

# The Reputational Constraint on Monetary Policy

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*In the context of a standard model of optimal monetary policy, I argue that expectations should be treated as adaptive rather than rational. This argument is justified by considering the rational expectations equilibrium of this model as the limit point of a sequence in which agents progressively modify their forecasts of inflation to make them efficient. I show that this learning process is unlikely to occur, in real time, because of the large amount of data that would be required. When expectations are adaptive, there is no longer a ‘time-inconsistency’ problem, and since inflation policy influences expectations of future inflation, the central bank’s concern for its reputation induces it to deliver optimal (time-consistent) policy. In a final section, the implications of these results for central bank independence are discussed.*

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The analysis of this paper is conducted within the basic model of monetary policy in which the central bank aims for low inflation and high employment subject to a Phillips curve, with employment rising when actual inflation exceeds expected inflation. When this optimizing exercise is solved as a rational expectations (or Nash) equilibrium, the result is ‘discretionary’ policy with ‘inflationary bias’: inflation is held above the desired level with no gain in employment.

In view of this unwelcome result, the early exponents of this model (Kydland and Prescott, 1977; Barro and Gordon, 1983) pointed out the improvement that would follow if the central bank were rather bound by a ‘rule’ committing it to hold inflation at the desired lower level. But the rule is ‘time inconsistent’, in the sense that the bank always has an incentive to reap the short term gain from returning to the discretionary policy. Agents therefore doubt the commitment and expected inflation remains high, which removes any advantage. These findings have led to a series of papers that study ways in which the monetary authority may be credibly induced to move away from ‘discretion’ and towards the ‘rule’, under a variety of model assumptions. They have also been used to justify central bank independence<sup>1</sup>

McCallum (1997) has however argued that, regardless of any commitment, a sustained policy of lower inflation must, in time, be rewarded by lower inflation expectations. Assuming that the central bank is interested in outcomes in the future in addition to the current period, this would provide an incentive to hold inflation policy below the discretionary level, without the need for any other special devices designed for this purpose. In other words, the bank will be keen to establish a reputation for low inflation and it will therefore follow a policy of low inflation.

In this paper I take up McCallum’s point, and argue that agents’ expectations of inflation should be adaptive. They should be released from the strict requirement that their expectations are rational (i.e. efficient) forecasts of the known policy process, and allowed to form their expectations from observations of previous policy. I also argue that the assumption of rational expectations does not fit comfortably with the exercise that the central bank is being asked to perform. The only reasonable interpretation of the bank’s optimizing exercise is that it is seeking the best policy at some arbitrary moment in time taking previous policy as given. While aware of the effect that its policy will have on expectations of future inflation, the bank has an open choice and is not bound in any way by the pattern of previous policy. It is then unrealistic to suppose that agents have the information necessary to form their required optimal forecasts.

For these reasons, I derive optimal policy in the standard framework under the assump-

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<sup>1</sup>The idea is that an independent central bank has a longer time horizon than the government, and its commitment to low inflation is therefore more credible. I question this reasoning in section 3 below.

tion that expectations are adaptive<sup>2</sup> (section 2). Equilibrium inflation turns out to be below the discretionary level, as expected, and it is a negative function of the discount factor: the more the central bank cares about the future, the lower its chosen inflation.

It is then confirmed that the policy under adaptive expectations is not, in general, a rational expectations equilibrium, because agents' expectations are not efficient forecasts. This leads to a discussion of how agents might learn to make their forecasts efficient, and it is shown that the end point of such a learning process is a return to the 'discretionary' rational expectations equilibrium. This exercise allows us to demonstrate how unlikely it is that such a process could complete its course, in real time.

I conclude that the assumption of adaptive expectations (or some similar process in which expectations follow the actual policy of the past few periods) is more appropriate for analyzing the problem in hand than rational expectations. The reputational constraint should then induce the central bank to conduct policy that is close to the social optimum.

Finally (section 3) I note that in the actual application of monetary policy, central banks set the short term nominal interest rate for the currency they issue, not the inflation rate. Employment and inflation both respond to the bank's interest rate choices, but with long lags. On the assumption that governments have a short time horizon, I suggest that the opportunity for temporary employment gain in the future is not a strong incentive for stimulatory monetary policy. But there remain reasons why governments may prefer interest rates that are lower than is consistent with inflation objectives. If a case is to be made for central bank independence, it should be these incentives on governments that are the main justification, rather than 'time-inconsistency' arguments.

I now set out the model formally and review the standard results.

## 1. The modeling framework and standard results

By choosing the inflation rate, the monetary authority (the central bank, in the following) aims at maximizing social welfare as expressed by a loss function that reflects a desire for low inflation (desired inflation is taken to be zero) and high employment, and an aversion to volatility in both these variables. The economy is represented by a single relationship: a Phillips curve in which actual inflation exceeds expected inflation when employment is higher than the natural rate.

Combining these elements together, the central bank's task is to find, in some period labeled  $t = 0$ , the path of the inflation rate  $\pi_t$ ,  $t = 0, \dots, \infty$ , that minimizes the expected value  $E_0(z_0)$  of the loss function  $z_0$

$$z_0 = \sum_{t=0}^{\infty} \frac{1}{2} \beta^t (\pi_t^2 + b(\pi_t - \pi_t^e - x^* + \varepsilon_t)^2) \quad (1)$$

where  $\beta \in [0, 1]$  is a discount factor,  $b \in (0, \infty)$  reflects the slope of the Phillips curve

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<sup>2</sup>Adaptive ('backward-looking') models have regained some popularity in a number of recent papers that formulate policy rules, such as Rudebusch and Svensson (1999). According to Blinder (1998, p.44), central bankers consider it obvious that expectations of inflation are closer to adaptive than rational.

and the weight attached to the employment objective relative to inflation,  $\pi_t^e$  is expected inflation,  $x^* > 0$  may be interpreted as the excess of desired employment over the natural rate of employment (expressed in logs and suitably normalized), and  $\varepsilon_t$  is white noise.<sup>3</sup>

In making its policy decision  $\pi_t$ , the central bank is assumed to observe current values of the state variables, being the agents' expectation of inflation  $\pi_t^e$  and the error term  $\varepsilon_t$ . The agents' information set at  $t$ , however, consists only of policy and their own expectations up to and including the previous period,  $t - 1$ . A solution is sought which is a rational expectations (or Nash) equilibrium, meaning in the present context that the central bank is optimizing taking agents' expectational behavior as given and expectations are efficient forecasts, written as  $\pi_t^e = E_{t-1}\pi_t$ .

### *'Discretion' and the 'rule'*

In the 'discretionary' solution to this problem, the central bank takes  $\pi_t^e$  as a given parameter in each period. The optimization exercise in any period is then independent of other periods, and the first-order condition which applies in all periods is  $(1 + b)\pi_t = b(\pi_t^e + x^* - \varepsilon_t)$ . Then applying the condition  $\pi_t^e = E_{t-1}\pi_t$  shows that  $\pi_t^e = bx^*$ , and optimal policy becomes

$$\pi_t = bx^* - b\varepsilon_t/(1 + b) \quad \text{'discretion' .} \quad (2)$$

Note that expectations  $\pi_t^e = bx^*$  are constant over time, which confirms that the central bank's treatment of  $\pi_t^e$  as a parameter is consistent with the solution being a rational expectations equilibrium as defined above.

This 'discretionary' solution contains the 'inflationary bias'  $bx^*$ , and the loss function is obviously not minimized. The desire to hold employment above the natural rate ( $x^* > 0$ ) causes average inflation to be permanently above its desired level (zero), but there is no average gain in employment because of the condition  $\pi_t^e = E_{t-1}\pi_t$ . Agents always expect the policy  $\pi_t = bx^* - b\varepsilon_t/(1 + b)$ , hence expectations are stuck at  $\pi_t^e = bx^*$ . The central bank would gain by reducing  $\pi_t$  below the discretionary level if this action led to some corresponding reduction in  $\pi_t^e$ . But agents interpret any deviations of  $\pi_t$  from  $bx^*$ , however prolonged, as being the usual random fluctuations (caused by the disturbance  $\varepsilon_t$ ), rather than as a signal of a change in policy. Agents have no reason to take notice of policy.

The 'inflationary bias' problem has led to the idea that the central bank should rather make a commitment to obey a state-contingent 'rule'  $\pi_t(\pi_t^e, \varepsilon_t)$  for all time. Assuming that agents believe in the commitment, this device enables the central bank to determine their inflation expectations. Suppose then that the central bank binds itself to the rule

$$\pi_t = \alpha_0 + \alpha_1\pi_t^e + \alpha_2\varepsilon_t \quad , \quad (3)$$

where it will choose the coefficients  $\alpha_k$  so as to minimize the unconditional expectation of the loss function  $E(z_0)$ . Seeing this policy, agents rationally form their expectations

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<sup>3</sup>The central bank's immediate task is to find  $\pi_0$  for the period  $t = 0$ . In general this implies simultaneously choosing an optimal plan  $\hat{\pi}_t$  for all periods  $t = 0, \dots, \infty$ , in which  $\hat{\pi}_t$  is contingent on the realizations of the errors  $\varepsilon_j$ ,  $j = 0, \dots, t$ .

according to  $\pi_t^e = E_{t-1}\pi_t$ , which leads to  $\pi_t - \pi_t^e = \alpha_2\varepsilon_t$ , i.e.  $\pi_t^e = \alpha_0/(1 - \alpha_1)$ . This confirms that, in setting the coefficients  $\alpha_k$ , the central bank implicitly chooses  $\pi_t^e$ . Rewriting (1) as a function of the coefficients, and taking unconditional expectations

$$E(z_0) = \sum_{t=0}^{\infty} \frac{1}{2}\beta^t \left( \left( \frac{\alpha_0}{1 - \alpha_1} \right)^2 + \alpha_2^2 \sigma_\varepsilon^2 + b(\sigma_\varepsilon^2(1 + \alpha_2)^2 - x^{*2}) \right) , \quad (4)$$

the exercise then amounts to setting the partial derivatives of (4) with respect to  $\alpha_k$  equal to zero. This leads to  $\alpha_0/(1 - \alpha_1) = 0$ , implying that  $\pi_t^e = 0, \forall t$ , and  $\alpha_2 = -b/(1 + b)$ . Substituting into (3), the ‘rule’ for all periods is

$$\pi_t = -b\varepsilon_t/(1 + b) \quad \text{‘rule’} \quad (5)$$

in which the inflationary bias  $bx^*$  of the discretionary solution (2) is no longer present. It is obvious that this rule yields a lower expected value of the loss function in all periods than the discretionary solution, and it is thus a superior outcome.<sup>4</sup>

### *Discussion*

How is the central bank to demonstrate its commitment to this rule? In the assumed framework in which agents know the central bank’s objectives, they also know that the bank would gain by returning to discretionary policy at any time, and they doubt any promise by the bank that it will adhere to the policy rule: the rule is ‘time-inconsistent’. Unless there is some credible ‘precommitment technology’ to bind the bank, the policy rule (5) is not a possible solution because agents expect inflation to stay at the discretionary level. The best that the central bank can do then is to validate these expectations by executing discretionary policy (2). We are thus left with the ‘time-consistent’ but inferior policy (2) as the rational expectations equilibrium corresponding to the loss function (1).<sup>5</sup>

This dilemma has motivated a number of studies seeking to move policy away from discretion and towards the rule, by giving the central bank an objective which differs in some way from the assumed social objective. Rogoff (1985), for instance, has recommended that the central bank should be made ‘conservative’ by giving it a loss function with less weight attached to employment than in the social loss function. Walsh (1995) shows that inflation is reduced if the bank faces the social loss function but with an added inflation target. And Svensson (1997a) ranks these proposals and others under the

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<sup>4</sup>Clearly the superiority of the time-inconsistent ‘rule’ in this simple model depends on the bank’s desire to raise employment above the natural level, i.e.  $x^* > 0$ , an assumption that has been thoroughly discussed elsewhere (e.g. Svensson (1997a, p.100)). But this is not true in general. In a model using a New-Keynesian Phillips curve, Woodford (1999) finds that the rule is superior to discretion even if  $x^* = 0$ . The essential difference between his model and the structure presented here is that  $\pi_t^e = E_{t-1}\pi_t$  in (1) is replaced by  $\pi_{t+1}^e = E_t\pi_{t+1}$ .

<sup>5</sup>Note that the ‘discretion’ and ‘rule’ results are not two different solutions to the same optimization problem; they arise from different model assumptions. In the ‘rule’, the central bank is enabled (by means of its commitment) to choose  $\pi_t^e$  in addition to  $\pi_t$ . An alternative way to generate the ‘rule’ would be to change the informational specification so that agents observe *current* policy. This would, of course, deny any opportunity to raise employment by ‘surprise’ inflation.

additional complication that employment persistence exists. In all these studies, the policy solutions are rational expectations equilibria, and the benchmark for comparing the various proposals is the ‘discretionary’ equilibrium which results when the central bank’s objective is the same as the social objective.

In a different approach, but remaining within the rational expectations framework, the model of Cukierman and Meltzer (1986) is deliberately constructed to show how inflation can be held in check by the reputational constraint. This is achieved by using a similar objective function to (1) but the weight on the employment argument is a persistent random variable unseen by agents which in turn causes persistence in the policy time-series.<sup>6</sup> In contrast to the discretionary policy derived above, this gives agents a reason to observe policy, as this information is now of value in their predictions of future policy. This influence of inflation policy on future expectations makes the central bank conscious of its reputation. It serves to moderate the central bank’s temptation to gain a short term improvement in employment by raising inflation, and equilibrium inflation is consequently lower than the discretionary result.

McCallum (1997), however, has argued that if the central bank were actually to keep inflation fixed at any level for an extended period, then *rational* agents would adjust their expectations accordingly. Agents do not need some particular time-series structure of policy (as in Cukierman and Meltzer) to make it worthwhile for them to observe it and change their expectations as appropriate. If, for instance, a central bank held  $\pi_t = 0$  for a long time, agents’ expectations would surely converge towards  $\pi_t^e = 0$  whatever their initial expectation  $\pi_0^e$ . The central bank, in turn, would not be blind to the reward that lower expectations would bring, in terms of an improvement in the tradeoff between inflation and employment. Hence, irrespective of any binding commitment, a central bank with a concern for the future (specified as a discount factor  $\beta > 0$ ) would be induced to reduce its policy  $\pi_t$  below the discretionary value and towards the rule. It should thus be unnecessary to ask the bank to work with some modified objective function that deliberately induces lower inflation.

This is a plausible argument, but it is not consistent with the solution being a rational expectations equilibrium. The expectations of McCallum’s *rational* agents are not the optimal forecasts of agents who know the time-series properties of inflation policy. If we are to follow McCallum’s reasoning, we must rather give agents an expectations-forming mechanism which reflects the intuition that agents’ expectations of inflation catch up with the path of actual policy, whatever the central bank chooses that path to be. When this is done, we should expect to find the central bank responding to the reputational incentive by setting  $\pi_t$  lower than the discretionary level. Moreover the level of optimal  $\pi_t$  should depend on the degree to which the central bank cares about future periods, as reflected in the discount factor,  $\beta$ . A higher  $\beta$  should cause a lower  $\pi_t$  closer to the target (zero). Neither of the two policies derived so far, ‘discretion’ or ‘rule’, is a function of  $\beta$ .

Another reason to move away from a rational expectations equilibrium is the informa-

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<sup>6</sup>Cukierman and Meltzer’s (1986) objective function also differs from (1) in being linear in the second argument, which removes the aversion to employment volatility.

tion requirement. At equilibrium, agents' expectations are efficient predictors of policy, hence they behave as if they know the time-series properties of inflation policy (trivially, an i.i.d. random variable with mean  $bx^*$  in the case of the above 'discretionary' policy). As is often acknowledged (by Clarida, Gali and Gertler, 1999, p.1703, for example), one needs to ask how agents find out about the optimal policy path before it has been derived.

One way to address this difficulty is to suppose that agents know the model of the economy, the form of the loss function, and all the relevant parameters. This information enables them to solve the optimization problem for themselves, thereby deriving the required time-series properties of policy. But this assumption is hardly compatible with the way the problem has been posed, in which the central bank is asked to discover its optimal policy starting afresh at some arbitrary time  $t = 0$ .<sup>7</sup>

An alternative assumption is that agents learn the properties of the policy series by observation over time. But suppose that there is a change in one of the model parameters, the slope of the Phillips curve, for instance. The nature of the exercise is that the central bank must be free to consider the relative merits of all alternative policies, and not be bound by previous policy behavior. But if the bank does change policy and agents' forecasts are based on the history of policy, then those forecasts will no longer be optimal. The model does not specify how agents' expectations will then behave and without this information the bank cannot find its optimum.

What is needed, therefore, is some expectations-forming process that applies independently of equilibrium and does not rely on agents' knowledge of the time-series properties of policy. I proceed by assuming that agents' expectations are formed mechanically from observation of previous policy. Later I shall consider how they might modify their expectations formula over time in attempt to make their forecasts efficient.

## 2. Adaptive expectations

The obvious choice of a simple mechanism in which inflation expectations catch up with actual inflation is the adaptive formula<sup>8</sup>

$$\pi_t^e = \lambda\pi_{t-1}^e + (1 - \lambda)\pi_{t-1} \quad , \quad \forall t \geq 1 \quad , \quad (6)$$

in which the error-correction parameter  $\lambda \in (0, 1)$  is assumed to be exogenous.

As before, the central bank's task is to choose the policy for period  $t = 0$  and thereafter that will minimize  $E_0(z_0)$  where  $z_0$  is given by (1). But in contrast with both the discretionary and rule solutions, the central bank now knows that its policy in any period will determine future expectations according to (6). In line with the above discussion, it

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<sup>7</sup>Svensson (1999) agrees that the central bank's job is to find optimal policy "more or less from scratch, without being bound by previous decisions". Woodford's (2000) call for policy to be 'history dependent' is relevant when optimal policy is a rational expectations equilibrium, and does not apply when expectations are adaptive ('backward-looking') as will be assumed below.

<sup>8</sup>The adaptive formula makes the Phillips tradeoff contained in (1) into an 'accelerationist' type: above-natural employment is associated with *rising* inflation.

is supposed that the central bank takes no account of the past (except to the extent that the past may help to inform the bank of the value of  $\lambda$ ), and the initial expectation  $\pi_0^e$  is taken as given.

Applying (6) to the loss function of (1), the resulting optimal policy (as derived in the appendix) is<sup>9</sup>

$$\pi_t = \pi^* + \frac{\theta_0 - \lambda}{1 - \lambda}(\pi_t^e - \pi^*) + \mu_t \quad , \quad \forall t \geq 0 \quad , \quad (7)$$

where 
$$\pi^* = bx^*(1 - \beta)/(1 - \beta\lambda) \quad , \quad (8)$$

where  $\theta_0 \in (\lambda, 1)$  is a function of parameters, satisfying

$$b = \frac{(1 - \beta\lambda\theta_0)(\theta_0 - \lambda)}{(1 - \beta\theta_0)(1 - \theta_0)} \quad , \quad (9)$$

and  $\mu_t$  is white noise.

Let us consider the properties of this solution. Using (6) and (7) it may be shown that policy follows the ARMA(1,1) process

$$\pi_t - \pi^* = \theta_0(\pi_{t-1} - \pi^*) + \mu_t - \lambda\mu_{t-1} \quad , \quad (10)$$

which implies, given  $\theta_0 < 1$ , that policy  $\pi_t$  tends towards the steady-state mean  $\pi^*$ .<sup>10</sup>

Equation (8) then shows that policy has the properties that were sought. Mean inflation  $\pi^*$  is negatively related to the discount factor  $\beta$ : the more the central bank cares about the future, the lower the chosen inflation rate. Moreover, if  $\beta$  is in the open interval  $(0, 1)$ ,  $\pi^*$  is a declining function of the speed  $(1 - \lambda)$  at which expectations adjust: the faster agents learn about central bank policy, the smaller the opportunity for short term gain by generating surprise inflation.

The limiting results are also as one would intuitively expect. The discretionary outcome  $\pi^* = bx^*$  follows either from  $\beta = 0$  meaning that the central bank is only concerned about the current period, or from  $\lambda \rightarrow 1$  implying that policy has no effect on future expectations. At the opposite extreme, the policy rule  $\pi^* = 0$  is obtained if  $\beta = 1$ .

The adaptive mechanism thus captures the idea of reputation in a straightforward way. The central bank is conscious that gaining a short term advantage from high inflation incurs the future cost of high inflation expectations. This provides the incentive for a policy of lower inflation.

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<sup>9</sup>It is straightforward to verify that the policy of (7) is time consistent. The optimal *plan* in period  $t$  for some future period  $t + j$  (contingent on the realizations of the disturbances  $\mu_{t+k}$ ,  $k = 1, \dots, j$ ) is the policy that will be found to be optimal when period  $t + j$  arrives. In other words, Bellman's principle is obeyed.

<sup>10</sup>When the central bank begins to execute this policy at  $t = 0$ , the initial expectation  $\pi_0^e$  is inherited from the past. If  $\pi_0^e \gg 0$  and  $\lambda = 0.6$  (see footnote 13), employment in period zero would be well below target because  $\pi_0 \ll \pi_0^e$ , as Sargent (1999, p.52) has pointed out in analyzing a similar setup.



### *Can adaptive expectations be made rational?*

The discretionary solution (2) derived at the outset is the stationary rational expectations equilibrium for the central bank's optimization problem of (1), which means agents' expectations are efficient predictors of policy. It follows that the above adaptive expectations (6) do not, in general, provide efficient forecasts of policy (10). It is of interest to determine the extent to which the adaptive formula leads to systematic errors. Substituting (6) into (7), policy under adaptive expectations may be written

$$\pi_t - \pi^* = \frac{\theta_0 - \lambda}{1 - \lambda} \left( \lambda(\pi_{t-1}^e - \pi^*) + (1 - \lambda)(\pi_{t-1} - \pi^*) \right) + \mu_t .$$

Comparing this with (6) expressed as deviations from  $\pi^*$ ,

$$\pi_t^e - \pi^* = \lambda(\pi_{t-1}^e - \pi^*) + (1 - \lambda)(\pi_{t-1} - \pi^*)$$

it is clear that in using the adaptive formula (6), agents are systematically overpredicting the deviation of  $\pi_t$  from  $\pi^*$ , by the factor  $(1 - \lambda)/(\theta_0 - \lambda)$ .<sup>11</sup> The intuition is that agents can do better than the adaptive formula because that formula does not take account of the mean reversion of policy  $\pi_t$  towards  $\pi^*$ .

In fact, the efficient predictor of the policy process (10) is

$$\pi_t^e = \lambda\pi_{t-1}^e + (\theta_0 - \lambda)\pi_{t-1} + (1 - \theta_0)\pi^* , \quad \forall t \geq 1 . \quad (11)$$

This differs from (6) by the inclusion of the final term, and given  $\theta_0 \in (\lambda, 1)$ , it allows agents to recognize the mean reversion of the policy path.

Suppose then that agents observe policy for several periods and they become conscious that their forecasting can be improved. They find that policy is described by (7) or equivalently (10), and  $\theta_0 < 1$  which is the signal that their forecasting formula (6) is not optimal. They then estimate the relevant parameters  $\theta_0$  and  $\pi^*$ , and switch to formula (11).

But the policy path has been derived on the assumption that the central bank believes expectations are given by equation (6). If agents switch to (11), policy is no longer optimal, and it should also be changed. This implies that expectations should be revised again leading to a further revision of policy, and so on.

If the stages of this revision sequence are denoted by the index  $k$ , while  $\theta_0$  changes to  $\theta_1, \theta_2, \dots, \theta_k, \dots$ , then policy at stage  $k$  is (see appendix)

$$\pi_t = \pi^* + \frac{\theta_k - \lambda}{\theta_{k-1} - \lambda} (\pi_t^e - \pi^*) + \mu_t , \quad (12)$$

or 
$$\pi_t - \pi^* = \theta_k(\pi_{t-1} - \pi^*) + \mu_t - \lambda\mu_{t-1} , \quad (13)$$

and expected inflation is 
$$\pi_t^e = \lambda\pi_{t-1}^e + (\theta_{k-1} - \lambda)\pi_{t-1} + (1 - \theta_{k-1})\pi^* , \quad (14)$$

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<sup>11</sup>This result also follows directly from standard theory given the ARMA(1,1) structure of the policy series. The fact that adaptive expectations would be efficient if  $\theta_0 = 1$  is Muth's (1960) well known result.

where  $\pi^* = bx^*(1 - \beta\theta_{k-1})/(1 - \beta\lambda)$  , (15)

$\theta_k \in (\lambda, \theta_{k-1})$  is related to  $\theta_{k-1}$  by  $b = \frac{(1 - \beta\lambda\theta_k)(\theta_k - \lambda)}{(1 - \beta\theta_{k-1}\theta_k)(\theta_{k-1} - \theta_k)}$  , (16)

and  $\mu_t$  is white noise.

It may be seen from (13) that policy remains an ARMA(1,1) series, but as this process of revision takes its course the parameter  $\theta_k$  falls from its initial value  $\theta_0$ . Concurrently, (15) shows that mean inflation  $\pi^*$  rises. The process is convergent, and  $\theta_{k-1} = \theta_k$  at its limit point. In view of (16), however, and given that  $b$  lies in the open interval  $b \in (0, \infty)$ , this condition can only be satisfied if  $\theta_k = \lambda$  also holds, and hence  $\theta_{k-1} = \lambda$ . Then (15) shows that, at the limit point of this sequence, mean inflation  $\pi^*$  reverts to the ‘discretionary’ level,  $\pi^* = bx^*$ , while (14) shows that policy no longer affects future expectations:  $\partial E_0(\pi_{t+j}^e)/\partial \pi_t = 0, \forall j > 0$ . This implies as in the discretionary solution (see the appendix, equation (A3)) that  $\pi_t(\pi_t^e, \varepsilon_t) = b(\pi_t^e + x^* - \varepsilon_t)/(1 + b)$ .

Setting  $\theta_{k-1} = \lambda$  in (14) shows that  $\pi_t^e = \pi^*$  in the steady state, and policy is thus

$$\pi_t = bx^* - b\varepsilon_t/(1 + b) .$$

This is identical with the ‘discretionary’ solution (2). Allowing the expectations formula to evolve to enable optimal prediction, while maintaining optimal behavior by the central bank, has resulted in the rational expectations equilibrium.

### *Appraisal*

It has been shown how the ‘discretionary’ rational expectations solution for the economy specified by (1) may be reached as the limit point of a learning process. This is a satisfying result in that it lends legitimacy to this solution.<sup>12</sup> However we should consider how this adjustment process might work in practice.

Suppose, for the purpose of argument, that the central bank somehow keeps track of agents’ expectational behavior and has no trouble in re-optimizing policy accordingly. Suppose also that agents somehow know that policy is an ARMA(1,1) series. Even then, agents would need a large number of observations of policy before making changes to the parameters of their forecasting formula.

The signal that prompts their first revision is  $\theta_0 < 1$  (in equation 10). Let us assign some values to the parameters to get an idea of the number of observations that are necessary for this signal to be received. Supposing that the data is quarterly, let  $\lambda = 0.6$ , meaning that 0.4 of the influence on this quarter’s inflation expectation comes from the previous

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<sup>12</sup>Several papers have specifically studied learning in rational expectations models with the aim of determining whether equilibria are dynamically stable, given assumptions about the learning processes (see Bullard and Mitra, 2001, and the survey of Evans and Honkapohja, 1999). It would be closer to usual practice to have supposed in this paper that  $\theta_k$  and  $\pi^*$  are revised continuously rather than in discrete jumps, but this would add unnecessary complication. The purpose in the following discussion is simply to question whether any such learning process is likely to occur, in real time.

quarter's actual inflation<sup>13</sup>, with the remaining influence from earlier quarters. Let  $b = 1$ , and let the quarterly discount factor  $\beta = 0.99$ , which is equivalent to a real rate of interest of 4%. Using these numbers it may be deduced that around 200 observations of policy would be needed for agents to be sure with 90% confidence that  $\theta_0 < 1$ .<sup>14</sup> Subsequent revisions to the parameters of (11) would require even larger numbers of observations, because the variance of the estimate of  $\theta_k$  rises as  $\theta_k$  approaches  $\lambda$ .

The frequency of inflation data that is commonly used in econometric studies is quarterly, because of the volatility at higher frequencies. And it is surely optimistic to suppose that the economic structure and the central bank policy stance would remain static for more than, say, 10 years. This gives an outside maximum of 40 observations of inflation between structural changes, and this is far too few to allow agents to make any headway in the above learning program. Hence this process is most unlikely to reach the rational expectations equilibrium.

I suggest that, for the purpose in hand, the most plausible assumption is that agents base their expectations on observation of policy over the previous 2 or 3 years. The adaptive formula captures this idea in a simple way, but qualitatively similar results would be produced by any formula that based inflation expectations on a few past observations of actual inflation. Any formula in which inflation expectations catch up with actual inflation will produce the required reputational constraint on policy.

What is the magnitude of the reputational constraint? Using parameter values  $\lambda = 0.6$  and  $\beta = 0.99$  as above, (8) gives  $\pi^* = bx^*(1-\beta)/(1-\beta\lambda) = 0.025bx^*$ , i.e. average inflation is 2.5% of the discretionary result. Given adaptive expectations, and to the extent that the economic model embodied in (1) is realistic, this does indeed indicate that the central bank's reputation can be a powerful constraint against inflation.

### 3. Monetary policy in practice

I now comment briefly on the implications of the above analysis for the practical application of monetary policy, drawing particularly on the thorough reviews of Blinder (1998) and Clarida, Gali and Gertler (1999). The Kydland and Prescott 'time-inconsistency' model of the sort reproduced in section 1 above continues to have influence in discussions of central bank operating arrangements. Besides giving rise to suggestions like Rogoff's (1985) 'conservative' central banker, it has also often been used to justify central bank

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<sup>13</sup>If quarterly US inflation is assumed to follow  $\pi_t = \pi_{t-1} + \mu_t - \lambda\mu_{t-1}$ , which is the process for which (6) would be the efficient predictor, time-series analysis of CPI data from 1989.4 to 1999.4 yields an estimate of  $\lambda = 0.61$  (*s.e.* = 0.13).

<sup>14</sup>If agents know that the policy series is given by (10) but they do not know the parameters  $\theta_0$  and  $\lambda$  (it is presumed they are unaware that the  $\lambda$  in their expectations formula (6) is the same as the MA parameter in (10)), then the asymptotic variance of their estimate of  $\theta_0$  is  $V(\hat{\theta}_0) = \left(\frac{1 - \theta_0^2}{n}\right) \left(\frac{1 - \lambda\theta_0}{\lambda - \theta_0}\right)^2$ , where  $n$  is the number of observations. The chosen parameter values imply by (9) that  $\theta_0 = 0.73$ , leading to  $V(\hat{\theta}_0) = 8.7/n$ . Using the approximation that  $\hat{\theta}_0$  is normally distributed, 197 observations of  $\pi_t$  would be required for 90% confidence that  $\theta_0 < 1$ .

independence. The idea is that an independent central bank has a longer time horizon (higher discount factor, or lower discount rate) than the government, and its commitment to low inflation is therefore more credible.<sup>15</sup> But in the model a lower discount rate does not induce the central bank to reduce inflation; the discount rate is not connected with the ability to precommit, which is what distinguishes the superior ‘rule’ from the inferior ‘discretionary’ policy. As stressed earlier, the discount rate does not appear in either of these solutions. Hence this model (with rational expectations) does not make for a good argument in favor of central bank independence.

When rational expectations are replaced by adaptive, however, the (time-consistent) equilibrium inflation rate is a positive function of the discount rate. The more the bank cares about the future, the lower its inflation policy. Indeed it was shown above, that given plausible parameters including a low discount rate, the optimal time-consistent ‘discretionary’ policy would have negligible inflationary bias. The model *does* then provide a valid underpinning for central bank independence, if it is additionally assumed that the government has a higher discount rate than society (as in Blinder, 1998, p.55, for instance, and in models of the political business cycle), while the central bank has a longer view and can apply the social discount rate. In other words, the purpose of independence is to lengthen the time horizon of monetary policy so that the time-consistent policy that is achieved is optimal. Its purpose is not to enable the bank to commit to a time-inconsistent policy.

There is one other matter that merits discussion. The model as presented above assumes that the inflation rate  $\pi_t$  is the central bank’s policy instrument, whereas it is now generally acknowledged that in practice the bank’s instrument is the short term nominal interest rate for the currency that it issues. The effects that interest rate policy has on employment and inflation are not known with any precision. There are several competing models which are designed to describe these transmission linkages, and empirical analysis does not help much in distinguishing between them. There is uncertainty in the lag and the magnitude of the response of these variables to interest rate changes, and the lag is long: the peak in the response function of inflation to an interest rate change is typically thought to be delayed by 18 months or more.<sup>16</sup>

In spite of this uncertainty, the sign of the response is not in doubt: lower interest rates are associated with temporarily higher employment and higher inflation, eventually. Thus the interest rate instrument can indeed be used to steer inflation towards some prescribed level (Svensson’s (1997b) inflation *forecast* targeting). It clearly remains possible for monetary stimulus to raise aggregate demand via some assumed IS function, where

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<sup>15</sup>Posen (1998) looks for evidence that central bank independence raises the credibility of monetary policy and is unable to find any.

<sup>16</sup>In the US, the method by which the Federal Reserve implements its choices of the Fed funds rate is somewhat indirect, but few would now disagree with the characterization of monetary policy as interest rate setting. Indeed, much of the current literature on monetary policy is concerned with finding simple feedback rules to guide central banks in their choices of the interest rate instrument (see, for instance, the papers collected in Taylor, 1999), and it is becoming more common to allow for transmission lags. Whether or not a central bank could, if it so wished, use some alternative policy instrument such as the money base is not a settled issue (see McCallum; 1999).

monetary stimulus is now identified as a reduction in the short term nominal interest rate given the prevailing rate of inflation. And evidence on the Phillips relationship from quarterly US data (King and Watson, 1994) confirms an association between rising inflation and unemployment that is below the natural rate (or, strictly, below the NAIRU), while Granger tests indicate that the temporal ordering runs from unemployment to inflation.

The causal direction implicit in the standard model presented above therefore needs revision. Rising inflation (or inflation that is higher than it was expected to be, as in the model) does not cause higher than natural employment. It is more appropriate to think of lower real interest rates causing higher employment with a lag and rising inflation with a further lag,<sup>17</sup> but with neither of these linkages being accurately determined. It is in this light that we should consider how monetary policy is best administered.

### *The case for central bank independence*

Let us maintain the assumption that, because of imperfections in the political process, elected politicians have a shorter time horizon (higher discount rate) than the society they represent. Then given the lag in the response of employment to lower interest rates, the opportunity for temporary employment gain that motivates inflationary policy in the Kydland and Prescott model is unlikely in practice to be a strong incentive for the government.

But there are other, more immediate, reasons why governments may err towards low interest rates. Low interest rates are always more popular than high, presumably because borrowers are more vocal than savers, and borrowers suffer more from a rise in rates than savers suffer from a fall. Furthermore, lower interest rates are generally associated with a weaker foreign exchange rate which is favored by exporters. If the government's fiscal policy is stimulatory, it may be particularly hard, politically, for it to maintain interest rates that are consistent with the inflation objective. If a case is to be made for central bank independence, it is surely these short term political incentives for governments which should be the justification, along with the evidence indicating a negative correlation between inflation and independence.<sup>18</sup> If inflation does follow in the future, this is of lesser consequence, given the assumed discounting of the government. And inflation anyway brings the benefit to the government of greater seignorage income and the erosion of the real value of its (non-indexed) debt. One would therefore expect highly indebted governments to be less vigilant about keeping interest rates high enough to hold down inflation.

In support of these points, let us note that interest rate setting cannot be done simply by

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<sup>17</sup>The presence of the lag stretches the plausibility of the information structure assumed in the standard model. Rather than assuming that agents observe inflation policy after a delay of one period, it is more likely that they are as capable as the central bank in observing and predicting inflation. As pointed out by Goodhart and Huang (1998) this reasoning implies that there is limited scope for the central bank deliberately to raise employment by creating *unexpected* inflation, and it largely removes this source of 'time-inconsistency'.

<sup>18</sup>See Alesina and Summers (1993), for example, but Forder (2000) argues that this evidence is not convincing. The political influences on monetary policy are discussed in Persson and Tabellini (1999).

applying some formula, like the Taylor (1993) rule.<sup>19</sup> Besides the lack of precise knowledge of the effects of its interest rate choices, the timing and size of interest rate changes and the reasons publicly stated for the changes are all signals which affect expectations of future interest rate policy.<sup>20</sup> These, in turn, affect long-term interest rates and inflation expectations. These important linkages are not captured in a simple policy rule. Thus, even with a well specified objective, the choice of the time path of the interest rate that is most appropriate to meet that objective has to rely on judgement. If interest rate choices are left to governments, the necessity for judgement in making these choices allows scope for cheating. With the government using its discretion (in the dictionary sense) in setting interest rate policy, it can publicly claim that its interest rate policy is truly devoted to social objectives, while actually delivering interest rates which it suspects are too low and will potentially generate higher future inflation.

#### 4. Concluding remarks

I have argued, in the context of a basic model of optimal monetary policy, that agents' expectations should be treated as adaptive rather than rational. This argument was supported by considering the rational expectations equilibrium of this model as the limit point of a sequence in which agents improve the efficiency of their inflation forecasts over time. The large amount of data that would be required for this exercise makes it more likely that their expectations remain adaptive.

Obviously the assumption that expectations are adaptive is oversimplified. For instance, real world agents are not ignorant of how a central bank has reacted in the past to exogenous events. Hence it is not only previous levels of inflation but also agents' knowledge of the bank's reaction function and other information such as the bank's announcements that will influence their expectations. However the principle derived in this paper remains intact. Given that expectations of policy are important for the successful achievement of the policy, and provided that the central bank has a low discount rate, its concern for its reputation constrains it to deliver policy that is genuinely directed towards the given goals. As Blinder (1998) emphasizes, central bankers are acutely aware of the value of building a reputation for achieving the policy that agents have been led to expect.

On these arguments, any case that is made for central bank independence must rest on the assumption that governments have a short time horizon (high discount rate). But then the urge to stimulate employment that causes inflationary policy in the simple model is unlikely to be a strong incentive in practice, because of the lagged response of employment to changes in the interest rate instrument. There are, however, other short-term reasons

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<sup>19</sup>In the current research programme into monetary policy rules, formulae are derived in which the interest rate is a linear function of a few observed variables such as output and inflation. The aim is to find formulae which are 'robust' under variations in the assumptions about the economic structure and the types of disturbances to which policy must respond. But as Taylor (1999) acknowledges, there is no presumption that policy could ever adhere rigidly to a formula. The rules are designed to help the bank in its judgement of suitable interest rate policy.

<sup>20</sup>See Goodhart (1999) for a discussion of how the pattern of changes in central banks' interest rates is influenced by the desire to avoid media accusations of inconsistency.

why governments may be inclined towards low interest rates. Thus the main point of central bank independence is to lengthen the time horizon of monetary policy, so that the (time-consistent) policy that is pursued is optimal. The rationale for independence is not to enable to bank to move closer to some ideal time-inconsistent policy.

I have not attempted to address several important related issues: how to achieve a satisfactory compromise between central bank independence and accountability, whether the bank should be publicly instructed to aim at a target for inflation or some other variable and with what margins of error, and how theory may be developed for guiding the bank in its judgements of the best path of interest rates to achieve its goals. These issues remain the subjects of a great deal of worthwhile ongoing research. But the arguments in this paper do tend to support the common current arrangement, in which central bankers are given a period in office of several years and are largely insulated from government interference in their day-to-day decisions about the interest rate.

## Appendix

The following derivation of optimal policy applies to section 2 of the text. The identification of the parameters  $\phi$  and  $\psi$  in the expressions below with parameters in the text will be explained at the end of the working.

Assume that expectations are formed according to

$$\pi_t^e = \lambda \pi_{t-1}^e + (\phi - \lambda) \pi_{t-1} + (1 - \phi) \pi^* , \quad \forall t \geq 1 , \quad (A1)$$

where  $0 < \lambda \leq \phi < 1$ . Alternatively, as a function of policy  $\pi_0$  to  $\pi_{t-1}$

$$\pi_t^e = (\phi - \lambda) \sum_{j=1}^t \lambda^{j-1} \pi_{t-j} + \lambda^t \pi_0^e + (1 - \phi) \frac{1 - \lambda^t}{1 - \lambda} \pi^* . \quad (A2)$$

Rewriting the loss function (1), the government has to minimize

$$2E_0(z_0) = \pi_0^2 + b(\pi_0 - \pi_0^e - x^* + \varepsilon_0)^2 + \sum_{t=1}^{\infty} \beta^t \left( E_0(\pi_t^2) + bE_0(\pi_t - \pi_t^e - x^*)^2 + b\sigma_\varepsilon^2 \right) .$$

Setting  $\partial(E_0(z_0))/\partial\pi_0 = 0$  to find optimal policy  $\pi_0$ ,

$$\pi_0 + b(\pi_0 - \pi_0^e - x^* + \varepsilon_0) - b \sum_{t=1}^{\infty} \beta^t E_0(\pi_t - \pi_t^e - x^*) \partial E_0(\pi_t^e) / \partial \pi_0 = 0 \quad (A3)$$

then using (A2),

$$\begin{aligned} & \pi_0 + b(\pi_0 - \pi_0^e - x^* + \varepsilon_0) \\ & - b \sum_{t=1}^{\infty} \beta^t \left( E_0(\pi_t) - (\phi - \lambda) \sum_{j=1}^t \lambda^{j-1} E_0(\pi_{t-j}) - \lambda^t \pi_0^e \right. \\ & \quad \left. - (1 - \phi) \frac{1 - \lambda^t}{1 - \lambda} \pi^* - x^* \right) (\phi - \lambda) \lambda^{t-1} = 0 \end{aligned} \quad (A4)$$

Let us choose  $\pi^*$  to satisfy

$$\pi^* = bx^*(1 - \beta\phi)/(1 - \beta\lambda) , \quad (A5)$$

then after some algebra, (A4) yields the following difference equation

$$\begin{aligned} & (\pi_0 - \pi^*) \left( (1 - \beta\lambda^2)/b + 1 - \beta\phi(2\lambda - \phi) \right) + \varepsilon_0(1 - \beta\lambda^2) \\ & = (1 - \beta\lambda\phi) \left( \pi_0^e - \pi^* + (\phi - \lambda) \sum_{t=1}^{\infty} \beta^t \lambda^{t-1} E_0(\pi_t - \pi^*) \right) . \end{aligned} \quad (A6)$$

We require a solution to (A6) in which policy  $\pi_t$  in all periods  $t$  is a linear function of the observed state variables,  $\pi_t^e$  and  $\varepsilon_t$ .

Let

$$\pi_t - \pi^* = \rho_0 + \rho_1(\pi_t^e - \pi^*) + \rho_2\varepsilon_t , \quad \forall t \geq 0 , \quad (A7)$$

then from (A7) and the expectations formula, (A1),

$$E_0(\pi_t^e - \pi^*) = \psi E_0(\pi_{t-1}^e - \pi^*) + (\phi - \lambda)\rho_0 , \quad \forall t \geq 2 \quad (A8)$$

and

$$E_0(\pi_1^e - \pi^*) = \psi(\pi_0^e - \pi^*) + (\phi - \lambda)(\rho_0 + \rho_2\varepsilon_0) , \quad (A9)$$



where, for convenience, the coefficient  $\rho_1$  has been replaced by  $\psi$ , defined by

$$\rho_1 = \frac{\psi - \lambda}{\phi - \lambda} . \quad (A10)$$

Iterating (A8), and using (A9),

$$E_0(\pi_t^e - \pi^*) = \psi^t(\pi_0^e - \pi^*) + (\phi - \lambda) \left( \frac{1 - \psi^t}{1 - \psi} \rho_0 + \psi^{t-1} \rho_2 \varepsilon_0 \right) ,$$

then using (A7),

$$E_0(\pi_t - \pi^*) = \frac{\psi - \lambda}{\phi - \lambda} \psi^t(\pi_0^e - \pi^*) + (\psi - \lambda) \psi^{t-1} \rho_2 \varepsilon_0 + \frac{\rho_0}{1 - \psi} (1 - \lambda - (\psi - \lambda) \psi^t) ,$$

from which it follows that

$$\sum_{t=1}^{\infty} \beta^t \lambda^{t-1} E_0(\pi_t - \pi^*) = \frac{\beta(\psi - \lambda)}{1 - \beta\lambda\psi} \left( \frac{\psi(\pi_0^e - \pi^*)}{\phi - \lambda} + \rho_2 \varepsilon_0 \right) + \rho_0 f(\beta, \lambda, \psi) , \quad (A11)$$

where the function  $f(\cdot)$  need not be written explicitly.

Substituting (A7) (with  $t = 0$ ) and (A11) into (A6), using (A10),

$$\begin{aligned} & (\rho_0 + \frac{\psi - \lambda}{\phi - \lambda}(\pi_0^e - \pi^*) + \rho_2 \varepsilon_0) \left( (1 - \beta\lambda^2)/b + 1 - \beta\phi(2\lambda - \phi) \right) + \varepsilon_0(1 - \beta\lambda^2) \\ &= (1 - \beta\lambda\phi) \left( \pi_0^e - \pi^* + \frac{\beta(\psi - \lambda)}{1 - \beta\lambda\psi} \left( \psi(\pi_0^e - \pi^*) + (\phi - \lambda)\rho_2 \varepsilon_0 \right) + \rho_0(\phi - \lambda)f(\cdot) \right) . \end{aligned} \quad (A12)$$

Equation (A12) must be satisfied for all values of the initial state variables  $\pi_0^e$  and  $\varepsilon_0$ . Equating coefficients of  $\pi_0^e - \pi^*$ ,

$$\frac{\psi - \lambda}{\phi - \lambda} \left( (1 - \beta\lambda^2)/b + 1 - \beta\phi(2\lambda - \phi) \right) = (1 - \beta\lambda\phi) \left( 1 + \frac{\beta\psi(\psi - \lambda)}{1 - \beta\lambda\psi} \right) ,$$

which serves to identify  $\psi$  as a function of parameters, most simply written as the implicit expression

$$b = \frac{(1 - \beta\lambda\psi)(\psi - \lambda)}{(1 - \beta\psi\phi)(\phi - \psi)} . \quad (A13)$$

With  $0 < \lambda \leq \phi < 1$ ,  $0 \leq \beta \leq 1$ ,  $0 < b < \infty$ , and  $|\psi| \leq 1$  (otherwise explosive solutions would be admitted), it may be deduced from (A13) that  $\lambda < \phi$  implies  $\lambda < \psi < \phi$ , and  $\lambda = \phi$  implies  $\lambda = \psi = \phi$ .

Equating the coefficients of  $\varepsilon_0$  in (A12), using (A13), identifies  $\rho_2$  as

$$\rho_2 = - \frac{(1 - \beta\lambda\psi)(\psi - \lambda)}{(1 - \beta\lambda\phi)(\phi - \lambda)} . \quad (A14)$$

Finally, from the constant terms remaining in (A12),  $\rho_0 = 0$  (as a result of the value (A5) chosen for  $\pi^*$ ).

Putting these results into (A7) yields the solution for optimal policy

$$\pi_t = \pi^* + \frac{\psi - \lambda}{\phi - \lambda}(\pi_t^e - \pi^*) + \mu_t \quad , \quad \forall t \geq 0 \quad , \quad (A15)$$

where  $\pi^*$  is defined by (A5),  $\psi$  is given by (A13), and  $\mu_t = \rho_2 \varepsilon_t$  is white noise with  $\rho_2$  given by (A14).

Equations (7), (8) and (9) in the text are obtained by setting  $\phi = 1$  and  $\psi = \theta_0$  in (A15), (A5) and (A13). Equations (12), (15) and (16) are obtained by setting  $\phi = \theta_{k-1}$  and  $\psi = \theta_k$  in (A15), (A5) and (A13).

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