operative in the Phillips Curve. In case this channel is absent from the Phillips Curve, ie if b=0, then the optimal relationship between real output and the rate of inflation is independent of

[13] Future values of y_t and π_t are not affected by policy today as the effect of policy is contemporaneous and the absence of persistence in the endogenous variables.

γ and the same for both the open and the closed economy framework: $-\mu a$.[14] There is a straightforward explanation for this result. Shutting off the direct exchange rate channel in the Phillips Curve enables the policymaker to offset any disturbances arising on the demand side of the economy by simply adjusting the setting of the policy instrument. Thus, demand-side factors should not have any role to play in the determination of the optimal relationship between real output and the rate of inflation. The degree of openness is, however, a characteristic of the demand-side of the economy as it denotes the share of the imported foreign consumption good in total consumption. Thus, if the policymaker is in a position to offset any demand-side disturbance, then γ should not matter in the determination of the optimizing condition.

In the more likely case of $b > 0$, the optimality condition depends on *all* parameters – except a_3 – of the model.[15]

There are two further noteworthy results. The first result is related to the stabilizing properties of optimal discretionary policymaking in the current open economy framework.[16] The second result pertains to the nature of the stochastic disturbances that hit the economy.

Combining the above optimizing condition with the Phillips Curve, the IS, and the UIP relation allows us to solve for the reduced form equations and the variances of the endogenous variables that appear in the policymaker's loss function. We solve the model under the assumption that all stochastic disturbances follow autoregressive processes with the degree of persistence for all shocks being the same and denoted by ρ. In addition, we also present the case where all shocks are white noise.

The two expected loss functions under a domestic inflation objective appear in Table 1. We observe that the perfect stabilizing property of optimal discretionary policymaking in the face of demand-side disturbances that is typically found in models of both open and closed economies does not carry over to the present framework. In the face of demand-side disturbances (v_t, y_t^f), a UIP disturbance (ε_t), and a foreign interest rate disturbance (R_t^f), the policymaker is unable to keep the real output gap and the rate of inflation at their respective

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[14] This is rather unlikely though as $b = \frac{1}{c}$. Thus c would have to become infinitely large for b to approach zero.

[15] The optimizing condition can be written in terms of all deep parameters of the model:

$$y_t = -\frac{\mu}{c}\left[\tau + \frac{1}{(1-\gamma)^2\sigma + \gamma((1-\gamma)\eta + \gamma^f\eta^f)}\right]\pi_t,$$ where all parameters are as previously defined.

[16] This result also carries over to the case of policymaking under commitment albeit in slightly different form.

Table 1. **Domestic inflation as the target variable in the objective function**

Flexible Domestic Inflation Targeting: $\mu = 1;\ \pi^* = 0$	
White Noise Disturbances $(\rho = 0)$	$E(L_t) = \frac{b^2}{(b+aA)^2 + A^2}\left[\sigma_{\hat{v}}^2 + a_1^2\left(\sigma_{R\hat{f}}^2 + \sigma_{\hat{\varepsilon}}^2\right) + \left(\frac{A}{b}\right)^2 \sigma_{\hat{u}}^2 + a_3^2\sigma_{y\hat{f}}^2\right]$
AR(1) Disturbances $(\rho > 0)$	$E(L_t) = \left[\frac{(b+aA)^2 + A^2}{(1-\rho^2)}\right]\frac{b^2}{\left[(b+aA)^2 + A^2(1-\rho)\right]^2}\left[\left(\frac{1}{1-\rho}\right)^2\left(\sigma_{\hat{v}}^2 + a_1^2\left(\sigma_{R\hat{f}}^2 + \sigma_{\hat{\varepsilon}}^2 + \rho^2\sigma_{\pi\hat{f}}^2\right)\right) + \left(\frac{A}{b}\right)^2 \sigma_{\hat{u}}^2 + a_3^2\sigma_{y\hat{f}}^2\right]$ or for future reference: $E(L_t) = \frac{\Lambda^2}{1-\rho^2}\left[\frac{(b+aA)^2\left((b+aA)^2 + A^2\right)}{\left((b+aA)^2 + A^2(1-\rho)\right)^2}\right]\left[\left(\frac{1}{1-\rho}\right)^2\left(\sigma_{\hat{v}}^2 + a_1^2\left(\sigma_{R\hat{f}}^2 + \sigma_{\hat{\varepsilon}}^2 + \rho^2\sigma_{\pi\hat{f}}^2\right)\right) + \left(\frac{A}{b}\right)^2 \sigma_{\hat{u}}^2 + a_3^2\sigma_{y\hat{f}}^2\right]$

$A = (1-\gamma)a_1 + a_2$

$\Lambda = \frac{b}{b+aA}$

target. If all disturbances are autocorrelated, then a foreign inflation shock will also cause the targets for output and inflation to be missed. In his attempt to offset the impact of any one of the aforementioned disturbances on real output by varying the nominal interest rate, the policymaker causes the real exchange rate to change. The change in the real exchange rate in turn directly affects the domestic rate of inflation in the Phillips Curve. Thus the policymaker sees himself confronted with changes in both the rate of inflation and real output. Inspection of the numerators of the coefficients of the variances of IS, UIP, and foreign interest rate disturbances (and foreign inflation shocks if the disturbances are persistent) reveals that the magnitude of b, which captures the potency of the direct exchange rate channel in the Phillips Curve, is instrumental in transmitting the effects of these disturbances on both real output and the rate of inflation. In short, all disturbances that impinge upon the economy – not just cost-push disturbances – cause the rate of inflation and real output to deviate from their respective target and hence cause the variances of both variables to increase if a direct exchange rate channel is operative in the Phillips Curve.

Examining the loss function for the case of AR(1) disturbances, we find that it is positively related to the size of the persistence parameter ρ. Again there is a straightforward explanation for this positive relationship. The greater the degree of persistence in the disturbances, the more closely the current expectations of future values of both endogenous (and exogenous variables) follow their current values. This property in turn implies that current real output and the rate of domestic inflation react more sensitively to the disturbances that impinge upon the economy. Hence both variables have a tendency to deviate more from their target values, causing their respective variance to increase. What is striking, however, is that the origin of a particular disturbance is crucial in determining the extent to which the loss function increases as the degree of persistence in the shocks increases. Closer inspection reveals that the loss function increases dramatically as persistence increases because the increase in persistence augments the effects of the variances of IS, foreign interest rate disturbances, UIP disturbances, and shocks to foreign inflation. The variances of all these shocks – but not the variances of cost-push shocks and foreign output shocks – are multiplied by the factor $\left(\frac{1}{1-\rho}\right)^2$. For comparatively high values of ρ this factor tends to become rather large. Thus in the face of rather persistent shocks we should expect to find huge differences in the numerical score of the loss function compared to the case of white noise disturbances.

3.2 CPI inflation as a target in the objective function

Most central banks aim at ensuring stability in the rate of CPI inflation. Indeed, the performance of central banks is judged in general on the basis of their ability to keep the rate of CPI inflation within tolerable bounds.[17] Thus, a case can be made for the CPI inflation rate to appear as a target variable in the objective function.

The rate of inflation is now defined in terms of changes in the level of the consumer price index:

$$\pi_t^{CPI} = (1-\gamma)\pi_t + \gamma(s_t - s_{t-1} + \pi_t^f) \tag{3.5}$$

Given the definition of the real exchange rate (q_t) and the assumption of complete exchange rate pass-through, the above can be restated as:

$$\pi_t^{CPI} = \pi_t + \gamma\Delta q_t \tag{3.6}$$

In view of the fact that the policymaker is concerned about stabilizing the rate of CPI inflation, it is necessary to recast the model of the economy in terms of the rate of CPI inflation. This is accomplished by solving the above definition of the rate of CPI inflation for π_t and substituting the right-hand side of this expression for π_t in both the Phillips Curve and the uncovered interest rate parity condition. The amended equations take the following form:

$$\pi_t^{CPI} = E_t\pi_{t+1}^{CPI} + (2\gamma + b)q_t - \gamma E_t q_{t+1} - \gamma q_{t-1} + ay_t + u_t \tag{3.7}$$

$$R_t - E_t\pi_{t+1}^{CPI} = R_t^f - E_t\pi_{t+1}^f + (1-\gamma)(E_t q_{t+1} - q_t) + \varepsilon_t \tag{3.8}$$

The IS relation remains unchanged:

$$y_t = E_t y_{t+1} - a_1(R_t - E_t\pi_{t+1}^{CPI}) + a_2(q_t - E_t q_{t+1}) + a_3(y_t^f - E_t y_{t+1}^f) + v_t \tag{2.14}$$

Again, the first step of the optimization routine is to reduce the dimension of the problem. This is accomplished by following the same procedure as outlined in Section 3.1. With the rate of CPI inflation rate entering the objective function, the minimization exercise that the policymaker undertakes can be stated formally as:

[17] See Siklos (1999) for a detailed description of the various ways in which central banks are held accountable for their policy actions.

$$\underset{y,\pi^{CPI}}{\text{Min}}\ \frac{1}{2}E_t\left[\sum_{i=0}^{\infty}\beta^i[y_{t+i}^2+\mu\pi^{CPI}{}_{t+i}^{2}]\right] \tag{3.9}$$

subject to

$$\pi_t^{CPI}=\left[a+\frac{2\gamma+b}{a_1(1-\gamma)+a_2}\right]y_t+f_t$$

where

$$\begin{aligned}f_t &= E_t\pi_{t+1}^{CPI}+u_t-\gamma q_{t-1}+(\gamma+b)E_t q_{t+1}\\ &\quad+\left[\frac{2\gamma+b}{a_1(1-\gamma)+a_2}\right]\left[a_1 Z_t-(E_t y_{t+1}+a_3(y_t^f-E_t y_{t+1}^f)+v_t)\right]\end{aligned}$$

and

$$Z_t=(R_t^f-E_t\pi_{t+1}^f+\varepsilon_t)$$

The minimization exercise gives rise to two first-order conditions. Combining these first-order conditions establishes the following optimal systematic relationship between the rate of CPI inflation and real output:

$$y_t=-\mu\left(a+\frac{b+2\gamma}{a_1(1-\gamma)+a_2}\right)\pi_t^{CPI} \tag{3.10}$$

Comparing the coefficient on CPI inflation in Equation (3.10) to the coefficient on domestic inflation in Equation (3.4), we observe that, ceteris paribus, the size of the former exceeds that of the latter. A one percentage point increase in CPI inflation evokes a greater negative response in real output than a one percentage point increase in domestic inflation. This is an important result as it foreshadows that focusing on CPI inflation as opposed to domestic inflation is associated with greater fluctuations in real output.

Owing to the appearance of a lagged endogenous variable in the model (q_{t-1}), analytical solutions for the endogenous variables are difficult to establish in the current context.[18] Nevertheless it is evident that the perfect stabilizing properties of optimal discretionary policy fail to hold in the present case just as they fail

[18] Due to the presence of a lagged endogenous variable (q_{t-1}), the current expectations of all endogenous variables for period t+1 depend on q_t. This fact complicates the derivation of analytical solutions immensely.

when the policymaker targets domestic inflation. Indeed, inspection of Equation (3.10) reveals that the focus on CPI inflation deprives the policymaker of his ability to insulate the economy against demand-side disturbances even if the direct exchange rate channel is shut off. Even if $b = 0$, demand-side parameters are involved in determining the optimizing condition adhered to by the policymaker.

To get a more concrete idea about the implications of selecting domestic as opposed to CPI inflation as a choice variable in the optimization problem faced by policymaker, we will resort to employing a numerical solution technique. With the help of this tool we will evaluate the behavior of the endogenous variables, the policy instrument, and the loss function for the two policy problems. The results of this exercise are discussed in the next section.

4 Applying the numerical solution technique to the optimal policy problem under flexible inflation targeting: A domestic inflation versus a CPI inflation target[19]

To understand the consequences of framing monetary policy in terms of a domestic inflation objective or a CPI inflation objective, it is essential to track the behavior of the variables that the policymaker cares about. For the sake of completeness and for the simple reason that the behavior of other variables may be of interest to the policymaker, too, even if these variables do not figure directly in the objective function, we examine the behavior of all endogenous variables of the model as well as the policy instrument. This is done against the backdrop of varying assumptions about two factors that may influence the choice of a particular rate of inflation as a policy objective. The first factor is the degree of openness of the economy. As shown in Section 2, the degree of openness is instrumental in determining the response of real output to the expected real rate of interest, expected changes in the real exchange rate and expected changes in demand abroad. In addition, the degree of openness is an important factor in pinning down the systematic relationship between real output and the rate of inflation in the optimizing condition. The second factor is the temporal property of the shocks that hit the economy. The two cases considered are white noise disturbances and persistent disturbances. Throughout the analysis the following values of the parameters and the variances of the stochastic disturbances are employed:

[19] This section draws on Dennis (2001) who has written an algorithm that produces numerical solutions to the optimization problem under discretion. The algorithm has been adapted to fit the models described in Sections 3.1. and 3.2.

$\sigma = 0.5$	$\eta = 1$	$\eta^f = 2$	$\gamma^f = 0.15$	$\beta^f = 0.9$	$\rho = 0.8$
$a = 0.25$	$b = 0.25$	$\mu = 1$	$\sigma_1^2 = 1$ for	$i = \hat{u}, \hat{v}, \hat{\varepsilon}, \hat{R}^f, \hat{\pi}^f, \hat{y}^f$	

The unitary weight on inflation represents the operational definition of flexible inflation targeting employed in this paper.

In the case of persistence in the disturbances, the degree of persistence is the same for all disturbances and fixed at $\rho = 0.8$.

The first step of the solution procedure is to rewrite the model in the following form:

$$\mathbf{A}_0\mathbf{Y_t} = \mathbf{A}_1\mathbf{Y}_{\mathbf{t}-1} + \mathbf{A}_2\mathbf{E_t}\mathbf{Y}_{\mathbf{t}+1} + \mathbf{A}_3\mathbf{R_t} + \mathbf{A}_4\mathbf{E_t}\mathbf{R}_{\mathbf{t}+1} + \mathbf{A}_5\mathbf{V_t} \tag{4.1}$$

$\mathbf{Y_t}$ = vector of endogenous variables in period t.
$\mathbf{Y}_{\mathbf{t}-1}$ = vector of lagged endogenous variables.
$\mathbf{E_t Y}_{\mathbf{t}+1}$ = vector of expectations of endogenous variables in period t+1.
$\mathbf{R_t}$ = policy instrument in period t (*scalar*).
$\mathbf{E_t R}_{\mathbf{t}+1}$ = expected setting of policy instrument in period t+1 (*scalar*).[20]
$\mathbf{V_t}$ = vector of stochastic disturbances of the model.
$\mathbf{A_j}$ = coefficient matrices, j = 1,…5.

Solving the model for the endogenous variables produces solutions that depend on the lagged endogenous variables and the exogenous disturbances:

$$\mathbf{Y_t} = \mathbf{H}_1\mathbf{Y}_{\mathbf{t}-1} + \mathbf{H}_2\mathbf{V_t} \tag{4.2}$$

$\mathbf{H_j}$ = coefficient matrices, j = 1, 2.

The solution for the policy instrument also depends on the vector of lagged endogenous variables and the exogenous disturbances:

$$\mathbf{X_t} = \mathbf{F}_1\mathbf{Y}_{\mathbf{t}-1} + \mathbf{F}_2\mathbf{V_t} \tag{4.3}$$

$\mathbf{F_j}$ = coefficient matrices, j = 1, 2.

The variances of the endogenous variables and the policy instrument are the diagonal elements of the respective variance and covariance matrix:

$$\mathbf{\Phi Y} = \mathbf{E}\left[\mathbf{Y_t Y_t'}\right] \tag{4.4}$$

[20] This scalar is irrelevant in the current context. Hence its coefficient matrix ($\mathbf{A}_4$) consists of zeros only.

$$\mathbf{\Phi X} = \mathbf{E}\left[\mathbf{X_t X_t'}\right] \tag{4.5}$$

The algorithm described in the preceding paragraphs is applied first to the model of Section 3.1 where the policymaker targets domestic inflation and then to the model of Section 3.2 where he targets CPI inflation. In each case we examine the sensitivity of the variances of the variables of the model to the specification of the disturbances that impinge upon the economy: a distinction is made between the stochastic disturbances following a white noise process and an autoregressive process. Throughout the analysis the only structural parameter that is allowed to vary is the degree of openness.

The presentation of the findings proceeds in two stages. In the first stage we present the comprehensive findings in numerical form, arrayed in tables. In the second stage, we use graphs to track the behavior of the two rates of inflation and real output under varying assumptions about the policy objectives and temporal properties of the stochastic disturbances. Graphs are also used to capture the extent to which the variances of the real exchange rate and the nominal rate of interest fluctuate.

The variances of the endogenous variables and the policy instrument for the case where the policymaker targets domestic inflation appear in Table 2.[21] All stochastic disturbances follow white-noise processes. As the degree of openness increases from 0.1 to 0.9:

– the variance of domestic inflation decreases steadily except for $\gamma = 0.2$
– the variance of real output decreases initially but then increases starting with $\gamma = 0.4$
– the variance of the real exchange rate declines initially but then increases at increasing rates at $\gamma = 0.4$
– the variance of CPI inflation and the variance of the nominal interest rate, respectively, steadily increases at an increasing rate
– the numerical score of the loss function initially rises, then declines, only to rise again at $\gamma = 0.5$

Table 3 presents the findings for the case when the policymaker targets CPI inflation. All stochastic disturbances follow white noise processes. As the degree of openness increases from 0.1 to 0.9:

– the variance of domestic inflation declines initially before it begins to rise at $\gamma = 0.5$

[21] As $\beta \rightarrow 1$, the standard discounted quadratic objective function can be expressed as a linear combination of the variances of the variables that appear in the objective function. See the appendix to Dennis (2001) for further details.

– the variance of real output rises throughout while the variance of the real exchange rate decreases throughout
– the variance of CPI inflation decreases at a decreasing rate
– the variance of the policy instrument decreases initially before it begins to rise at $\gamma = 0.5$
– the numerical losses rise throughout.

Several findings deserve mentioning. Except for $\gamma = 0.1$ the variance of CPI inflation is always lower than the variance of domestic inflation under CPI inflation targeting.[22] Also, the variance of domestic inflation is now somewhat lower than in Table 2. Thus, framing the inflation objective in terms of the CPI buys not only much lower variability in the CPI but also in the rate of domestic inflation. It appears that with increasing openness the policymaker can progressively reduce the variability of the CPI inflation rate but only at the cost of substantial increases in the variability of real output. The dramatic reduction in the variance of the real exchange rate and the relative stability of the variance of the policy instrument are additional benefits of concentrating on the rate of CPI inflation. Both the real exchange rate and the nominal rate of interest tend to fluctuate enormously if domestic inflation figures as a policy objective. Nevertheless, for the chosen weight on the variance of inflation ($\mu = 1$), focusing on the rate of domestic inflation leads to lower losses as the comparison of the final columns of Tables 2 and 3 reveals.

Tables 4 and 5 contain the findings for the case where the disturbances exhibit persistence. Not surprisingly, the variances of the variables are much larger if shocks exhibit persistence than if shocks follow white noise processes. Table 4 contains the variances of the variables when the policymaker cares about the rate of domestic inflation. As the rate of openness increases:

– the variance of domestic inflation decreases throughout.
– the variance of real output decreases initially before increasing at $\gamma = 0.6$.
– the variance of the real exchange rate decreases at the outset but then increases starting with $\gamma = 0.7$.
– the variance of CPI inflation increases throughout while the variance of the nominal rate of interest decreases throughout.
– the loss function decreases for all values of γ but $\gamma = 0.9$.

[22] This implies that the covariance between the rate of domestic inflation and the change in the real exchange rate is negative.

Table 2. **The variances of the endogenous variables and the policy instrument under flexible inflation targeting: The policymaker targets domestic inflation**

Case I: All shocks are white noise

γ	$V(\pi_t)$	$V(y_t)$	$V(q_t)$	$V(\pi_t^{CPI})$	$V(R_t)$	$E(L) = V(y_t) + \mu V(\pi_t)$
0.1	0.5560	0.2985	3.888	0.6550	3.236	0.8545
0.2	0.5669	0.2882	3.596	0.8627	3.282	0.8552
0.3	0.5660	0.2843	3.474	1.193	3.460	0.8502
0.4	0.5629	0.2861	3.507	1.686	3.771	0.8491
0.5	0.5577	0.2941	3.702	2.426	4.229	0.8518
0.6	0.5500	0.3094	4.090	3.558	4.875	0.8594
0.7	0.5396	0.3347	4.731	5.337	5.778	0.8743
0.8	0.5257	0.3756	5.731	8.204	7.058	0.9012
0.9	0.5066	0.4428	7.271	12.945	8.911	0.9494

Table 3. **The variances of the endogenous variables and the policy instrument under flexible inflation targeting: The policymaker targets CPI inflation**

Case I: All shocks are white noise

γ	$V(\pi_t)$	$V(y_t)$	$V(q_t)$	$V(\pi_t^{CPI})$	$V(R_t)$	$E(L) = V(y_t) + \mu V(\pi_t^{CPI})$
0.1	0.4583	0.4499	2.881	0.4600	2.342	0.9099
0.2	0.4050	0.5771	2.037	0.3718	2.006	0.9489
0.3	0.3837	0.6832	1.527	0.3010	1.934	0.9841
0.4	0.3777	0.7794	1.212	0.2433	1.940	1.023
0.5	0.3802	0.8757	1.006	0.1962	1.961	1.072
0.6	0.3883	0.9806	0.8651	0.1572	1.980	1.138
0.7	0.4008	1.101	0.7645	0.1240	1.993	1.225
0.8	0.4171	1.243	0.6898	0.0952	1.999	1.339
0.9	0.4376	1.411	0.6324	0.0696	2.001	1.481

Table 4. **The variances of the endogenous variables and the policy instrument under flexible inflation targeting: The policymaker targets domestic inflation**

Case II: All shocks are autocorrelated: $\rho = 0.8$.

γ	$V(\pi_t)$	$V(y_t)$	$V(q_t)$	$V(\pi_t^{CPI})$	$V(R_t)$	$E(L) = V(y_t) + \mu V(\pi_t)$
0.1	50.938	26.862	116.463	53.902	35.293	77.800
0.2	47.774	24.284	106.334	54.002	33.589	72.058
0.3	44.929	22.567	98.972	54.727	31.772	67.495
0.4	42.406	21.556	94.049	56.181	29.877	63.962
0.5	40.168	21.183	91.378	58.512	27.906	61.351
0.6	38.140	21.454	90.902	61.921	25.837	59.593
0.7	36.199	22.456	92.680	66.663	23.629	58.655
0.8	34.134	24.386	96.857	73.012	21.219	58.521
0.9	31.574	27.599	103.587	81.132	18.525	59.173

Table 5. **The variances of the endogenous variables and the policy instrument under flexible inflation targeting: The policymaker targets CPI inflation**
Case II: All shocks are autocorrelated: $\rho = 0.8$

γ	$V(\pi_t)$	$V(y_t)$	$V(q_t)$	$V(\pi_t^{CPI})$	$V(R_t)$	$E(L) = V(y_t) + \mu V(\pi_t^{CPI})$
0.1	41.081	30.834	102.396	43.225	34.505	74.059
0.2	31.411	31.604	83.059	34.631	31.866	66.235
0.3	24.405	32.563	69.471	28.021	28.912	60.583
0.4	19.206	33.689	59.786	22.804	25.846	56.493
0.5	15.246	35.049	52.823	18.566	22.816	53.615
0.6	12.164	36.744	47.838	15.032	19.903	51.776
0.7	9.733	38.902	44.355	12.010	17.151	50.912
0.8	7.813	41.680	42.064	9.367	14.593	51.047
0.9	6.329	45.274	40.759	7.006	12.261	52.279

Table 5 provides feedback on the size of the variances if the policymaker cares about CPI inflation. As the degree of openness increases:

– the variance of domestic inflation decreases throughout.
– the variance of real output increases throughout.
– the variance of the real exchange rate decreases throughout.
– the variance of CPI inflation decreases throughout.
– the variance of the nominal rate of interest decreases throughout.
– the loss function decreases for all values of γ except for $\gamma = 0.9$.

The variances of all variables except real output decrease as openness increases. Notice that the variance of CPI inflation exceeds the variance of domestic inflation for all values of γ.

Comparing the contents of Tables 4 and 5 shows once again that focusing on the rate of CPI inflation results in lower variability of the rate of CPI inflation itself as well as lower variability of the rate of domestic inflation, the real exchange rate, and the policy instrument. However, there is a cost in the form of much greater variability of real output. Nevertheless, the sizeable fluctuations in real output are not sufficient for the loss function of Table 5 to exceed its counterpart in Table 4.

We now turn to a visual inspection of the variability of real output and the two rates of inflation. Figure 1 tracks the behavior of the variances of the variables in question under domestic inflation and for white noise disturbances. The degree of openness does not materially affect the extent of fluctuations of domestic inflation and real output. However, greater openness causes the variance of CPI inflation to shoot up, ever widening the gap between the variances of CPI and domestic inflation. Figure 3 presents a sharp contrast to Figure 1. It represents the case where the policymaker pays attention to CPI inflation and where all shocks are white noise disturbances. Here we observe the gap between the variance of CPI inflation and domestic inflation widening as well. However, CPI inflation variability is now increasingly less than domestic inflation variability. Notice that as the economy becomes more open, both rates of inflation remain well under control while fluctuations in real output increase dramatically.

Figure 5 illustrates the case of flexible domestic inflation targeting in the presence of AR(1) disturbances. Both the variance of domestic inflation and the variance of real output actually decline initially as γ increases. At higher values of γ the variance of domestic inflation continues to decrease while the variance of real output begins to increase. As is the case for white noise disturbances, the variance of real output is always less than the variance of domestic inflation. Again, the variance of CPI inflation is always greater than the variance of domestic inflation; the gap between the two variances widens as γ increases.

When the policymaker targets CPI inflation and the disturbances are AR(1) processes, he succeeds in increasingly mitigating fluctuations in both CPI inflation and domestic inflation as the degree of openness rises. But there is a substantial cost. For $\gamma \geq 0.2$. the variance of real output lies above the variance of CPI inflation and keeps on rising as the economy becomes more open. This case is illustrated in Figure 7. Notice also that the variance of domestic inflation is always lower than the variance of CPI inflation.

Figures 2, 4, 6, and 8 capture the behavior of the real exchange rate and the nominal rate of interest under the varying policy objectives and assumptions about the temporal properties of the stochastic disturbances. Analyzing the case of white noise disturbances depicted by Figures 2 and 4, we find that both the variances of the real exchange rate and the nominal rate of interest are smaller if the policymaker's attention rests on the CPI inflation rate. Notice also that the variances of both variables increase in line with the degree of openness in Figure 2 while the opposite holds in Figure 4. A most dramatic difference between the variances of the real exchange rate and the policy instrument is depicted by Figure 6. There we observe that the variance of the real exchange rate is more than three times the size of the variance of the policy instrument. If disturbances are autocorrelated, attention to minimizing fluctuations in the domestic rate of inflation can thus result in dramatic swings in the real exchange rate. This problem can be eased somewhat by the policymaker if he focuses his attention on CPI inflation. Figure 8 illustrates this case. The variability of the nominal rate of interest and in particular the variability of the real exchange rate are lower than in Figure 6. Finally, for AR(1) disturbances we find the variance of the nominal rate of interest declining throughout as the degree of openness increases irrespective of which rate of inflation is chosen as a target variable. In contrast, the variance of the real exchange decreases monotonically as γ increases only if the policymaker targets CPI inflation.

Figure 1. **The variances of inflation and real output: Dom. inflation in objective function and white noise disturbances**

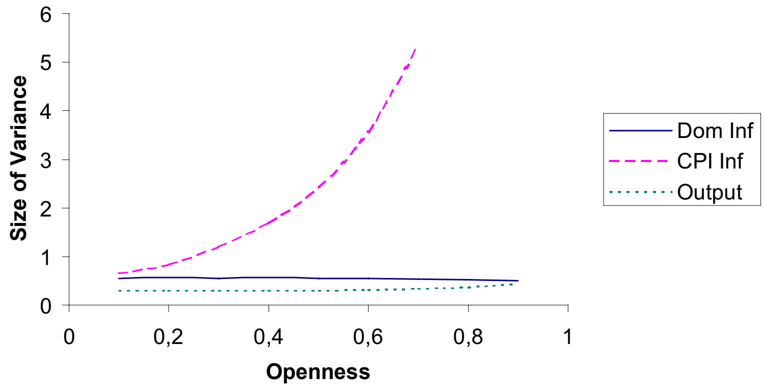


Figure 2. **The variances of the real exchange rate and the nom. rate of interest: domestic inflation in objective function and white noise disturbances**

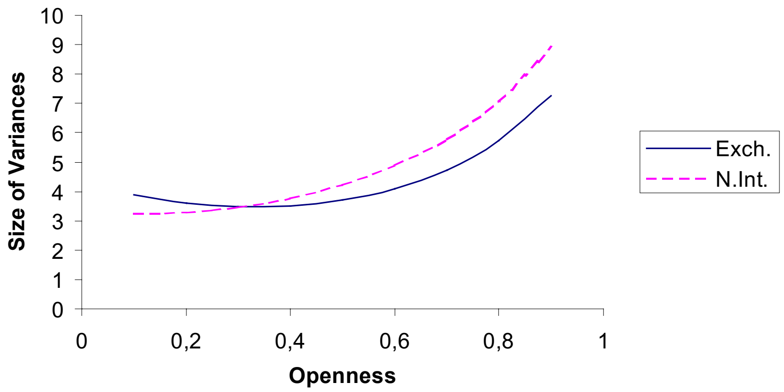


Figure 3. **The variances of inflation and real output: CPI inflation in objective function and white noise disturbances**

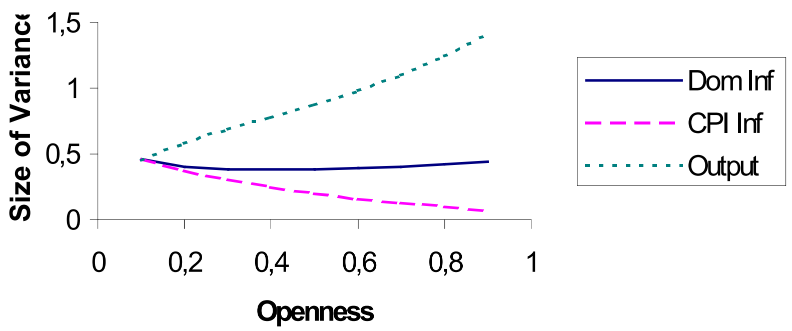


Figure 4. **The variance of the real exchange rate and the nom. rate of interest: CPI inflation in objective function and white noise disturbances**

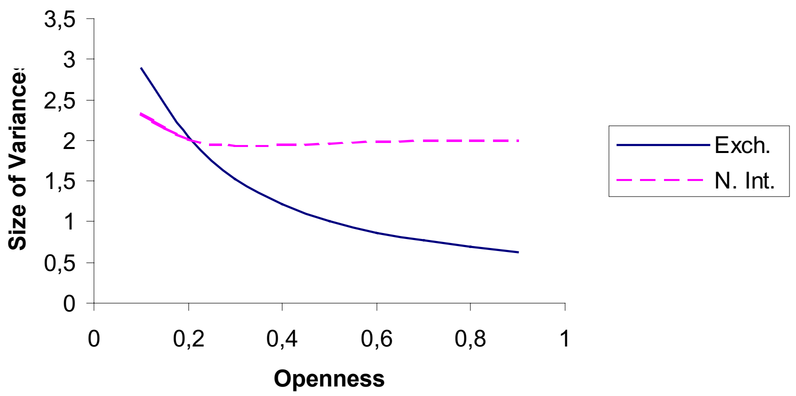


Figure 5. **The variances of inflation and real output: dom. inflation in objective function and AR(1) disturbances**

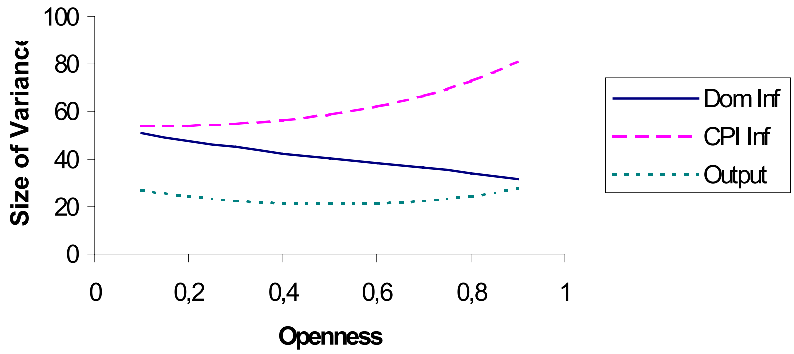


Figure 6. **The variances of the real exchange rate and the nom. rate of interest: dom. inflation in objective function and AR(1) disturbances**

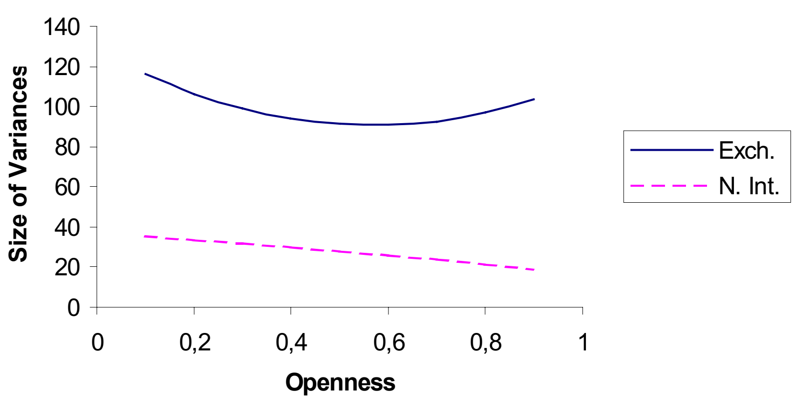


Figure 7. **The variances of inflation and real output: CPI inflation in objective function and AR(1) disturbances**

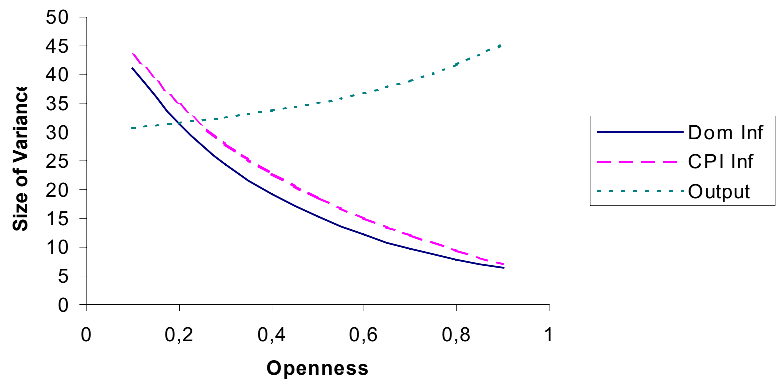
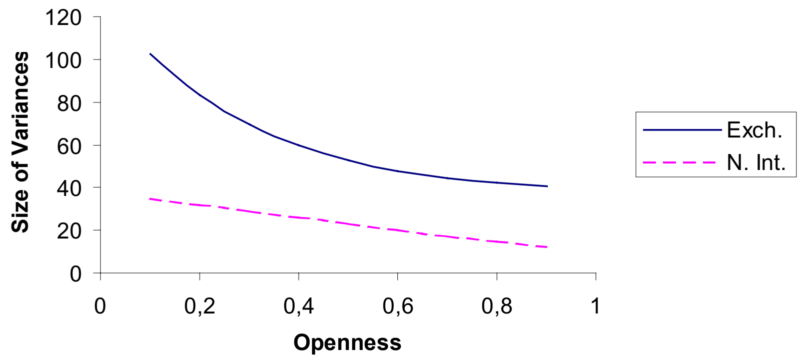


Figure 8. **The variances of the real exchange rate and the nom. rate of interest: CPI inflation in objective function and AR(1) disturbances**



5 Strict inflation targeting regimes

In the preceding section, we evaluated the implications of specifying the inflation target in terms of the rate of domestic inflation as opposed to the rate of CPI inflation for the endogenous variables of the model and for the policy instrument. In doing so, we made the critical assumption that the policymaker cares equally about the squared deviations of real output and the rate of inflation from their respective target. In this section, our attention will focus on an extreme case of optimal policy: strict inflation targeting. Under this regime the policymaker lets the relative weight on inflation in the loss function approach infinity with a view towards keeping the rate of inflation at its zero target level. While the obvious benefit of strict inflation targeting is the attainment of the zero inflation objective, the obvious cost lies in the increased variability of real output.

As in the standard case of flexible inflation targeting (where μ=1), the policymaker has a choice of defining the strict inflation target (where $\mu \rightarrow \infty$) in terms of the percentage change of the domestic price level or the percentage change of the CPI. We begin our discussion of strict inflation targeting by analyzing the case of domestic inflation targeting under the assumption of white noise and autoregressive disturbances. A similar analytical exercise is undertaken for the case of strict CPI inflation targeting but only for white noise disturbances.

The top panel of Table 6 presents the analytical findings for the scenario where the policymaker pursues a strict domestic inflation target. The first row lists the expected loss function under the assumption of white noise disturbances while the second row contains the expected loss function for AR(1) disturbances. As is the case under flexible inflation targeting, we find that under strict inflation targeting and AR(1) disturbances, pronounced persistence in the disturbances causes expected losses to snowball thanks to the magnified effect exercised by the variances of shocks that impact on the IS relation directly or indirectly: $\sigma^2_{\hat{v}}$, $\sigma^2_{\hat{R}f}$, $\sigma^2_{\hat{\varepsilon}}$, $\sigma^2_{\hat{\pi}f}$.

The results associated with strict CPI inflation targeting are arranged in the bottom panel of Table 6. A tractable solution exists only for the case of white noise disturbances. Interpreting the behavior of the variance of real output under strict CPI targeting becomes rather difficult in light of the complexity of the coefficients, in particular on the variances of the shocks that impinge directly or indirectly on the IS relation. What becomes immediately obvious, however, is the fact that under strict CPI targeting, the parameter b does not play as critical a role in stabilizing the economy as under strict domestic inflation targeting. Even if the direct exchange rate channel is absent from the Phillips Curve, demand-side disturbances, exchange rate shocks, and foreign disturbances will affect real output. As foreshadowed by the optimizing condition (Equation 3.10) under flexible inflation targeting, the term b+2γ is instrumental in determining the stabilizing properties of strict CPI targeting, too.

Owing to the complexity of the results under strict CPI inflation targeting, it is exceedingly difficult to determine with certainty whether strict CPI targeting is preferred to strict domestic inflation targeting. The outcome of this comparison must be established with the help of the numerical solution procedure. The findings of this exercise appear in Table 7–10.

Table 6. **Two strategies of strict inflation targeting: domestic vs CPI inflation**

	Strict domestic inflation targeting: $\mu \to \infty$ and $\pi_t = \pi^* = 0$
White Noise disturbances (ρ=0)	$E(L_t) = V(y_t) = \Lambda^2\left[\sigma_{\hat{v}}^2 + a_1^2\left(\sigma_{R\hat{f}}^2 + \sigma_{\hat{\varepsilon}}^2\right) + \left(\frac{A}{b}\right)^2 \sigma_{\hat{u}}^2 + a_3^2\sigma_{y\hat{f}}^2\right]$
AR(1) disturbances (ρ>0)	$E(L_t) = V(y_t) = \frac{\Lambda^2}{1-\rho^2}\left[\left(\frac{1}{1-\rho}\right)^2 \left(\sigma_{\hat{v}}^2 + a_1^2\left(\sigma_{R\hat{f}}^2 + \sigma_{\hat{\varepsilon}}^2 + \rho^2\sigma_{\pi\hat{f}}^2\right)\right) + \left(\frac{A}{b}\right)^2 \sigma_{\hat{u}}^2 + a_3^2\sigma_{y\hat{f}}^2\right]$

$A = (1-\gamma)a_1 + a_2$

$$\Lambda = \frac{b}{b + aA}$$

	Strict CPI inflation targeting: $\mu \to \infty$ and $\pi_t^{CPI} = \pi^{*CPI} = 0$
White Noise disturbances (ρ=0)	$E(L_t) = V(y_t) = \frac{1}{D^2}\left[\left(-aA + b + 2\gamma + \sqrt{(aA+b)(aA+b+4\gamma)}\right)^2 + \frac{(4A\gamma a)^2}{D^2 - 4\gamma^2}\right]\sigma_{\hat{v}}^2 + \left[\frac{(2A)^2}{D^2 - 4\gamma^2}\right]\sigma_{\hat{u}}^2 + \frac{a_1^2}{D^2}\left[\left(-aA + b + 2\gamma + \sqrt{(aA+b)(aA+b+4\gamma)}\right)^2 + \frac{(4A\gamma a)^2}{D^2 - 4\gamma^2}\right](\sigma_{R\hat{f}}^2 + \sigma_{\hat{\varepsilon}}^2) + \frac{a_3^2}{D^2}\left[\left(-aA + b + 2\gamma + \sqrt{(aA+b)(aA+b+4\gamma)}\right)^2 + \frac{(4A\gamma a)^2}{D^2 - 4\gamma^2}\right]\sigma_{y\hat{f}}^2$
AR(1) disturbances (ρ>0)	Too complex

$$D = aA + 2\gamma + b + \sqrt{(aA + 2\gamma + b)^2 - 4\gamma^2}$$

Note: By setting γ=0, the reader can verify that the expected loss function under strict CPI inflation targeting reduces to the expected loss function under strict domestic inflation targeting. In addition, by using the parameter values that are listed in Section 4 of the paper, the reader can establish that the above analytical results are consistent with the results produced by the numerical solutions method.

Table 7. **The variances of the endogenous variables and the policy instrument under strict domestic inflation targeting:**
Case I: All shocks are White Noise

γ	$V(\pi_t)$	$V(y_t)$	$V(q_t)$	$V(\pi_t^{CPI})$	$V(R_t)$	$E(L) = V(y_t) + \mu V(\pi_t)$
0.1	0	2.504	7.487	0.1497	8.307	2.504
0.2	0	2.537	7.317	0.5853	8.278	2.537
0.3	0	2.543	7.255	1.306	8.349	2.543
0.4	0	2.519	7.298	2.335	8.519	2.519
0.5	0	2.467	7.450	3.725	8.794	2.467
0.6	0	2.387	7.721	5.559	9.187	2.387
0.7	0	2.284	8.127	7.964	9.717	2.284
0.8	0	2.163	8.698	11.133	10.416	2.163
0.9	0	2.035	9.479	15.355	11.332	2.035

Table 8. **The variances of the endogenous variables and the policy instrument under strict CPI inflation targeting:**
Case I: All shocks are White Noise

γ	$V(\pi_t)$	$V(y_t)$	$V(q_t)$	$V(\pi_t^{CPI})$	$V(R_t)$	$E(L) = V(y_t) + \mu V(\pi_t^{CPI})$
0.1	0.0580	1.738	3.525	0	3.376	1.738
0.2	0.1277	1.494	2.199	0	2.424	1.494
0.3	0.1860	1.376	1.563	0	2.151	1.376
0.4	0.2352	1.316	1.202	0	2.055	1.317
0.5	0.2783	1.297	0.9739	0	2.018	1.297
0.6	0.3175	1.312	0.8202	0	2.005	1.312
0.7	0.3542	1.360	0.7121	0	2.000	1.360
0.8	0.3897	1.440	0.6339	0	2.000	1.440
0.9	0.4248	1.554	0.5767	0	2.000	1.554

Table 9. **The variances of the endogenous variables and the policy instrument under strict domestic inflation targeting:**
Case II: All shocks are autocorrelated: $\rho = 0.8$

γ	$V(\pi_t)$	$V(y_t)$	$V(q_t)$	$V(\pi_t^{CPI})$	$V(R_t)$	$E(L) = V(y_t) + \mu V(\pi_t)$
0.1	0	51.100	64.944	0.2598	5.603	51.100
0.2	0	47.152	60.428	0.9669	5.941	47.152
0.3	0	44.115	57.205	2.059	6.299	44.115
0.4	0	41.855	55.131	3.258	6.681	41.855
0.5	0	40.296	54.140	5.414	7.095	40.296
0.6	0	39.421	54.236	7.810	7.547	39.421
0.7	0	39.269	55.500	10.878	8.052	39.269
0.8	0	39.950	58.104	14.875	8.625	39.950
0.9	0	41.672	63.348	20.201	9.290	41.672

Table 9. **The variances of the endogenous variables and the policy instrument under strict CPI inflation targeting:**
Case II: All shocks are autocorrelated: $\rho = 0.8$

γ	$V(\pi_t)$	$V(y_t)$	$V(q_t)$	$V(\pi_t^{CPI})$	$V(R_t)$	$E(L) = V(y_t) + \mu V(\pi_t^{CPI})$
0.1	0.1599	54.441	55.490	0	6.072	54.441
0.2	0.4430	52.476	46.494	0	6.740	52.476
0.3	0.7597	50.692	40.508	0	7.091	50.692
0.4	1.085	49.258	36.353	0	7.266	49.258
0.5	1.425	48.272	33.470	0	7.346	48.272
0.6	1.783	47.822	31.558	0	7.373	47.822
0.7	2.173	48.007	30.451	0	7.372	48.007
0.8	2.611	48.953	30.072	0	7.357	48.953
0.9	3.119	50.822	30.405	0	7.341	50.822

The variances of the endogenous variables and the policy instrument for both strict domestic and strict CPI inflation targeting under the assumption of white noise disturbances appear in Tables 7 and 8. In stark contrast to flexible inflation targeting, under strict inflation targeting a CPI target produces smaller fluctuations in real output than a domestic inflation target. In addition, the variances of all other variables except domestic inflation will be smaller under strict CPI inflation targeting compared to strict domestic inflation targeting. By targeting the CPI, the policymaker succeeds in limiting variations in domestic inflation. In contrast, by targeting the rate of domestic inflation, the policymaker loses the ability to control the CPI inflation rate, particularly in fairly open economies ($\gamma \geq 0.5$). Thus, in case the policymaker is set on keeping inflation at bay at all cost, he will choose the rate of CPI inflation as his target variable.

Very different results emerge in the case where the disturbances exhibit a fairly high degree of persistence. Comparing the variance of real output across the whole range of permissible values for γ in Tables 8 and 9, we observe that strict CPI targeting causes greater fluctuations in real output and hence higher losses than strict domestic inflation targeting. Also note that fluctuations in the policy instrument are now greater under strict CPI inflation targeting compared to strict domestic inflation targeting for $\gamma \leq 0.5$.[23]

[23] For the sake of brevity, we do not present graphs that track the behavior of the endogenous variables and the policy instrument.

6 Domestic or CPI inflation targeting?

In this section we intend to analyze initially the findings of Sections 3, 4, and 5 with a view towards establishing the preferred target for inflation from the perspective of the central bank. As indicated earlier, this paper draws a distinction between the objective function faced by the policymaker and the objective function faced by society. The latter part of the current section therefore discusses the choice problem from the perspective of society and examines the extent to which the choice of the targeting strategy by the central bank reflects the preferences of society.

A succinct summary of the results of Sections 3–5, which are the outcome of comparisons of the expected loss functions under the different targeting regimes, is given by the table below. The target variable for inflation preferred by the central bank appears in boldface type in the body of the table.

Shocks	Flexible inflation targeting	Strict inflation targeting
White Noise	**Domestic inflation**	**CPI inflation**
AR(1)	**CPI inflation**	**Domestic inflation**

A domestic inflation target dominates a CPI target if the central bank engages in flexible inflation targeting and the disturbances are white noise. In the event that the central bank pursues a strict inflation target then the CPI should serve as the target variable provided that the shocks are white noise. Exactly the opposite pattern emerges for persistent disturbances. The rate of CPI inflation is to be chosen as the target for inflation if the policymaker is set on flexible inflation targeting. In contrast, under strict inflation targeting a domestic inflation target is preferred. Clearly, this intriguing pattern needs to be explained.

As we have recourse to analytical findings for both strict domestic and strict CPI inflation targeting it is best to begin our discussion by scrutinizing the response of real output to the disturbances of the model under this extreme form of optimal policy. Consider the variances of real output under white noise disturbances in Table 6. As already mentioned, it is virtually impossible to establish analytically whether the coefficient on the variance of a given shock is greater under strict domestic CPI relative to domestic inflation targeting. However, we can get important feedback on the size of the coefficients of the variances of *all* disturbances by simply drawing on the parameter values that were chosen to solve the model numerically. For fairly representative values of the parameters, $\gamma = 0.3$, $a = b = 0.25$, we get the following coefficients on the variances of the shocks:

	$\sigma^2_{\hat{u}}$	$\sigma^2_{\hat{v}}$	$\sigma^2_{\hat{R}f} + \sigma^2_{\hat{\varepsilon}}$	$\sigma^2_{\hat{y}f}$
Strict domestic inflation target	1.99	0.42	0.05 + 0.05	0.03
Strict CPI inflation target	0.43	0.72	0.09 + 0.09	0.05

It is readily apparent that the effect of cost-push shocks on real output under strict domestic inflation targeting is much worse than under strict CPI inflation targeting. At the same time, strict domestic inflation targeting insulates real output better against IS, UIP, foreign interest, and foreign output shocks. There is a straightforward explanation for the first result. Under domestic inflation targeting, the cost-push shock hits domestic inflation directly, and the size of the cost-push shock determines the extent to which the domestic inflation target is missed. Hence a substantial change in the policy instrument may be required, which in turn may cause a substantial change in real output. Under strict CPI targeting, the cost-push shock hits the domestic component of the CPI. But the story does not end there. The cost-push shock also affects the real exchange rate but in the opposite direction of the change in domestic inflation. Thus, in the wake of a positive cost-push shock, the domestic component of the CPI increases but the other component, the real exchange rate, appreciates, ie decreases. Hence CPI inflation does not stray as far from target. Indeed a smaller adjustment in the policy instrument is required. As a result, there is a smaller output loss.[24]

The other relevant piece of information concerns the size of the coefficients on the variances of IS, UIP, foreign interest, and foreign output shocks. Under domestic inflation targeting, these coefficients are relatively small compared to the size of the coefficient on the variance of the cost-push shock. Under strict CPI inflation targeting, the coefficient of the IS shock variance is larger than the coefficient on the variance of the cost-push shock. Finally, notice that the coefficients of the variances of IS, UIP, foreign interest rate, and foreign output shocks are greater under strict CPI inflation targeting than under strict domestic inflation targeting.

In summary, under white noise disturbances, the loss of real output in the wake of a positive cost-push shock is large enough to make strict domestic inflation targeting inferior to strict CPI inflation targeting.

In the case of AR(1) disturbances, inspection of the second row of Table 6 reveals that the variances of IS, UIP; foreign interest, and foreign inflation but not

[24] This story is consistent with the response of the policy instrument when the model is solved numerically. For the chosen parameter values, the coefficient on the cost-push shock in the optimal reaction function under strict domestic inflation targeting is approximately five times the size of the coefficient under strict CPI targeting.

cost-push or foreign output shocks are multiplied by the term $\left(\frac{1}{1-\rho}\right)^2$ under domestic inflation targeting. We would expect that the variances of these shocks are multiplied by a similar term under CPI inflation targeting. We also found that under strict CPI targeting and white noise disturbances, the coefficients on the variances of IS, UIP, foreign interest rate and foreign output shocks were greater than their counterparts under domestic inflation targeting. Thus, coefficients that are larger to begin with are multiplied by relatively large numbers (under domestic inflation targeting and $\rho = 0.8$ this number is 25). The resulting coefficients are large enough to make the effects of IS, UIP, foreign interest rate, and foreign inflation shocks big enough so that CPI targeting ends up being the inferior strategy compared to strict domestic inflation targeting.

Under flexible inflation targeting, a domestic inflation target dominates a CPI inflation target in case the disturbances are white noise. The principal reason underlying this result is that the variability of real output is considerably higher for a flexible strategy centered on CPI inflation compared to domestic inflation. Indeed a flexible strategy that targets domestic inflation yields fairly stable variances for both domestic inflation and real output irrespective of the degree of openness. Notice that the variance of domestic inflation always exceeds the variance of real output. Not so under a CPI target except for $\gamma = 0.1$. In general, the variability of real output and inflation under a CPI target is very sensitive to the degree of openness. As openness increases, a reduction in the variability of inflation is traded off for greater instability of the variance of real output.

The relative instability of real output under flexible CPI targeting is much less apparent when shocks are persistent. The ratio of the variance of real output under flexible CPI targeting to the variance of real output under flexible domestic inflation targeting is always less than two. This contrasts sharply with the same ratio in the case of white noise disturbances where it is always greater than 2 except for $\gamma = 0.1$. The gain in relative output stability under flexible CPI inflation targeting is accompanied by a continuously decreasing variance of CPI inflation. Notice that a flexible CPI inflation targeting strategy is far more successful in lowering the variance of the target rate of inflation than a domestic inflation targeting strategy as openness increases. The superior control over the variability of the target rate of inflation combined with the gain in relative output stability accounts for why a flexible CPI inflation targeting strategy outperforms a flexible domestic inflation targeting strategy when shocks are persistent.

A central question that that has not been addressed so far is whether the choice of target by the central bank is broadly consistent with the preferences of society. Examining this issue necessitates the specification of the objective function for society at large. Under ideal circumstances, society would delegate its objective function to the central bank and instruct it to maximize social welfare. In practice, the representatives of society, lawmakers, do not provide the central bank with a precise description of the preferences of society.[25] Instead, the central bank is given a far broader and less specific mandate. Generally, central banks are held accountable for ensuring a degree of price stability (defined as a specific numerical target or a target range for the rate of inflation) that does not conflict with reasonably stable employment or stable exchange rates over the business cycle. Central banks thus enjoy some leeway in designing strategies for monetary policy. This flexibility manifests itself in the central bank's objective function being different from that of society's. In the current context, the differences pertain to the distaste for inflation variability relative to output variability and the target variable of inflation in the objective function. In view of these differences, it seems important to ask to what extent the design and implementation of monetary policy coincides with the underlying preferences of society. We shall do so with the help of two different specifications of society's objective function.

In the recent literature, the criterion that measures the welfare of society is taken to be the utility of the representative consumer.[26] If steady state consumption of the representative household serves as the measure of society's welfare, then the objective function that measures society's losses in an open economy framework takes the following form:[27]

$$(1-\gamma)E_t\sum_{i=0}^{\infty}\zeta^i\left[y_{t+i}^2+\mu^s(\gamma)\pi_{t+i}^2\right] \tag{6.1}$$

where $\mu^{s}{}'(\gamma)>0 \qquad 0<\zeta\leq 1$

The welfare of society in the open economy depends on the same variables as in the closed economy: the real output gap and the rate of domestic inflation. However, characteristics of the open economy matter as well. The objective function is scaled by (1–γ), the share of total consumption accounted for by

[25] On this point, see chapter 1 of Blinder (1998).

[26] See Woodford (2001) and Clarida, Gali, and Gertler (2002).

[27] This is an adapted version of the objective function in the open economy model of Clarida, Gali, and Gertler (2002). They derive the objective function as a second-order approximation of the utility of the representative household.

domestic consumption. In addition, the weight on domestic inflation (μ^s) is an increasing function of the degree of openness (γ).[28] Let the dependence of μ^s on γ be described by a simple linear relationship:

$$\mu^s = \psi + \gamma \tag{6.2}$$

ψ is a constant parameter that reflects the dependence of μ^s on the deep structural parameters of the model other than the degree of openness. Depending on the weight of the base parameter ψ, society's weight on domestic inflation in its objective function, $\psi + \gamma$, may exceed the weight of unity that the central bank places on the rate of inflation in its respective objective function under flexible inflation targeting.[29] In light of the sensitivity of the size of μ^s to the value chosen for ψ, the latter is assumed to take on two different values: 0.5 and 1.

With society's objective function expressed by Equation (6.1), we can now proceed to examine whether the central bank, the agent, chooses the target variable for inflation in a way that broadly reflects the objectives of society, the principal. This is an easy task to accomplish. Take the variances of domestic inflation and real output under both CPI inflation targeting and domestic inflation targeting that appear in Tables 2–5 and 7–10, substitute them into society's loss function, and compare the losses under CPI and domestic inflation targeting. The target for inflation that is associated with smaller losses for society appears in boldface type in the table below.

[28] Greater openness is presumed to exacerbate the costs of resource misallocation due to relative price dispersion, which itself moves proportionately with the rate of domestic inflation.

[29] It is important to note that the weight on the rate of domestic inflation in *society's objective function* varies in accordance with the degree of openness. In contrast, the weight on the rate of inflation in the *central bank's objective function* is fixed at one under flexible inflation targeting and approaches infinity under strict inflation targeting.

	$\psi = 0.5 \quad (1-\gamma)E_t\sum_{i=0}^{\infty}\zeta^i\left[y_{t+i}^2 + (0.5+\gamma)\pi_{t+i}^2\right]$	
Shocks	Flexible inflation targeting	Strict inflation targeting
White Noise	**Domestic inflation**	**CPI inflation***
AR(1)	**CPI inflation**	**Domestic inflation**

	$\psi = 1 \qquad (1-\gamma)E_t\sum_{i=0}^{\infty}\zeta^i\left[y_{t+i}^2 + (1+\gamma)\pi_{t+i}^2\right]$	
Shocks	Flexible inflation targeting	Strict inflation targeting
White Noise	**Domestic inflation**	**CPI inflation***
AR(1)	**CPI inflation**	**Domestic inflation**

*except for $\gamma = 0.9$ when losses under a CPI target are slightly larger than under a domestic inflation target.

The welfare-enhancing choice of the target variable from society's point of view is the same for both values of ψ and coincides almost perfectly with the choice made by the central bank. Society prefers a CPI inflation target to a domestic inflation target under flexible (strict) inflation targeting provided that the disturbances of the model are persistent (white noise). A domestic inflation target is more attractive than a CPI target under flexible (strict) inflation targeting if the shocks are white noise (autocorrelated) processes. All told, the central bank acts in the best interest of society even though the objective function of the central bank differs from that of society.

Earlier contributions to the literature define the objectives of society in a more *ad hoc* fashion. For instance, Frankel and Chinn (1995) and Froyen and Guender (2000) employ a standard quadratic loss function that consists of the squared deviations of real output, the domestic price level, and the nominal exchange rate. In the current context where the rate of inflation and the real exchange rate matter, a loss function for society that is similar in spirit to the one employed by the above-named authors is:

$$E_t\sum_{i=0}^{\infty}\zeta^i\left[y_{t+i}^2 + \pi_{t+i}^2 + \gamma q_t^2\right] \qquad 0 < \zeta \le 1 \tag{6.3}$$

In short, the squared deviations of *all* endogenous variables of the original model appear as arguments in the objective function for society. The relative weight on domestic inflation equals unity. The greater the degree of openness, the greater the importance of the real exchange rate in determining the welfare of society. Hence the relative weight on the real exchange rate increases in line with the degree of openness of the economy. Just as the CPI does not explicitly enter the objective function expressed by Equation (6.1), the CPI does not form part of the *ad hoc* specification. However, nearly all components of the definition of the CPI – domestic inflation, the degree of openness, and the real exchange rate – appear in the latter. If the *ad hoc* specification serves as the welfare criterion, then society will express its preferred choice for the inflation target in the following way:

Shocks	Flexible inflation targeting	Strict inflation targeting
White Noise	**CPI inflation**	**CPI inflation**
AR(1)	**CPI inflation**	**Domestic inflation $\gamma \leq 0.4$** **CPI inflation $\gamma > 0.4$**

If society's objective function is represented by the sum of the squared deviations of the endogenous variables of the model, then the choice of the inflation target variable made by the central bank may differ sharply from the choice preferred by society. Given white noise disturbances, under a flexible inflation targeting strategy, society unambiguously prefers a CPI inflation target even though the central bank pursues a domestic inflation objective. Moreover, the target choice of the central bank – a domestic inflation target – is at variance with the target preferred by society under strict inflation targeting and persistence in the disturbances for $\gamma > 0.4$. In the remaining two cases, society and the central bank share a preference for a CPI target. Taken overall, based on the *ad hoc* specification of its objectives, society prefers a CPI target to a domestic inflation target. A domestic inflation target becomes unattractive from society's perspective because of the accompanying excessive variability of the real exchange rate. As a result, the targeting strategy chosen by the central bank may not match the strategy that society prefers.

7 Strategy choice and the temporal properties of the disturbances for a given definition of the inflation target

The purpose of this section is to explore to what extent the temporal properties of the disturbances matter in the choice between flexible and strict inflation targeting.

Consider the realistic scenario where the central bank is instructed by lawmakers to target either CPI inflation or domestic inflation. While the central bank is not free to choose the definition of the goal variable, the central bank is free to decide on the appropriate monetary policy strategy, ie the one that minimizes its objective function. An important question that arises in this context is whether the choice of the optimal strategy is independent of the temporal properties of the stochastic disturbances. We shall attempt to provide an answer to this policy problem by drawing on both the analytical results and the numerical results presented earlier in the paper.

Table 11 presents the case where the central bank faces a zero domestic inflation objective. The core of the table lists the preferred policy choice and indicates whether the choice of strategy is based on analytical results, numerical results or both. The presence of "–" means that the policy choice could not be determined by the method in question. According to our analytical findings, drawn from Tables 1 and 6, flexible inflation targeting dominates strict inflation targeting when all stochastic disturbances are white noise. The denominator of the loss function in the top panel of Table 1 is unambiguously greater than the loss function in the top panel of Table 6. These findings are corroborated by the findings based on the numerical solution method (last column of Table 2 and Table 7, respectively). The dominance of flexible over strict inflation targeting does not necessarily prevail in case the stochastic disturbances are persistent. Comparing the expected loss function that appears at the bottom of Table 1 to its counterpart in Table 6, we find that the dominance of flexible over strict inflation targeting depends critically on the size of

$$\frac{(b+aA)^2((b+aA)^2+A^2)}{((b+aA)^2+A^2(1-\rho))^2} \tag{7.1}$$

The greater the degree of persistence in the stochastic disturbances, the larger this expression becomes. For rather persistent disturbances, this expression is greater than one. In this event strict inflation targeting dominates flexible policy. This result is confirmed by the findings based on the numerical solution method where ρ is equal to 0.8. This intriguing result can be explained intuitively as follows.

Under flexible inflation targeting the policymaker sets *both* real output and inflation so as to minimize the objective function. The presence of both the variance of real output and the variance of inflation in the expected loss function is reflected by the term above (Expression (7.1)). As ρ increases, the variances of both inflation and real output increase. Hence the above term increases in size. Thus, the loss function is bound to increase faster under flexible policy than under strict inflation targeting.

The policymaker faces a similar policy problem if he decides to target CPI inflation. The findings for this case are summarized in Table 12. Due to the complexity of the policy problem there are no analytical results. Therefore, the issue of whether flexible inflation targeting is preferred to strict inflation targeting is settled by applying the numerical solution method. We observe that flexible inflation targeting dominates strict inflation targeting in case the stochastic disturbances follow white noise processes. In contrast, strict inflation targeting is preferred to flexible inflation targeting in the event that the stochastic disturbances are fairly persistent, ie $\rho = 0.8$. Again, the pronounced persistence in the stochastic disturbances causes the variances of *both* inflation and real output to snowball under flexible policy. Thus, expected losses rise faster under flexible inflation targeting than under strict inflation targeting.

Table 11. **A domestic inflation target**

Analytical results		Numerical results	
Preferred policy			
$\rho = 0$	flexible inflation targeting	$\rho = 0$	flexible inflation targeting
$\rho > 0$	inconclusive	$\rho = 0.8$	strict domestic inflation targeting

Table 12. **A CPI inflation target**

Analytical results		Numerical results	
Preferred policy			
$\rho = 0$	–	$\rho = 0$	flexible inflation targeting
$\rho > 0$	–	$\rho = 0.8$	strict CPI inflation targeting

8 Qualitative aspects in the choice of an inflation target

The analysis carried out up to this point has relied extensively on quantitative evaluations of objective functions. To round out the discussion, we will also present qualitative evidence about the performance of CPI relative to domestic inflation targeting. Due to its comprehensive nature, this comparison will be very helpful in assessing the overall implications of specifying an inflation target in terms of domestic or CPI inflation. The comparison takes a very simple form. For a given targeting strategy (flexible or strict inflation targeting), we compare the size of the variances of all endogenous variables and the policy instrument under domestic inflation targeting to the variances in question under CPI inflation targeting. The comparison is made for both white noise and persistent disturbances and appears in Table 13.[30] The dominating target, ie the target that produces a smaller variance, appears in the body of the table.

Under flexible inflation targeting, a CPI target yields smaller variances of the policy instrument and all endogenous variances except the output gap irrespective of the temporal properties of the stochastic disturbances. Notice further that the variance of domestic inflation is lower under a CPI target than under a domestic inflation target.

Under strict inflation targeting the results are somewhat different. A CPI target dominates a domestic inflation target from the standpoint of output stabilization provided that the disturbances are white noise. Under a strict regime, the variance of the target rate of inflation is zero and thus lower than the alternative rate of inflation. That explains why the variance of domestic inflation is now lower under a domestic inflation target. Another marked difference pertains to the behavior of the policy instrument. The variance of the policy instrument is less under domestic inflation targeting for $\gamma < 0.6$.

The qualitative rankings based on Svensson (2000) are added to Table 13 for comparative purposes. They underscore the fact that the qualitative results reported in the current section are very much in line with his findings.[31] The only difference pertains to the variance of the real exchange rate under strict inflation targeting. The similarity of the findings is remarkable in light of the absence in the current framework of any transmission lags in the conduct of monetary policy, the absence of any lags of inflation and real output, and slightly different interpretations of flexible and strict inflation targeting regimes.

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[30] The variances are taken from Tables 2–5 and 7–10. Although the variances are by their very nature quantitative evidence, the comparison of the variances is qualitative.

[31] Svensson considers only AR(1) disturbances.

In summary, the qualitative analysis establishes the clear dominance of a CPI target over a domestic inflation target unless the variance of real output is of overriding concern under a flexible inflation targeting strategy. The temporal property of the stochastic disturbances is immaterial in establishing the dominance of a given inflation target under flexible inflation targeting. Under strict inflation targeting the temporal property of the stochastic disturbances is also less important. It matters only for determining the choice of the preferred inflation target from the standpoint of real output stabilization and, to a lesser extent, the stabilization of the policy instrument.

The results generated by the qualitative analysis are congruent with those established by the quantitative analysis from the perspective of society provided that the *ad hoc* objective function serves as the welfare criterion and the central bank pursues flexible inflation targeting. Sharp differences in policy prescriptions arise between the qualitative analysis and the quantitative analysis, however, if the latter takes the utility of the representative household as the welfare criterion.

Table 13.

Flexible inflation targeting

	$V(\pi_t)$	$V(y_t)$	$V(q_t)$	$V(\pi_t^{CPI})$	$V(R_t)$
White Noise	CPI	DOM	CPI	CPI	CPI
AR(1)	CPI	DOM	CPI	CPI	CPI
Svensson* AR(1)	CPI	DOM	CPI	CPI	CPI

Strict inflation targeting

	$V(\pi_t)$	$V(y_t)$	$V(q_t)$	$V(\pi_t^{CPI})$	$V(R_t)$
White Noise	DOM	CPI	CPI	CPI	CPI
AR(1)	DOM	DOM	CPI	CPI	DOM $\gamma < 0.6$ CPI $\gamma \geq 0.6$[#]
Svensson* AR(1)	DOM	DOM	DOM	CPI	DOM

Note:
CPI = CPI inflation
DOM = Domestic inflation
*Svensson's quantitative findings, which are based on a given degree of openness ($\gamma = 0.3$) and reported in Table 3 of his paper, have been converted to qualitative findings.
[#] This is the only instance where the degree of openness matters in determining the qualitative ranking.

9 Conclusions

This paper has considered four different targeting strategies of monetary policy in a forward-looking small open economy model: flexible domestic inflation targeting, flexible CPI inflation targeting, strict domestic inflation targeting, and strict CPI inflation targeting. The objective function that the central bank attempts to minimize is composed of the squared deviations of the target variables from their respective target levels. The central bank acts with discretion and chooses a given strategy of monetary policy by assigning the appropriate weight to the target rate of inflation in the objective function.

Against this backdrop, we initially compare CPI targeting to domestic inflation targeting from the perspective of optimal flexible policy. Given the central bank's objectives, our findings suggest that in the forward-looking open economy framework a flexible inflation targeting strategy centered on domestic inflation is not necessarily superior to a flexible CPI inflation strategy. Whether a domestic inflation target dominates a CPI inflation target depends critically on the temporal properties of the stochastic disturbances. If the stochastic disturbances follow white noise processes, a domestic inflation target dominates a CPI inflation target. In contrast, if the stochastic disturbances exhibit persistence, then an inflation target framed in terms of CPI inflation dominates a domestic inflation target. The greatly improved stabilization performance of real output under flexible CPI targeting helps explain why flexible CPI inflation targeting dominates domestic inflation targeting in the case of persistent disturbances.

The evaluation of strict inflation targeting regimes yields just the opposite conclusions. Comparing strict domestic inflation targeting to strict CPI inflation targeting, we find the latter dominates the former in case the shocks are white noise. The severe effect of cost-push shocks on real output under strict domestic inflation targeting is responsible for this result. For autocorrelated disturbances, however, strict domestic inflation targeting is superior to strict CPI inflation targeting. This result is due to the magnified effect of persistent shocks that impinge directly or indirectly on demand under strict CPI targeting.

We find that the targeting strategies pursued by the central bank are in line with the interests of society if the objective function of the latter is based on the utility of the representative household. A more *ad hoc* specification of society's objective function adduces much less support for the notion that the central bank chooses the variable that serves as the target for inflation in line with the preferences of society.

The paper also seeks to ascertain whether there exists a preferred policy choice between flexible and strict inflation targeting in a scenario where the government defines the target variable of inflation. Our analytical and numerical results indicate that, in the context of domestic inflation targeting, flexible inflation targeting dominates strict inflation targeting for white noise shocks. In case of AR(1) disturbances, the attractiveness of flexible inflation targeting wanes as the degree of persistence of the disturbances increases. Indeed in case the shocks are fairly persistent, strict domestic inflation targeting dominates flexible policy. Less conclusive results emerge for the scenario where the CPI inflation serves as the target variable. Our numerical results show, however, that flexible inflation targeting is preferred to strict inflation targeting in case of white noise shocks. The opposite holds in the event of fairly persistent autoregressive disturbances.

The outcome of the quantitative assessment of the different monetary policy regimes must be put into perspective. It hinges critically on the specification of the objective function that the central bank faces. Only real output and inflation appear in the objective function. Thus, the policymaker does not care about the volatility of the policy instrument; nor does he care about the volatility of the real exchange rate. Moreover, no allowance has been made for the possibility that a change in the real exchange rate might change the target level of real output. Despite these limitations, the quantitative analysis underscores the importance of the temporal properties of the stochastic disturbances and the direct exchange rate channel in determining the choice of the target for inflation upon which flexible and strict inflation targeting strategies are based.

A discussion of qualitative aspects in the choice of an inflation target forms the final part of the paper. This approach has the advantage of being more comprehensive than the quantitative approach as it evaluates the behavior of all relevant variables. The qualitative findings ascribe a much less prominent role to the temporal nature of the disturbances in determining the choice of an inflation target. At the same time, the qualitative findings lack the precise information about the relative stabilizing properties of the targeting regimes that is inherent in the quantitative approach.

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