Abstract

In a New Keynesian macroeconomic model under credible commitment, price level targeting dominates inflation targeting. But with sufficient inflation aversion the inflation targeting central bank can produce quantitatively similar results to one targeting the price level. The current degree of inflation aversion demonstrated by the Bank of England may be sufficient to reap the benefits of price level targeting.

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Inflation and Price Level Targeting in a New Keynesian Model[1]

Jagjit S. Chadha[2] Charles Nolan[3]
University of Cambridge University of Durham

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1. Introduction

Inflation targeting has arguably been the key monetary policy innovation over the past decade and accordingly there has been an important debate on the desirability of this new regime.[4] Although the details of inflation targeting regimes differ somewhat across countries, the following elements are generally included: a quantified target for the rate of change in the aggregate price level (generally a consumer price index); an independent central bank, charged with achieving the target;[5] and perhaps penalty clauses in the event of significant policy misses. Its supporters argue that inflation targeting has a number of desirable properties. For example, it may embody a favourable response to the credibility-flexibility trade-off,[6] in others words it may be close to an optimal constrained discretionary rule. It may also encourage a coherence and discipline in monetary policy-making that might otherwise be absent.[7] Naturally, inflation targeting also has its critics (see, for example, the concerns raised in Mishkin 2000). One of the most obvious concerns

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[2]Clare College, Cambridge. Address: Department of Applied Economics, Austin Robinson Building, Sidgwick Avenue, University of Cambridge, Cambridge CB3 9DE, UK. Tel: +44 1223 335242. E-mail: jagjit.chadha@econ.cam.ac.uk. http://www.econ.cam.ac.uk/dae/people/chadha/

[3]Department of Economics and Finance, 23/26 Old Elvet, Durham DH1 3HY. Tel +44 191 374 7273. E-mail: Charles.Nolan@durham.ac.uk. http://www.dur.ac.uk/charles.nolan/index.html

[4]There have been a number of attempts to survey inflation targeting and its influence, see Bernanke *et al* (1999) and McCallum (1999). Earlier contributions are Haldane (1995) and Leiderman and Svensson (1995).

[5]See Gerlach (1999) for an interesting empirical relationship between inflation targeting and central bank independence.

[6]See, for example, Canzoneri, Nolan and Yates (1997)

[7]See Bernanke and Mishkin (1997).

is the presumption that successful inflation targeting, characterised by low and stable inflation, constitutes an acceptable notion of price stability. In this paper we therefore consider the possible narrowing of the definition of monetary stability such that price stability implies stability in the aggregate price level rather than its rate of change.

Policymakers seem to identify a role for inflation targets in developing the credibility of monetary policy. And in those economies a number of subsidiary issues have come to be associated with the strategy of inflation targeting, such as the accountability and transparency in monetary policy, which seem to have helped underpin credibility.[8] This perception of success has also promulgated interest in the regime from an increasing number of developing countries. The success of inflation targeting in the UK has been axiomatic: Over the period from late 1992, when inflation targeting was first introduced, the UK economy has combined stable output growth with low and stable inflation. This economic record and continued institutional reform has combined to produce a remarkable degree of credibility. Figure 7.1 draws on evidence from the financial markets and indicates the degree of credibility associated with the current regime in the UK since the adoption of central bank independence in May 1997. Measures of forward inflation expectations 10 and 20 years out indicate that these have consistently remained within the government's target.[9]

But inflation targeting may not be the only route to such performance. In general a number of diverse nominal rules, such as money targeting, could be consistent with the macroeconomic performance we have outlined. And it also seems clear that successful monetary regimes share a number of common characteristics with those of inflation targeting.[10] However, a number of analysts (notably Woodford 1999) have recently argued that direct targeting of inflation may have a number of specific advantages over alternative nominal regimes. To the extent that inflation

[8] See Chadha and Nolan (2001b) for a discussion of transparency and credibility and King (1997) for a discussion of credibility under inflation targeting.

[9] Source: Bank of England. These expectations are calculated as RPI inflation rather than RPIX (the targeted rate of inflation) and are subject to a number of distortions (see Breedon and Chadha 1997) but the extent of measured confidence is nevertheless remarkable.

[10] For example, see Clarida and Gertler (1999) for an analysis of the 'money targeting' Bundesbank's monetary operations and an interpretation of that central bank as an 'inflation targeter'.

targeting implies adherence to some form of the 'Taylor Rule', two specific attributes stand out. First, it may ensure nominal determinacy. Second, the focus of the Taylor Rule on output and inflation stability does much to maximise the welfare of the representative household as losses are proportional to quadratic terms in both inflation and output deviations from their 'flex-price' equilibrium.[11]

It is well known that in a model with a forward-looking New Keynesian (NK) Phillips curve much of the supposed benefits of stabilisation policy boil down to the attainment of 'price-stability'. But, in general inflation targeting is not consistent with price stability *per se*. An obvious question for the policymaker then is whether further improvement in macroeconomic performance may result from price rather than inflation stabilisation. Traditional concerns with targeting price levels have centred on the implications for output variability. However, these analyses have resulted from the use of reduced-form models and it is unclear whether these conclusions are robust to richer modelling environments. We therefore explore alternative rules in a micro-founded dynamic model where the policy-maker follows a credible Taylor-type rule. Our results suggest that it is possible to interpret price level targeting as a more aggressive monetary rule in that it magnifies the weight placed on any given inflation deviation We explore the conditions under which this rule might be seen to dominate an inflation rule and find that sufficiently 'aggressive' inflation targeting may offer a close approximation.

Section 2 outlines the specific policy experiment we conduct in light of related research. In section 3 we develop a representative agent dynamic general equilibrium model with a fully specified corporate sector, forward-looking agents and a policy maker charged with stabilisation policy. In section 4 we analyse and discuss the main responses of this model to productivity and monetary perturbations. In section 5 we assess how the model performs under some additional policy experiments. In section 6 examine the case for price level targeting within the context of this stylised

[11] The expected utility of the representative household is proportional to the quadratic loss function in inflation, π, and deviations of output y from the (in general time-varying) natural level y^n and x a target level for output, i.e., $(y - y^n - x)$. Hence, a monetary policy maker charged with minimising such deviations will also maximise expected utility. This is because the deadweight loss from output deviations is proportional to the squared deviation of output from the efficient level defined by $(y^n + x)$ and the dispersion of prices across goods (due to the imperfect synchronisation of prices), and hence the dispersion of output levels across goods, is proportional to the square of the inflation rate. See Woodford (1999) on this point.

model and with regard to current monetary policy in the UK. Section 7 offers some concluding remarks.

2. Price Level versus Inflation Targeting

The recent debate on price level versus inflation targeting was triggered by Fischer's (1994) conjecture that inflation targeting, in contrast to price-level targeting, would likely avoid high frequency output variability. Of course, that may come at the expense of base-drift in the price-level. McCallum (1999) argued, however, that over most practical planning horizons with low and stable inflation, the cost associated with such uncertainty is likely to be limited.[12] On the other hand, Svensson (1999) has argued that, given a persistent output gap, focussing on the price level rather than the inflation rate will actually reduce *both* inflation and output variability under discretionary policy. The implicit suggestion here that there is no output-inflation variability trade-off is also a feature of the NK literature but for somewhat different reasons. Briefly, within a credible framework, current inflation can be written solely in terms of future output gaps, so that stabilising inflation also stabilises expected output gaps.

We examine the two rules in our artificial economy as if they are credible rules timelessly committed to by the policy maker in the manner of Woodford (1999). Clarida, Gali and Gertler (1999) and Woodford (1999) show 'that, even in the absence of an inflation bias there are potential welfare gains associated with the central bank's ability to commit credibly to a systematic pattern of response to shocks'. Erceg *et al.* (2000) and Gali (2000) find that the typical Taylor-rule formulation closely approximates behaviour under the 'constrained' optimal rule. In addition they show that as responses to *measured* output might represent undue responses to 'natural' cycles of output, an inflation targeting rule, with near zero weight on output may out-perform one with a more robust feedback from output. We therefore model the credible policy maker as following a Taylor-type rule.

Finally we do not consider any potential transitional issues that may again

[12] McCallum undertakes a nice back-of-the-envelope calculation to demonstrate his argument. We find McCallum's argument persuasive on this point. If he is correct, then the benefits of price-level targeting must lie in the stabilising properties of such a rule. It is these properties upon which the current study is focussed.

exacerbate the costs of moving to price targeting. If our results are plausible, then any transition costs may be key in deciding which rule to adopt and we say more on this point in our concluding remarks. In this paper, we therefore examine macroeconomic stability in an economy solely differentiated by whether the policy maker operates on deviations from inflation or the price level from target.

The experiment is to ask whether paying attention to the price level, but by otherwise doing the same things as an inflation targeter, the outcomes may be preferable in terms of macroeconomic stabilisation. In particular, we compare the outcomes for the model's endogenous variables in the face of the same sequence of exogenous real and nominal shocks, under alternative stabilisation policy rules.

3. The Model

In this section we construct a model of a dynamic economy in the presence of price rigidity. The endogenous variables, when perturbed by various shocks, will display a familiar pattern of reversion to steady state. For some shocks, technology, this reversion is a somewhat lengthy process, while for others, nominal, the reversion is much more rapid. Our model has three sectors. There are profit maximising monopolistically competitive firms who face unspecified impediments in price-setting behaviour (Calvo 1983). Individuals in our model maximise each period a utility function defined over infinite sequences of consumption, money balances and labour supply. And finally a central bank sets the short-run nominal interest rate, or money supply.[13]

The model developed, in short, deviates from a well-functioning perfectly competitive macroeconomy because of two distortions — the bar to perfectly flexible prices and an imperfectly competitive corporate sector. The former distortion leads to a potential role monetary policy.

3.1. The Firm's Problem

There is a continuum of differentiated goods in the economy, each produced by a monopolistically competitive firm. These goods can be aggregated, in the manner of Dixit and Stiglitz (1977), to yield a consumption basket in which is measured

[13] We present results for an interest rate setting monetary authority but our code includes an option for setting the money supply as an alternative monetary regine.

consumers' utility. Let the index i cover firms and goods. We assume that firm i produces, in period t, $c_t(i)$ units of output. The composite good just mentioned is then given by

$$C_t = \left(\int_0^1 c_t(i)^{(\theta-1)/\theta} di \right)^{\theta/(\theta-1)} \tag{3.1}$$

where $\theta > 1$. The firm faces prices for factor inputs determined in perfectly competitive markets. We also assume that the firm meets demand for its produce at the posted price (whether or not the firm has been able to change its posted price in that period). As is well known the demand schedule facing firm i, and the price index for the composite good, are given by (3.2) and (3.3) respectively:

$$c_t(i) = \left(\frac{p_{t(i)}}{P_t} \right)^{-\theta} C_t, \tag{3.2}$$

$$P_t = \left(\int_0^1 p_t(i)^{1-\theta} di \right)^{1/(1-\theta)} . \tag{3.3}$$

We assume a constant returns to scale production function.[14] The production function is subject to exogenous changes in total factor productivity, $A_t(i)$, and embodies a labour augmenting growth factor given at time t by $(1+\gamma)^t$,

$$Y_t(i) = A_t(i) F[K_t(i), (1+\gamma)^t (N_t(i))]. \tag{3.4}$$

The firm faces costs of adjustment in the face of investment, denoted by $\phi(.)$, which are increasing in investment and strictly concave. Let ν denote depreciation. The firm's capital stock therefore evolves in the following way:

$$K_{t+1}(i) = (1-\nu(i))K_t(i) + \phi\left(\frac{I_t(i)}{K_t(i)} \right) K_t(i). \tag{3.5}$$

There are a number of ways to characterise optimal behaviour by the firm. King and Wolman (1996) suggest breaking the firm into three parts in thinking about

[14] In our code, we also allow for the incorporatation of overhead labour and capital requirements. Under certain assumptions, as exposited in King and Watson (1996), such overhead costs affect the exposition of the model equations only slightly, but in a quantitatively significant way. In an appendix (available on request) we detail these ammendments. More details can be found in King and Watson (op cit.). We use the solution code developed by King and Watson (1998).

optimal behaviour. One part of the firm minimises costs given the requirement to meet all demand at the posted price. The second part formulates a dynamic program for investment - acting as a price-taker in the investment goods market, and taking as given the rental price of capital. Finally, for those firms so able, the optimal, profit-maximising price is set. In fact the first two decision units can be lumped together to form a dynamic cost minimisation problem. This leads to a slight alteration to the optimality conditions, but our simulations show that nothing changes using this alternative approach. However, for consistency, here we exposit the optimality conditions in a more familiar way. The requirements for cost minimisation result in :

$$W_t = \Lambda_t \frac{\partial F_t(i)}{\partial N_t(i)}, \tag{3.6}$$

$$Z_t = \Lambda_t \frac{\partial F_t(i)}{\partial K_t(i)}. \tag{3.7}$$

The dynamic aspects of the firm's problem requires, at an optimum, that[15]

$$\mu_t = \Psi_t \phi' \left(\frac{I_t(i)}{K_t(i)} \right), \tag{3.8}$$

$$\begin{aligned} &\left(\frac{1}{1+r}\right) E_t \mu_{t+1} Z_{t+1} + \left(\frac{1}{1+r}\right) E_t \Psi_{t+1} \\ &\quad \times \left[1 - \nu(i) + E_t \phi \left(\frac{I_{t+1}(i)}{K_{t+1}(i)} \right) - E_t \phi' \left(\frac{I_{t+1}(i)}{K_{t+1}(i)} \right) \frac{I_{t+1}(i)}{K_{t+1}(i)} \right] = \Psi_t, \end{aligned} \tag{3.9}$$

where μ_t is the current value of marginal utility of consumption of the representative agent, Ψ_t is a Lagrange multiplier associated with (3.5), and is interpretable as a measure of Tobin's q, and Λ_t is a Lagrange multiplier associated with (3.4) and interpretable as nominal marginal cost. Z_t and W_t are nominal rental prices associated with capital and labour respectively and set in competitive factor markets, as earlier noted.

Each period all firms behave identically, as regards the foregoing optimality conditions. However, as regards price setting behaviour we follow Calvo (1983) and

[15] That is, we envisage a profit maximisation problem, where $\sum_{t=0}^{\infty} (\beta^t \mu_t)(Z_t K_t - I_t)$ represents total profits of the investment sector, and where the the optimisation is subject to a sequence of equations (3.5).

many subsequent analysts (e.g., Yun 1996, Woodford 1996, King and Wollman 1997) and assume that firms which set prices in period t face a probability, α $(0 \leq \alpha < 1)$ of having to live with the same decision next period. More generally, we assume that a firm which sets its price this period faces the probability α^k of having to charge the same price in $k-$periods time. Before we can calculate the optimal price we need to calculate the per period costs and these are given by:

$$\Lambda_t K_t(i) \frac{\partial F_t(i)}{\partial K_t(i)} + \Lambda_t N_t(i) \frac{\partial F_t(i)}{\partial N_t(i)}. \tag{3.10}$$

Given our homogeneity assumptions, we can write down period t profits as

$$\Pi_t(i) = p_t(i) \left(\frac{p_t(i)}{P_t} \right)^{-\theta} C_t - \Lambda_t \left(\frac{p_t(i)}{P_t} \right)^{-\theta} C_t. \tag{3.11}$$

The firm now has to choose its optimal price.[16] The optimal price, p_t', is therefore given by:

$$p_t' = \frac{\theta \sum_{k=0}^{\infty} (\alpha\beta)^k E_t(\mu_{t+k} P_{t+k}^{\theta} C_{t+k} \Lambda_{t+k})}{(\theta - 1) \sum_{k=0}^{\infty} (\alpha\beta)^k E_t(\mu_{t+k} P_{t+k}^{\theta-1} C_{t+k})}. \tag{3.12}$$

The evolution of the aggregate price-level is given by

$$P_t = [(1-\alpha) p_t'^{1-\theta} + \alpha P_{t-1}^{1-\theta}]^{1/(1-\theta)}. \tag{3.13}$$

Note that each firm in the economy faces the problem as set out in stage 1. The firms are identical save for the differentiated product they produce. Consequently, we take equations (3.4)-(3.9), without the i index to represent aggregate behaviour. The stage 2 decision, which is granted to $(1-\alpha)$ of producers, results in all producers choosing the same price which as equation (3.12) makes clear is a function only of aggregate (i.e., economy wide) variables. Consequently aggregate price level behaviour is given by equations (3.12) and (3.13).

3.2. The Agent's Problem

There are a large number of identical agents. A representative agent each period maximises the expected value of (3.14) by formulating contingency plans for

[16] The details of this problem are well understood, and we leave them to an appendix, available upon request.

consumption (across goods and time), leisure (where available time is normalised to unity) and money balances (which ease transactions costs). That is, she maximises (3.14) subject to (3.15) and (3.16):

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\sigma \log C_t^j + (1-\sigma) \log L_t^j + \log \left(\frac{M_t^j}{P_t} \right) \right], \tag{3.14}$$

$$P_t C_t^j + B_{t+1}^j + M_{t+1}^j = B_t^j (1 + i_{t-1}) + M_t^j + P_t \Pi_t^j + W_t N_t^j, \tag{3.15}$$

$$N_t^j + L_t^j = 1, \tag{3.16}$$

where C_t denotes units of consumption in period t; M_t denotes nominal money balances, at the beginning of period t; B_t represents the stock of nominal one period bonds at the beginning of period t; i_t is the nominal interest rate between period t and $t+1$; Π_t denotes profits from the representative firm; and $W_t N_t$ represents period t nominal labour income.[17]

An interior solution to this problem will be unique if the utility function is strictly concave and will be characterised by the following first-order conditions which hold for all t, and across all states:

$$\frac{\sigma}{C_t^j} = \mu_t^j, \tag{3.17}$$

$$\frac{1-\sigma}{\mu_t^j L_t^j} = W_t, \tag{3.18}$$

$$\mu_t^j = \beta(1 + r_t) E_t \mu_{t+1}^j, \tag{3.19}$$

$$E_t \frac{M_{t+1}^j / P_{t+1}}{C_{t+1}^j / \sigma} = \frac{i_t}{1 + i_t}. \tag{3.20}$$

[17] There is no need to incorporate a j superscript on W_t.

These optimality conditions are well understood. Briefly, (3.17) and (3.18) describe intratemporal (labour-leisure) efficiency, (3.17) and (3.19) describe intertemporal (consumption-saving) efficiency, and (3.20) implies, for a given level of i_t, the optimal quantity of base money that the agent should carry over into time period $t+1$.

3.3. Monetary Policy

An intense research effort has recently been directed into characterising the behaviour of monetary authorities. In particular, whilst monetary authorities have long regarded themselves as setting interest rates, theoretical concerns with such practice often led academic economists to cast monetary policy in terms of the stochastic evolution of a narrow money aggregate. More recent work has served to lessen these concerns. Extremely influential work by Taylor (1993) demonstrated that US monetary policy could be well approximated by an interest rate feedback from the output gap and inflation.

Recent research has clarified many aspects of this 'Taylor rule'.[18] Work by Woodford (1998, 1999, 2000) has demonstrated that an interest rate rule is consistent with nominal determinacy for a class of forward-looking models, even when money demand is almost non-existent. We do not review that analysis here but our model can certainly be thought of as mimicking the 'cashless' economy, in which case one can exclude consideration of the money demand function. More generally, however, whether or not one wishes to adopt that cashless perspective, the class of models currently under inspection can yield unique bounded solutions under rational expectations for a wide range of plausible parameter values, and we demonstrate this property below. We also, for completeness sake, incorporate in our code monetary rules characterised by a process for the money supply. In other words our monetary policy rules are, under inflation targeting, of the form:

$$i_t = \phi[y_{t-1}, \pi_{t-1}, y_t, \pi_t, E_t y_{t+1,} E_t \pi_{t+1}, i_{t-1}, E_t i_{t+1}], \tag{3.21}$$

[18] We are thinking of issues such as 'appropriate' and/or optimal elasticites and lag structures, and so on. See Taylor (1999) for a discussion.

$$M_t = \phi[y_{t-1}, \pi_{t-1}, y_t, \pi_t, E_t y_{t+1}, E_t \pi_{t+1}, M_{t-1}, E_t M_{t+1}]. \tag{3.22}$$

And in the case of price-level targeting they are of the form:

$$i_t = \phi[y_{t-1}, P_{t-1}, y_t, P_t, E_t y_{t+1,} E_t P_{t+1}, i_{t-1}, E_t i_{t+1}], \tag{3.23}$$

$$M_t = \phi[y_{t-1}, P_{t-1}, y_t, P_t, E_t y_{t+1}, E_t P_{t+1}, M_{t-1}, E_t M_{t+1}]. \tag{3.24}$$

In what follows we only discuss the results under interest rate rules. Nominal shocks, therefore, are unexpected shifts in the interest rate.

The basic model, then, is given by equations (3.4) to (3.9) in aggregate form, loosely speaking the quantity decisions of the corporate sector, (3.12) and (3.13), the pricing (and hence aggregate supply) decisions, (3.16) to (3.20), the representative agent's quantity decisions, and one of equations (3.21) to (3.24), the policy block. Together these equations determine, output, capital, investment, marginal cost, Tobin's-q, the optimal firm price, the aggregate price-level, consumption, savings, labour supply, leisure, wages, money balances, and the monetary instrument.[19]

3.3.1. Stationary variables and some steady state calculations

We discuss these matters only briefly, as they are well understood. Date t variables are detrended in the usual manner. E.g., $C_t \equiv C_t/(1+\gamma)^t$, $M_t \equiv M_t/(1+\mu)^t$, $P_t \equiv P_t \left(\frac{1+\gamma}{1+\mu}\right)^t$, $(1+\gamma)K_{t+1} = (1+\gamma)K_{t+1}/(1+\gamma)^{t+1}$, and so on.

Table 1 lists the values we attach to some fundamental parameters. Using these, we can derive the other necessary steady state parameter values that we require. The quarterly real return on capital, z, in the UK is taken to be 1.25%. The share of capital, s_k, in the production function is taken to be 38%. We assume, in line with Chadha, Janssen and Nolan (2001), that the quarterly rate of capital depreciation, ν, is 2.5%. Per capita income growth, γ, is 0.5%. And the quarterly rate of time

[19]In practice we also incorporate a number of convenient identities which allow us to add leads/lags of various variables.

preference is assumed to be around the level implied by UK market real interest rates, 0.75%. We can calculate the remaining parameters, $\beta, b, c, y, i, l, N, L$ and θ in turn. First we have

$$z = \frac{\theta}{\theta - 1}(r + \psi) = s_k \left(\frac{K}{N}\right)^{s_k - 1}, \tag{3.25}$$

where we have used the steady state analogues of equations (3.5), (3.8) and (3.9). We solve for K/N and find 21.79.[20] From (3.25) we note that $Y/N = K/N^{s_k} = 3.23$ and thus $K/Y = 6.76$. Consequently, we find that $i/k = 0.03$ and $i/y = 0.203$. Now note:

$$w = (1 - s_k)\left(\frac{K}{N}\right)^{s_k}, \tag{3.26}$$

and so equals 0.399. We shall assume that we spend a fifth our time working so $N/L = 0.25$ and y, k and i equal 0.645, 4.36 and 0.131, respectively. Finally, σ, is given by the intratemporal efficiency conditions (3.17) and (3.18) and is 0.616.

3.4. Deriving The New Keynesian Phillips Curve

The model developed above is consistent with what has been termed the NK Phillips Curve. To see this, recall that the capital stock is pre-determined in period t. In addition, due to sticky prices, output is demand determined in the short-run, which implies that the demand for labour is effectively given by (3.4). In addition equation (3.6) provides an expression for nominal marginal cost. Combining a linear approximation to these equations and combining them with the linearised versions of equations (3.12) and (3.13), and letting hats above variables denote the deviation of a variable from steady state, it can be shown that:[21]

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \kappa \hat{y}_t + \varphi \hat{x}_t \tag{3.27}$$

where $\kappa \equiv \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}\frac{s_k}{s_n}$, $\varphi \equiv -\kappa/s_k$, and, $x_t \equiv (\hat{a}_t - s_n \hat{w}_t + s_k \hat{k}_t)$. s_k and s_n denote capital and labour share respectively. The exogenous term, $\hat{x}_t$, is a function of the

[20] It is interesting to note in passing that this is around half of the value this ratio takes in an RBC model. Chadha, Janssen and Nolan (2001) find this value to be 41.9.

[21] See Chadha and Nolan (2001a) for more details on the theoretical and econometric implications of the New Keynesian Phillips curve.

exogenous shock to total factor productivity, the wage set in competitive markets, and the predetermined stock of capital. In other words $\hat{x}_t$, far from being simply a 'productivity' or 'cost' shock' as is often assumed in the literature, is actually a complex (but in our model well-defined) composite term in factors outside of the control of the firm in period t. This equation is central to our findings. And as Chadha and Nolan (2001a) demonstrate, formulation (3.27) provides advantages when taking the NKPC to the data.

4. The Model Output

To examine the properties of this model we examine the results of a number of simulation exercises designed to examine issues of policy design. We assume that the nominal shock is i.i.d. However, this shock has long-lasting implications via the interest rate smoothing that we generally incorporate in the monetary rule. In contrast, our technology shock is highly persistent. Our shocks are constructed to be uncorrelated with one another. We simulated the model 20 times with each simulation lasting 150 periods. In calculating our results we used only the final 100 observations from each simulation, meaning that we had 2000 observations on each variable. All output is detrended using the Baxter-King filter. The construction of this filter is exposited in Chadha, Janssen and Nolan (2000). This is basically a two sided (symmetric) moving average filter which is an approximation to the optimal bandpass filter.[22] Compared with the more familiar Hodrick-Prescott filter, the Baxter-King filter - and indeed any version of the bandpass filter - is designed to address the problem high-frequency leakage. This appealing feature aside, our results would be little changed if we adopted the Hodrick-Prescott filter, or indeed Christiano and Fitzgerald's (2000) version of the bandpass filter. For a discussion of these filters, and a demonstration of the fact that they tend to return very similar views of the business cycle see Chadha, Janssen and Nolan (2000).

4.1. The artificial economy

The relative variability and cross-correlations for our artificial baseline economy under both price level and inflation targeting rules are detailed in an appendix

[22] Our programmes for implementing this filter are available on request.

available from the authors. It shares many similarities with the standard RBC-type economies. Our baseline Taylor rules under inflation and price-level targeting are given respectively by:

$$\hat{\imath}_t = 0.8\hat{\imath}_{t-1} + \phi_y \hat{y}_{t-1} + \phi_\pi \hat{\pi}_{t-1} + \phi_y \hat{y}_t + \phi_\pi \hat{\pi}_t + \phi_y E_t \hat{y}_{t+1} + \phi_\pi E_t \hat{\pi}_{t+1}, \tag{4.1}$$

$$\hat{\imath}_t = 0.8\hat{\imath}_{t-1} + \phi_y \hat{y}_{t-1} + \phi_\pi \hat{P}_{t-1} + \phi_y \hat{y}_t + \phi_\pi \hat{P}_t + \phi_y E_t \hat{y}_{t+1} + \phi_\pi E_t \hat{P}_{t+1}, \tag{4.2}$$

where $\phi_y = 0.5$ and $\phi_\pi = 3.5$. Again, hats denote log-deviations from steady state. As well as analysing a general rule (GEN) with backward, contemporaneous and forward-looking indicators, we also analyse the output from more specific formulations, such as backward and contemporaneous alone (BAKCON) or solely forward-looking (FWD). In the baseline models inflation targeting induces greater cyclical variability in labour supply, real wages, inflation, the price level, nominal interest rates and the marginal efficiency of capital. But there is little difference in the cyclical relationship across variables as all are pro-cyclical other than inflation, the price level and nominal interest rates. In many respects, therefore, these artificial economies appear as standard dynamic stochastic general equilibrium economies.

4.2. The impulse response functions

Figure 7.2 plots the response of a number of key variables to a technology shock under the two alternative rules. Equilibrium output and real rate paths are essentially identical under the two regimes (as well as persistently pro-cyclical) but both the price level and inflation respond with greater elasticity to a technology shock. There are two reasons for this result: (i) the technology shock induces a greater wage responses under inflation targeting and hence nominal marginal costs rise by more and (ii) monetary policy strongly tempers the inflation response in the case of price level targeting because the relative weight on inflation deviations is magnified.

Figure 7.3 plots the response of the same variables to a monetary shock. In each case the variables show amplified responses in the inflation targeting world. The higher penalty on inflation deviations in the price-level targeting world induces a dampened policy shock and a significantly lower response in inflation expectations and these effects translate into lower nominal variability. In summing up it seems that nominal variability is exacerbated by choosing inflation over price level targeting. To this extent, we confirm an emerging consensus in the literature.

4.2.1. A comment on the monetary policy responses

Some authors have compared the impulse responses from models such as that analysed in this paper to those generated by VAR-based analyses. However, caution should be exercised in any such comparison. The impulse responses of our economy to a monetary policy shock do not measure the efficacy of policy in the usual sense of simply how much the economy responds to an exogenous (and unexpected) monetary perturbation: these responses should not be interpreted as simple impact parameters. For in that case it would appear that a greater responsiveness is a signal of more powerful policy. What these responses *do* show is the economy's response under two classes of monetary rules, when agents also know the policy rule in place. Recall that the policy maker is acting to offset the partial inability of firms to set prices with full flexibility. The results tell us that there are two effects at work here. First, once agents know that price shocks will be temporary, the consequent lack of inflation expectations will mitigate against large scale initial responses to the monetary action. And because the inflation response in a NK Phillips curve model is greater than the price-level response (under inflation targeting), the output response will be larger. Second, as a result of this, the policy response under price-level targeting is more muted than it would be otherwise.

5. Some Policy Experiments

We extend the basic policy experiment in this section in order to assess further the extent of the case for price level targeting. We do this in three stages. First, we alter the variables which determine the equilibrium nominal interest rate period by period. Then, we alter the weights that are attached to these different feedback variables. Finally, we assess the implied sacrifice ratios under a number of these experiments. Space considerations mean that we are unable to reproduce here all our charts and tables. However, a full annex is available from either authors' webpage.

5.1. The policy-maker's use of lagged information and forecasts

We examine the artificial economy when we alter the lags and leads in the indicator variables of the Taylor rule. The basic rules we employ are as before:

$$\hat{\imath}_t = 0.8\hat{\imath}_{t-1} + \phi_y \hat{y}_{t-1} + \phi_\pi \hat{\pi}_{t-1} + \phi_y \hat{y}_t + \phi_\pi \hat{\pi}_t + \phi_y E_t \hat{y}_{t+1} + \phi_\pi E_t \hat{\pi}_{t+1}, \tag{5.1}$$

$$\hat{\imath}_t = 0.8\hat{\imath}_{t-1} + \phi_y \hat{y}_{t-1} + \phi_\pi \hat{P}_{t-1} + \phi_y \hat{y}_t + \phi_\pi \hat{P}_t + \phi_y E_t \hat{y}_{t+1} + \phi_\pi E_t \hat{P}_{t+1}, \tag{5.2}$$

incorporating various zero restrictions on the ϕ parameters. The main results of this exercise are listed: (i) The price target leads to lower variability in each of the three variables irrespective of lag structure of the indicator variables, particularly in terms of inflation and nominal interest rates; (ii) across both rules, the employment of most information i.e. the use of forward-looking expectations, backward looking realisations and current outturns (GEN) would seem to allow the policymaker to obtain low output and inflation variability with the lowest variability in nominal interest rates; (iii) across both rules, a purely forward-looking indicator increases variability of inflation and output quite markedly; (iv) across both rules, a purely backward-looking indicator increases the variability of interest rates markedly; (v) use of contemporaneous information seems to result in a better policy frontier; (vi) output variability is an order of magnitude higher than nominal variability under these rules.

5.2. Increasing the weight on ϕ_y

The next policy experiment is to increase the weight placed on the output indicator variable. We find that the results under price level targeting are practically insensitive to this but once ϕ_y increases much beyond 1, the variability of output, inflation and interests in the inflation targeting regime increase rapidly. Figure 7.4 showing the behaviour of inflation is illustrative (in the sense that both output and nominal interest rates display a very similar pattern–see the appendix on our websites for the complete bank of charts). As we would expect the NK framework does not deliver the traditional trade-off between inflation and output variability. Because inflation is a function of current and anticipated output gaps, increasing the weight on output deviations indicates a more volatile time path for inflation.

However, note that adopting a price level target will make the economy more forgiving if ϕ_y is set rather high because the variability of key variables to increases in ϕ_y is substantially less elastic in the case of price targeting. We conclude that increasing ϕ_y in either regime implies a more volatile path for inflation.

5.3. Increasing the weight on ϕ_π

Figure 7.5 shows that output variability is relatively high under an inflation targeting regime in comparison to the price level regime when ϕ_π is less than 3. Pushing ϕ_π to 5 or above would ensure similar, but still somewhat inferior, performance to the price level rule. Again, similar patterns are generated for inflation and nominal interest rates. To sum up it appears that performance is markedly improved as ϕ_π increases to 3.5 but there is little improvement thereafter, and that across regimes adopting a strategy of low ϕ_y and high ϕ_π seems sensible. We shall return below to the issue of a high ϕ_π.

5.4. Price Stickiness

The gains from price level targeting (Figure 7.6) increase in the extent of time dependent price stickiness, α. There is increasing equivalence for the rules as $\alpha \to 0.5$.[23] This seems intuitively reasonable since as prices become more rigid a given monetary shock would appear to leave proportionately more producers further from the optimal price-output strategy.

5.5. Comparing nominal income uncertainty

Figures 7.7 compares the outcomes across the use of indicator variables in output and inflation space. As suggested by Woodford (2000) the purely forward looking rules appear to have unattractive properties implying, as they do, somewhat more variable outturns for inflation and output.

5.6. Sacrifice Ratios

We now consider the ratio of the standard deviation of output and inflation at a business cycle horizon of 20 quarters for different parameters in the Taylor

[23] This equivalence is not surprising, since in log-deviation form we have that $\hat{\pi}_t = \frac{1-\alpha}{\alpha}\hat{p}'_t$. This can be seen by log-linearising equation (3.13), and noting that in steady state $p' = P$

Rule. Consider figures 7.8 and 7.9, which plot the ratio for increasing ϕ_y and ϕ_π respectively. Note that even though the cost of output losses per unit of inflation can be similar, the absolute variability is still somewhat higher under inflation targeting. But the model produces a zone of 'indifferent' regions, where $\phi_y < 0.6$ and $\phi_\pi > 3.0$. Both models can produce similar relative movements, or seeming *costs* of monetary policy, providing the weights on output is sufficiently low and that on inflation is sufficiently high.

6. Estimated 'Taylor' Rules

The paper has found that price targeting offers a more stable set of outcomes for our artificial economy compared with inflation targeting. Specifically price level targeting provides significant stabilisation advantages over inflation targeting should the weight on output (inflation) stabilisation be set too high (low). Also in the presence of significant price stickiness price targeting seems to offer advantages.[24] We do, however, seem to have uncovered a set of parameter choices that will make inflation targeting a close approximation to price targeting. An interesting question, then, is to what extent might current UK practice have captured the benefits of price targeting. Is the real world data consistent with a 'sufficiently' high weight on inflation and 'sufficiently' low weight on output?

Nelson (2000) estimates a Taylor-type rule on UK data for the inflation targeting period. We basically replicate his estimation strategy. Tables 2 and 3. These show the results of Taylor-type rules estimated on the artificial data generated from our model. We have estimated backward, contemporaneous and forward-looking Taylor rules from our models generated with both price level and inflation targeting with ϕ_π set at both 3.5 and 5.0. The long run coefficients on the Taylor rule are estimated by IV and found in the final panel of Tables 2 and 3 and suggest that the artificial model with high ϕ_π provides a close approximation to the estimates of the Taylor rule on actual UK data of 1.27 on inflation and 0.47 on output.[25] One interpretation

[24] See Chadha and Nolan (2001a) for an econometric analysis of price stickiness in the UK based on equation (3.27). We find that α lies in the range: 0.4-0.6. Note that these estimates would also make the policy more likely to lie in the zone of indifference between inflation and price level targeting.

[25] Note that Tables 4 and 5 tell us that price level targeting would, as we have suggsted earlier in the paper, imply higher estimated Taylor rule coefficients on the inflation rate.

of current UK policy is then that it represents a credible inflation targeting regime in which inflation aversion, ϕ_π, seems sufficiently high to allow the regime to capture most of the benefits, implied by this model, from any move to price level targeting.

7. Concluding Remarks

This paper has explored the implications for macroeconomic stability within an artificial economy from two forms of monetary policy rule. Our economy is inhabited by agents making forward-looking plans for consumption and investment in light of technology and monetary shocks. Agents supply their own labour and own the firm. Their choices are subject to some rigidities in the setting of prices. These agents have also charged a credible monetary policy maker with setting interest rates according to inflation or price deviations from a target. We find that the macroeconomy appears more stable under a price level target than an inflation target, in that inflation, output and interest rates tend to be less volatile. Forward looking agents incorporate credible policy into their contingency plans and when given the chance to set prices will make their choices accordingly. It does appear, however, that the better outcomes implied by an aggressive rule, such as a price targeting, can be nearly matched when an inflation target is pursued with sufficient vigour.

If the UK authorities therefore decided to move beyond inflation targeting to a regime of price level targeting, what might they expect to be different? The answer from the current exercise is 'not much'. We find that the observed degree of output and inflation variability will not be very different across regimes provided that the weight on inflation in the Taylor rule is sufficiently high under inflation targeting (and the weight on output sufficiently low). Furthermore, we found that the weight on inflation, under the current UK regime, appears to be above this 'cut-off' point. Of course an alternative way to view our results is that if the transition costs to a price level targeting regime were large, then it may be not be a worthwhile switch.

Of course, a comprehensive comparison of price-level and inflation targeting opens up a number of issues outside the realms of our framework: (i) the consequences of price drift versus price stationarity on nominal uncertainty, (ii) the relative ease of price adjustments under price drift, given downward nominal rigidity, (iii) the possibility that deflation might increase the likelihood of multiple equilibria, such as may be associated with debt deflation. Each of these topics is worthy of separate study and certainly (ii) and (iii) seem likely to exacerbate the case for any regime switch to price level targeting. But in describing price level targeting in a light which best shows its advantages we have shown that inflation targeting might nevertheless provide a pretty good substitute.

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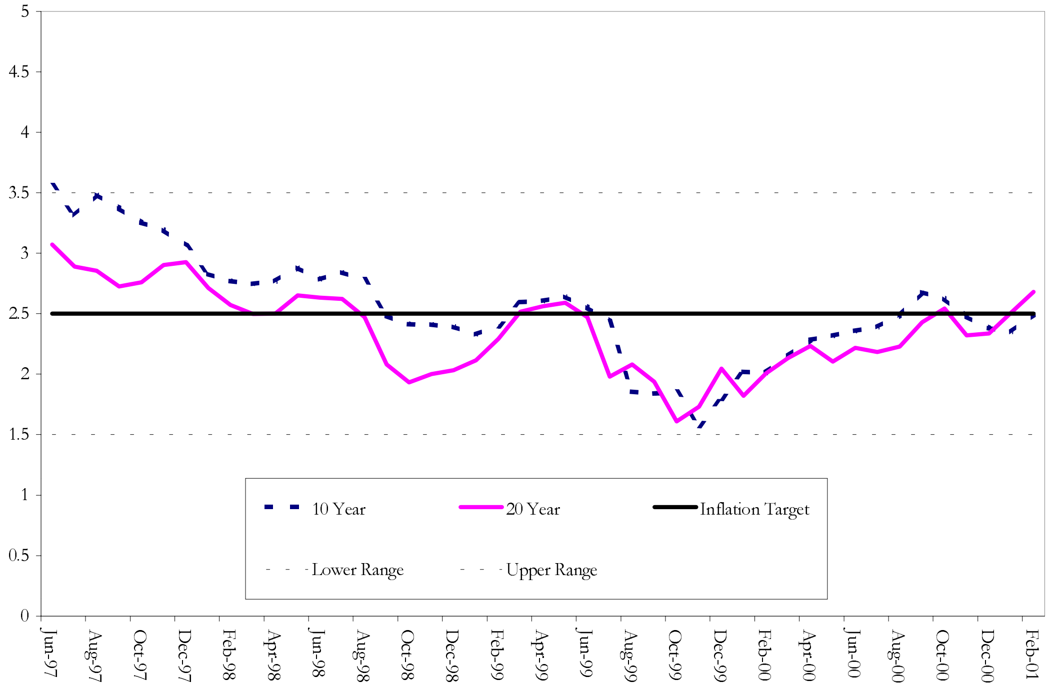

5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
10 Year
20 Year
Inflation Target
Lower Range
Upper Range
Jun-97
Aug-97
Oct-97
Dec-97
Feb-98
Apr-98
Jun-98
Aug-98
Oct-98
Dec-98
Feb-99
Apr-99
Jun-99
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Figure 7.1:

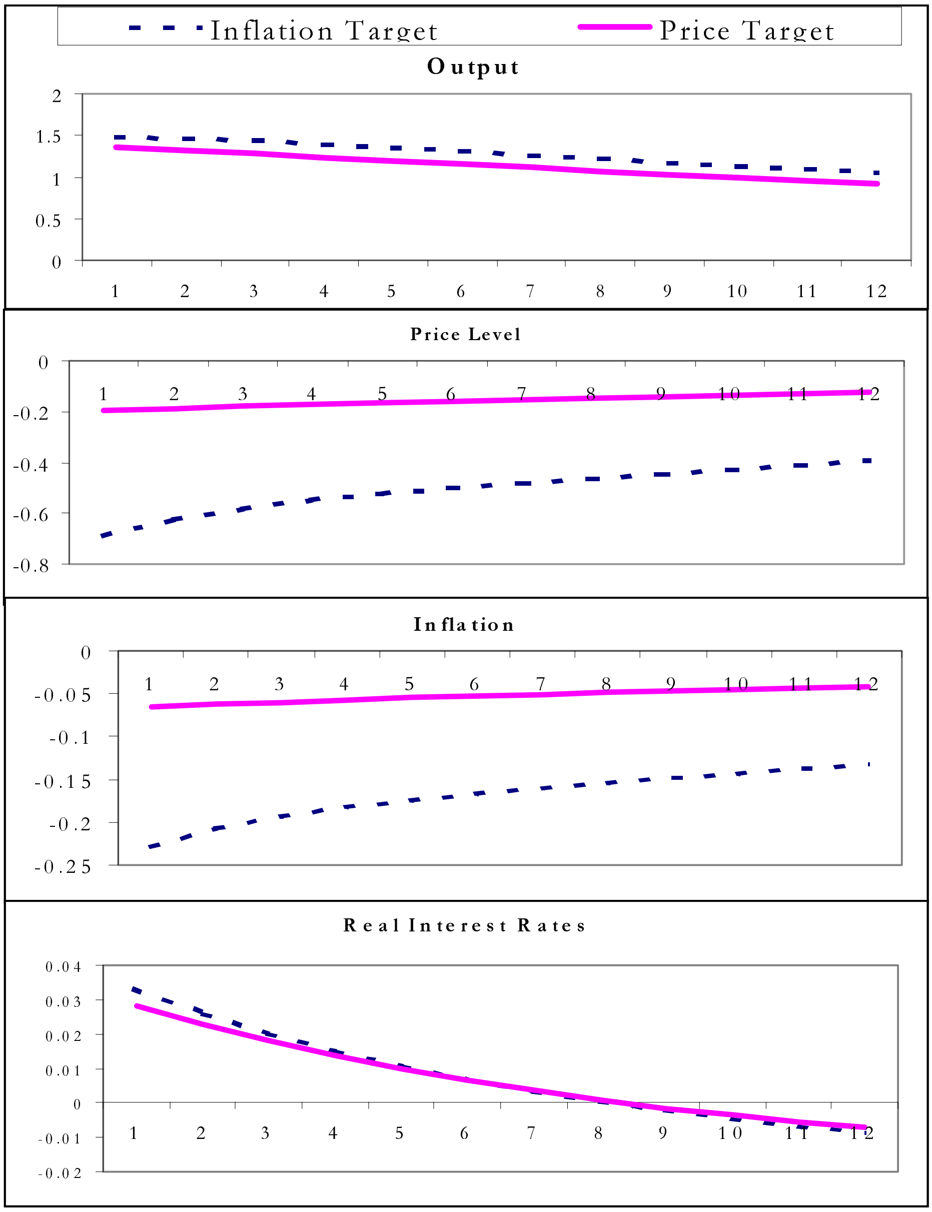

Figure 7.2: Impulse Responses to a Technology Shock-% deviaiton from baseline

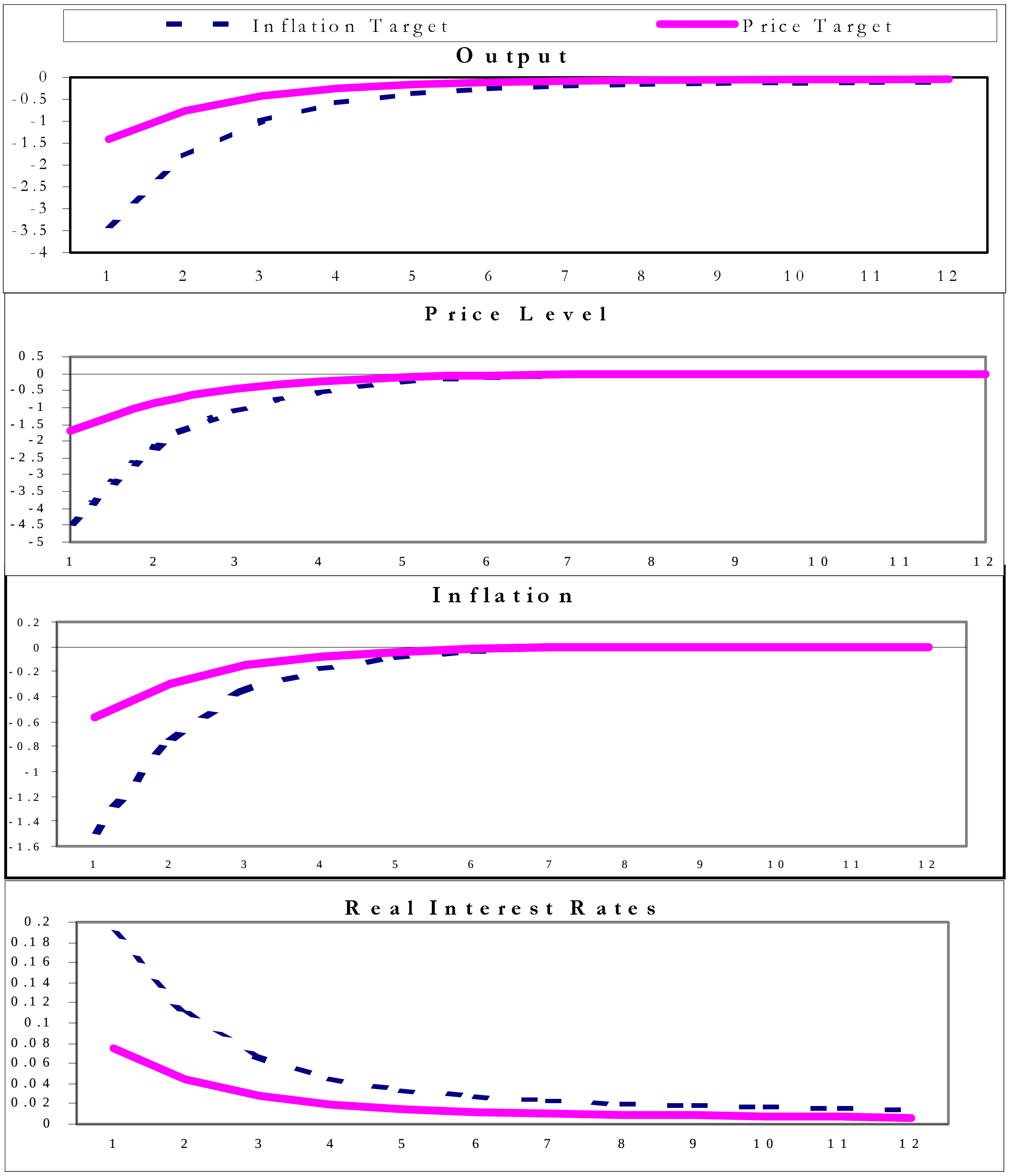

Figure 7.3: Impulse Responses to a Monetary Shock-% deviaiton from baseline

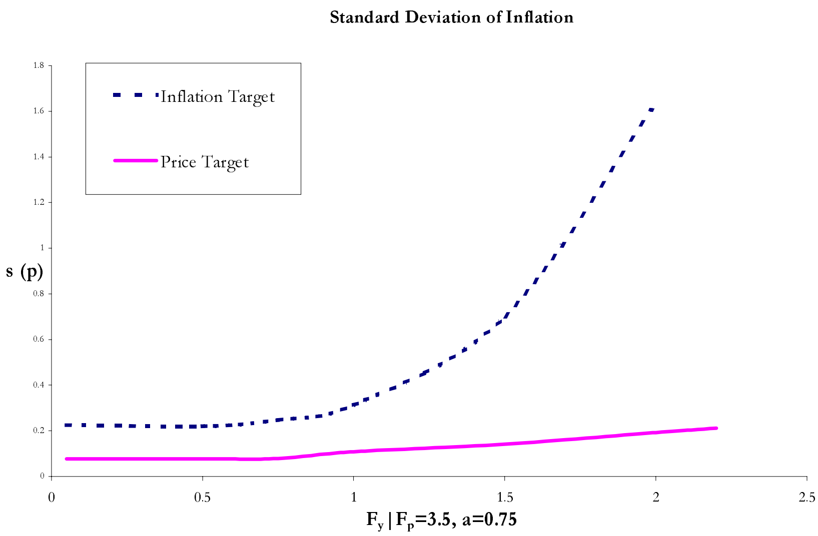

Figure 7.4: Increasing the Weight on Output Deviations and Inflation Variability

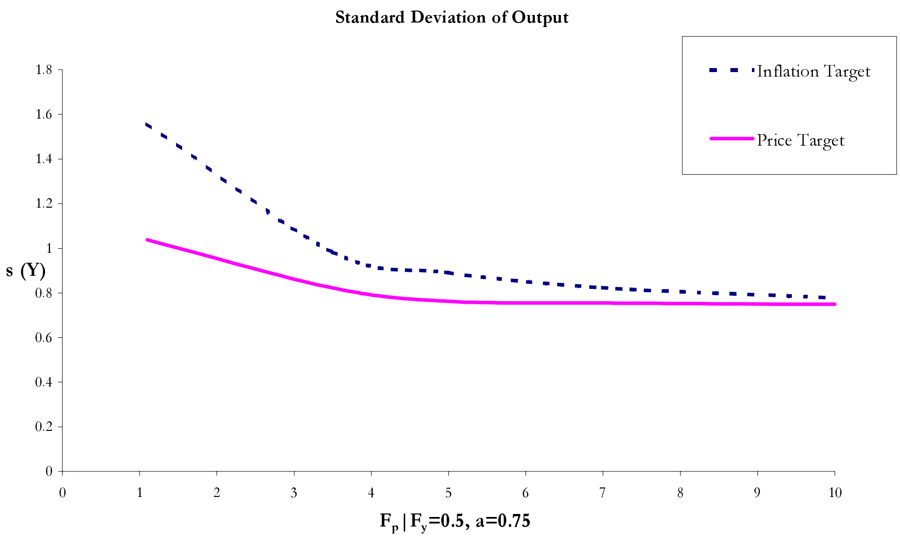

Figure 7.5: Increasing the Weight on Inflation Deviations and Output Variability

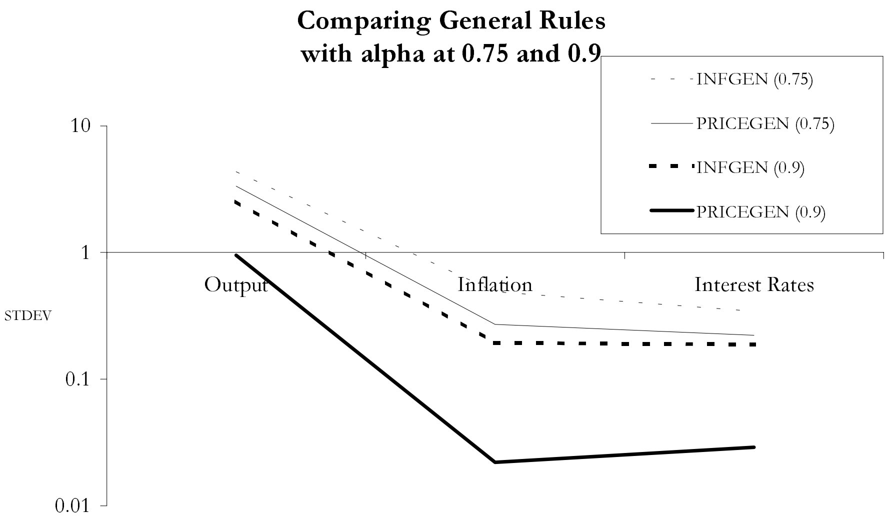

Figure 7.6: The Impact of Increasing Price Stickiness

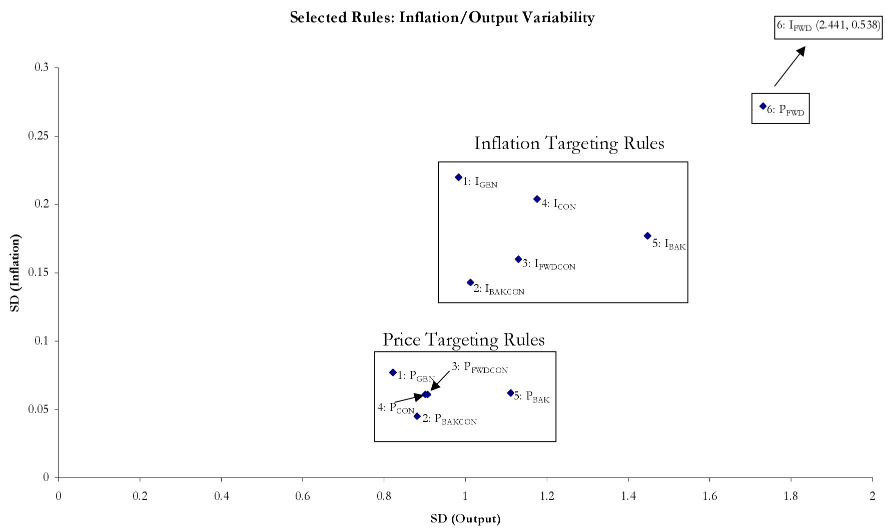

Figure 7.7: Comparing the Standard Rules in Output and Inflation Space

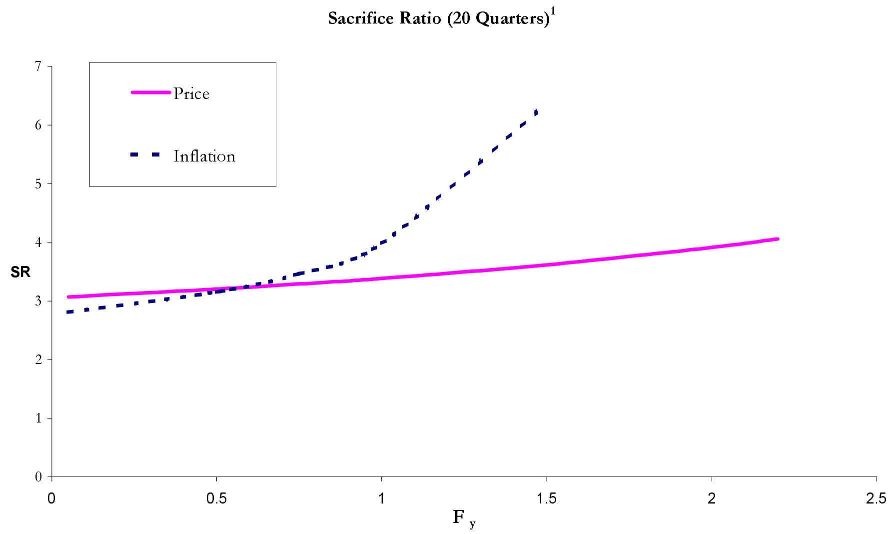

Figure 7.8: Sacrifice Ratios and Increasing Output Stabilisation

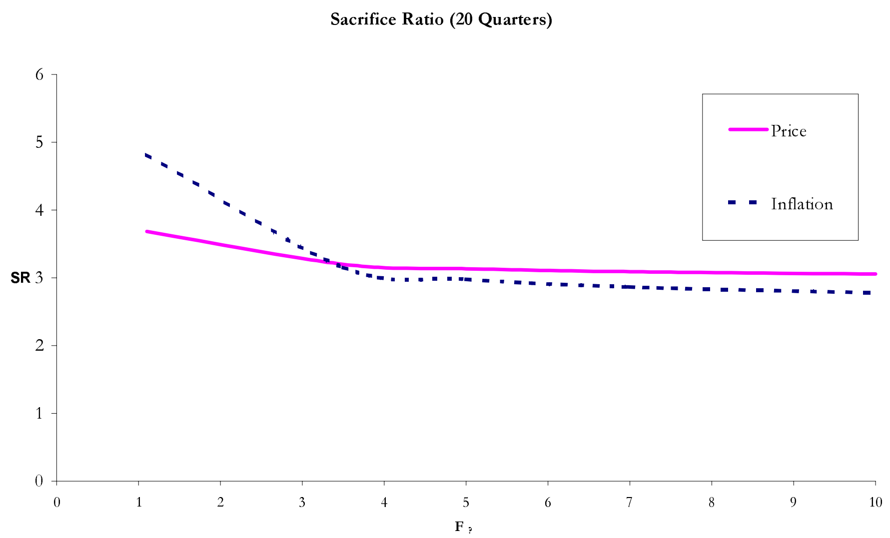

Figure 7.9: Sacrifice Ratios and Increasing Inflation Stabilisation

Table 1 Quarterly percentages

r	s_k	ν	γ	δ
1.25	38	2.5	0.5	0.75

Table 2 Inflation Targeting Rule - Bandpass Filtered

Variable	$\frac{\sigma_x}{\sigma_y}$	y_{t-4}	y_{t-3}	y_{t-2}	y_{t-1}	y_t	y_{t+1}	y_{t+2}	y_{t+3}	y_{t+4}
y	1									
c	0.77	0.783	0.824	0.867	0.914	0.947	0.863	0.779	0.701	0.628
i	2.27	0.325	0.447	0.584	0.732	0.903	0.799	0.702	0.612	0.532
k	0.64	0.801	0.780	0.742	0.687	0.612	0.546	0.491	0.442	0.399
l	0.16	-0.274	-0.406	-0.545	-0.681	-0.856	-0.727	-0.618	-0.521	-0.442
n	0.63	0.274	0.406	0.545	0.681	0.856	0.727	0.618	0.521	0.442
w	0.89	0.732	0.791	0.853	0.918	0.978	0.882	0.789	0.704	0.626
pi	0.15	-0.567	-0.524	-0.502	-0.525	-0.483	-0.539	-0.547	-0.546	-0.515
p	0.45	-0.568	-0.524	-0.502	-0.525	-0.483	-0.539	-0.547	-0.545	-0.515
$Real$	0.02	-0.296	-0.301	-0.272	-0.192	-0.142	-0.040	0.014	0.053	0.065
R	0.11	-0.764	-0.764	-0.777	-0.817	-0.814	-0.796	-0.750	-0.704	-0.643
Z	1.16	0.045	0.190	0.342	0.486	0.684	0.556	0.454	0.364	0.297
M	0.36	0.340	0.296	0.208	0.138	0.037	-0.013	-0.047	-0.055	-0.047

Table 3 Price Targeting Rule - Bandpass Filtered

Variable	$\frac{\sigma_x}{\sigma_y}$	y_{t-4}	y_{t-3}	y_{t-2}	y_{t-1}	y_t	y_{t+1}	y_{t+2}	y_{t+3}	y_{t+4}
y	1									
c	0.78	0.805	0.842	0.880	0.925	0.953	0.874	0.790	0.716	0.648
i	2.22	0.404	0.510	0.629	0.769	0.909	0.839	0.754	0.683	0.621
k	0.66	0.807	0.784	0.747	0.695	0.625	0.560	0.502	0.450	0.401
l	0.10	-0.248	-0.375	-0.508	-0.649	-0.805	-0.723	-0.635	-0.562	-0.504
n	0.41	0.247	0.375	0.508	0.648	0.804	0.723	0.634	0.562	0.504
w	0.84	0.772	0.821	0.873	0.931	0.976	0.893	0.805	0.728	0.658
pi	0.06	-0.528	-0.479	-0.463	-0.495	-0.479	-0.502	-0.499	-0.491	-0.465
p	0.19	-0.578	-0.480	-0.463	-0.495	-0.479	-0.503	-0.500	-0.491	-0.464
$Real$	0.02	-0.306	-0.259	-0.176	-0.044	0.078	0.120	0.133	0.146	0.150
R	0.04	-0.830	-0.799	-0.779	-0.780	-0.744	-0.708	-0.661	-0.616	-0.565
Z	0.90	0.135	0.267	0.407	0.557	0.725	0.654	0.573	0.508	0.457
M	0.70	0.831	0.873	0.911	0.942	0.864	0.776	0.700	0.631	0.589

Table 4 Taylor Rule Estimates – $\phi_\pi = 3.5$

OLS[1]

π_{t-i}, y_{t-j}	Long Run Coefficients Price Target	LM Test	p-value	Long Run Coeffici Inflation Target
i=1,... 8, j=1,... 8	$\pi_t = -7.1$ $y_t = 0.39$ [-3.56]	2.56	0.01	$\pi_t = 1.23$ $y_t = 0.$
i=1,... 7, j=1,... 7	$\pi_t = 11.92$ $y_t = -0.61$ [-3.59]	1.86	0.08	$\pi_t = 1.24$ $y_t = 0.$
i=1,... 6, j=1,... 6	$\pi_t = 3.34$ $y_t = -0.18$ [-3.58]	2.94	0.01	$\pi_t = 1.25$ $y_t = 0.$
i=1,... 5, j=1,... 5	$\pi_t = 3.37$ $y_t = -0.26$ [-3.58]	4.73	0.000	$\pi_t = 1.28$ $y_t = 0.$
i=1,... 4, j=1,... 4	$\pi_t = 3.30$ $y_t = -0.27$ [-3.62]	3.61	0.008	$\pi_t = 1.28$ $y_t = 0.$
i=1,... 3, j=1,... 3	$\pi_t = 2.44$ $y_t = -0.09$ [-3.60]	3.96	0.01	$\pi_t = 1.23$ $y_t = 0.$
i=1, 2, j=1, 2	$\pi_t = 2.01$ $y_t = -0.02$ [-3.59]	12.96	0.000	$\pi_t = 1.18$ $y_t = 0.$
i=1, j=1	$\pi_t = 2.22$ $y_t = -0.06$ [-3.60]	0.58	0.45	$\pi_t = 1.24$ $y_t = 0.$
i=0, 1,... 4, j=0, 1,... 4	$\pi_t = 1.35$ $y_t = 0.11$ [-8.20]	112.43	0.000	$\pi_t = 1.08$ $y_t = 0.$
i=0, 1,... 3, j=0, 1,... 3	$\pi_t = 1.29$ $y_t = 0.14$ [-8.12]	173.25	0.000	$\pi_t = 1.05$ $y_t = 0.$
i=0, 1,... 2, j=0, 1,... 2	$\pi_t = 1.25$ $y_t = 0.17$ [-8.09]	247.27	0.000	$\pi_t = 1.03$ $y_t = 0.$
i=0, 1, j=0, 1	$\pi_t = 1.21$ $y_t = 0.19$ [-8.08]	466.28	0.000	$\pi_t = 1.02$ $y_t = 0.$
i=0, j=0	$\pi_t = 0.85$ $y_t = 0.01$ [-4.29]	24.68	0.000	$\pi_t = 0.80$ $y_t = 0.$

[1] Values in parenthesis are Akaike Information Criteria.

IV[2]

π_{t+i}, y_{t+j}	Long Run Coefficients Price Target	Long Run Coefficients Inflation Target
i=1,... 4, j=1,... 4	$\pi_t = -4.7$ $y_t = 2.54$	$\pi_t = -0.3$ $y_t = 1.5$
i=1,... 3, j=1,... 3	$\pi_t = 0.80$ $y_t = 0.07$	$\pi_t = 0.85$ $y_t = 0.1$
i=1, 2, j=1, 2	$\pi_t = 0.72$ $y_t = 0.05$	$\pi_t = 0.80$ $y_t = 0.12$
i=1, j=1	$\pi_t = 0.75$ $y_t = 0.04$	$\pi_t = 0.83$ $y_t = 0.09$
i=0, 1,... 4, j=0, 1,... 4	$\pi_t = 1.39$ $y_t = -0.16$	$\pi_t = 3.61$ $y_t = -2.91$
i=0, 1,... 3, j=0, 1,... 3	$\pi_t = -1.11$ $y_t = 1.50$	$\pi_t = 0.50$ $y_t = 0.78$
i=0, 1,... 2, j=0, 1,... 2	$\pi_t = 0.51$ $y_t = 0.19$	$\pi_t = 0.73$ $y_t = 0.25$
i=0, 1, j=0, 1	$\pi_t = 0.68$ $y_t = 0.12$	$\pi_t = 0.82$ $y_t = 0.15$
i=0, j=0	$\pi_t = 0.51$ $y_t = 0.01$	$\pi_t = 0.67$ $y_t = 0.01$
i=-1, 1, j=-1, 1[3]	$\pi_t = 1.77$ $y_t = 0.05$	$\pi_t = 1.24$ $y_t = 0.06$

[2] For all IV estimation, the instruments comprise a constant, and lags 1-4 or R_t, π_t and y_t.

[3] Instruments comprise a constant and lags 2-4 of R_t, π_t and y_t.

Table 5 Taylor Rule Estimates – $\phi_\pi = 5$

OLS[2]

π_{t-i}, y_{t-j}	Long Run Coefficients Price Target	LM Test	p-value	Long Run Coeffici Inflation Target
i=1,... 8, j=1,... 8	$\pi_t = -0.53$ $y_t = 0.18$ [-4.30]	1.99	0.05	$\pi_t = 1.40$ $y_t = 0.$
i=1,... 7, j=1,... 7	$\pi_t = -1.54$ $y_t = 0.28$ [-4.32]	2.38	0.03	$\pi_t = 1.42$ $y_t = 0.$
i=1,... 6, j=1,... 6	$\pi_t = -48.62$ $y_t = 5.17$ [-4.30]	3.82	0.002	$\pi_t = 1.39$ $y_t = 0.$
i=1,... 5, j=1,... 5	$\pi_t = 32.26$ $y_t = -3.57$ [-4.31]	3.68	0.004	$\pi_t = 1.46$ $y_t = -$
i=1,... 4, j=1,... 4	$\pi_t = 10.92$ $y_t = -1.14$ [-4.33]	4.78	0.001	$\pi_t = 1.48$ $y_t = -$
i=1,... 3, j=1,... 3	$\pi_t = 4.49$ $y_t = -0.28$ [-4.29]	3.57	0.016	$\pi_t = 1.37$ $y_t = 0.$
i=1, 2, j=1, 2	$\pi_t = 3.16$ $y_t = -0.11$ [-4.28]	8.05	0.000	$\pi_t = 1.29$ $y_t = 0.$
i=1, j=1	$\pi_t = 3.48$ $y_t = -0.15$ [-4.30]	0.17	0.68	$\pi_t = 1.37$ $y_t = 0.$
i=0, 1,... 4, j=0, 1,... 4	$\pi_t = 1.55$ $y_t = 0.13$ [-8.73]	125.52	0.000	$\pi_t = 1.13$ $y_t = 0.$
i=0, 1,... 3, j=0, 1,... 3	$\pi_t = 1.49$ $y_t = 0.15$ [-8.73]	179.50	0.000	$\pi_t = 1.09$ $y_t = 0.$
i=0, 1,... 2, j=0, 1,... 2	$\pi_t = 1.44$ $y_t = 0.17$ [-8.69]	262.33	0.000	$\pi_t = 1.07$ $y_t = 0.$
i=0, 1, j=0, 1	$\pi_t = 1.41$ $y_t = 0.19$ [-8.68]	484.95	0.000	$\pi_t = 1.05$ $y_t = 0.$
i=0, j=0	$\pi_t = 0.95$ $y_t = -0.00$ [-8.68]	13.69	0.000	$\pi_t = 0.79$ $y_t = 0.$

[2] Values in parenthesis are Akaike Information Criteria.

IV[2]

π_{t+i}, y_{t+j}	Long Run Coefficients Price Target	Long Run Coefficients Inflation Target
i=1,... 4, j=1,... 4	$\pi_t = -8.17$ $y_t = 3.42$	$\pi_t = 0.29$ $y_t = 0.61$
i=1,... 3, j=1,... 3	$\pi_t = 0.95$ $y_t = 0.04$	$\pi_t = 0.87$ $y_t = 0.06$
i=1, 2, j=1, 2	$\pi_t = 0.79$ $y_t = 0.04$	$\pi_t = 0.79$ $y_t = 0.08$
i=1, j=1	$\pi_t = 0.76$ $y_t = 0.04$	$\pi_t = 0.81$ $y_t = 0.07$
i=0, 1,... 4, j=0, 1,... 4	$\pi_t = 1.21$ $y_t = 0.05$	$\pi_t = 1.14$ $y_t = 0.36$
i=0, 1,... 3, j=0, 1,... 3	$\pi_t = -13.46$ $y_t = 7.60$	$\pi_t = 0.38$ $y_t = 0.77$
i=0, 1,... 2, j=0, 1,... 2	$\pi_t = 0.38$ $y_t = 0.22$	$\pi_t = 0.69$ $y_t = 0.21$
i=0, 1, j=0, 1	$\pi_t = 0.67$ $y_t = 0.14$	$\pi_t = 0.79$ $y_t = 0.12$
i=-1, 1, j=-1, 1[3]	$\pi_t = 2.13$ $y_t = 0.43$	$\pi_t = 1.14$ $y_t = 0.28$

[2] For all IV estimation, the instruments comprise a constant, and lags 1-4 or R_t, π_t and y_t.

[3] Instruments comprise a constant, and lags 2-4 or R_t, π_t and y_t.