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WHY DOES HIGH INFLATION RAISE INFLATION UNCERTAINTY?

Laurence Ball

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ABSTRACT

This paper presents a model of monetary policy in which a rise in inflation raises uncertainty about future inflation. When inflation is low, there is a consensus that the monetary authority will try to keep it low. When inflation is high, policymakers face a dilemma: they would like to disinflate, but fear the recession that would result. The public does not know the tastes of future policymakers, and thus does not know whether disinflation will occur.

Laurence Ball
Department of Economics
Princeton University
Princeton, NJ 08544-1017

Economists frequently argue that a rise in current inflation leads to greater uncertainty about future inflation. This idea is a central theme, for example, in Okun's (1971) "The Mirage of Steady Inflation" and in Friedman's (1977) Nobel Lecture. Many empirical studies provide evidence of such an effect. But the accompanying explanations for the effect are usually loose (Okun, for example, uses an analogy to driving over a bumpy road). It appears that economists find the inflation level-uncertainty relation plausible but have trouble pinning down why. This paper attempts to improve our understanding of this relation by presenting a model that predicts it.[1]

The idea behind the model is simple: high inflation creates uncertainty about future monetary policy. To understand why, consider first a period of low inflation, such as the early 60s in the United States. In this situation, it is a good bet that the Fed is happy with the status quo and will attempt to prolong it. Inflation may rise at some point for a reason exogenous to the Fed, such as spending on Viet Nam. It is unlikely, however, that the Fed will simply decide that it is desirable to inflate.

Contrast this situation with a time of high inflation, such as the late 70s. Now it is not obvious what the Fed will do, because it faces a dilemma: it would like to disinflate but fears the recession that would probably result. It is likely that disinflation will occur eventually, but the timing is uncertain. It depends on factors that are difficult to gauge in advance, such as the values and opinions of FOMC members and the political pressures that they face. In the late 70s, it would have been difficult to predict that sharp disinflation would arrive in 1981-82.[2]

These ideas are similar to some previous discussions of inflation uncertainty. Logue and Willet (1976) argue that "at higher average rates [of inflation] government financial policy will tend to be less stable as it tries to bring inflation under control while avoiding steep recession." Fischer and Modigliani (1978) suggest that "governments typically announce unrealistic stabilization programs as the inflation rate rises, thus increasing uncertainty about what the actual path of prices will be." And Friedman argues that "[a] burst of inflation produces strong pressure to counter it. Policy goes from one direction to the other, encouraging wide variation in... inflation." The common theme is that high inflation creates uncertainty about how policy will respond.

This paper formalizes this idea by applying recent advances in the positive theory of monetary policy. Specifically, I make two modifications to Barro and Gordon's (1983b) model of the repeated game between the Fed and the public. First, following Canzoneri (1985), I introduce exogenous shocks that cause low-inflation equilibria to break down occasionally. The economy alternates between periods of high and low inflation, and I can compare uncertainty in the two situations. Second, following Alesina (1987), I capture policy uncertainty by assuming that there are two policymakers who alternate in power stochastically. The conservative policymaker (C) views inflation as very costly relative to unemployment, while the liberal (L) views inflation as less costly. (As described below, a switch in policymakers is interpreted broadly as a regime change that need not involve new personnel.)

These assumptions lead naturally to a link between inflation and uncertainty. C hates inflation, so when inflation is low he tries to keep it low and when it is high he disinflates. L also tries to prolong low inflation -- that is, he resists the temptation to create an inflationary boom -- but he is not willing to create a recession to disinflate. L's behavior results from a crucial asymmetry: as explained below, the welfare gain from a boom is smaller than the cost of a recession. When inflation is low, the public is certain of future policy because C and L do the same thing. High inflation creates uncertainty because the policymakers respond differently to the disinflation dilemma and the public does not know who will be in charge.

There are two versions of my model. In the first, as in previous work, policymakers attach a cost to the level of inflation. While this specification is plausible, the subject of the paper suggests an alternative. The inflation-uncertainty link is important because it helps to explain why inflation is costly: economists often argue that inflation has small costs if it is perfectly anticipated but larger costs if it raises uncertainty. Motivated by this view, the second model includes a cost of uncertainty as well as a smaller cost that depends on the inflation level. This specification creates a paradox: conservatives view inflation as costly because it creates uncertainty, but uncertainty arises from their efforts to disinflate (along with liberals' resistance). It appears that conservatives would do better by accepting high inflation. I show, however, that this may not be true.

The rest of the paper contains five sections. Section II presents the basic model. Section III describes behavior that produces an inflation-uncertainty link, and Section IV determines when this behavior is an equilibrium. Section V considers the model with a cost of uncertainty, and Section VI concludes.

II. THE MODEL

The model combines elements of Barro-Gordon (1983a,b), Canzoneri (1985), and Alesina (1987). There are two policymakers, C and L. Their loss functions are

$$(1) \quad Z_{it} = (U_t - U^O)^2 + a_i \pi_t^2 , \quad i=C,L ; \quad a_C > a_L ,$$

where Z_{it} is policymaker i's loss in period t, U is actual unemployment, U^O is optimal unemployment (a constant), π is inflation, and a is a taste parameter. C views inflation as more costly relative to unemployment than L does.

The policymakers face a short run Phillips curve:

$$(2) \quad U_t = U^N - (\pi_t - \pi_t^e) , \qquad U^N = U^O + 1 ,$$

where U^N is the natural rate of unemployment and π_t^e is expected inflation at t given information at t-1. As in previous work, $U^N > U^O$ creates the time-consistency problem that leads to inflation. (The assumptions that $U^N - U^O = 1$ and that the coefficient on $\pi - \pi^e$ equals one are normalizations on the units of U and π.) Substituting (2) into (1) yields the loss in terms of actual and unexpected inflation:

$$(3) \quad Z_{it} = (\pi_t - \pi_t^e - 1)^2 + a_i \pi_t^2 .$$

The policymakers gain and lose power stochastically. For simplicity, the probability that C is in power in a given period is a constant, c. L is in power with probability 1-c. One can interpret a change of policymakers as an election or appointment of a new Fed chairman. But it is more realistic to interpret it broadly as a policy shift, probably resulting from an FOMC meeting, that does not require new personnel. For example, the Fed may first act liberal, tolerating high inflation, but then crack down because it decides that the problem is serious or succumbs to political pressure.[3]

As in Canzoneri, the Fed does not control inflation perfectly. This assumption is needed for high inflation to arise occasionally, since (in the equilibrium below) policymakers never inflate on purpose. Each period, the policymaker in power chooses a target inflation rate π^*. With probability q, a shock causes actual inflation to deviate from the target. That is,

$$(4)\quad \pi_t = \pi_t^* \qquad \text{with probability } 1-q\ ;$$

$$= \pi_t^* + \varepsilon_t \qquad \text{with probability } q\ .$$

The shock ε is distributed symmetrically around zero, with greatest density at zero. The public does not observe ε, so it cannot tell whether a rise in inflation is intentional. One should think of q as fairly small: a shock is an occasional event, such as a significant shift in the money demand function. (The role of this assumption is explained below.)[4]

The two policymakers play a simple repeated game. At the start of each period, the public sets expected inflation; expectations are assumed to be rational. Then the current policymaker is determined and he chooses the target π^*. Finally, the inflation shock (if any) arrives, determining actual inflation. In choosing π^*, the policymaker in power minimizes the expected present value of his loss, with discount factor β, putting equal weight on periods when he is in and out of power. Each policymaker takes the other's behavior as given.

III. A PROPOSED EQUILIBRIUM

This section and the next show how the model can produce a positive relation between inflation and uncertainty. This section describes behavior by the two policymakers that implies such a relation. The next section determines when this behavior is an equilibrium and discusses other possible equilibria.

The proposed equilibrium is presented in Table I. It is a modification of the equilibrium for one policymaker in Barro-Gordon (1983b) and Canzoneri (1985). Expected inflation and the policymakers' inflation targets depend on inflation in the previous period. If previous inflation was non-positive, then expected inflation is zero and both policymakers target zero. If previous inflation was positive, then expected inflation is positive. In this situation, C still targets zero but L targets $\bar{\pi}>0$ (the value of $\bar{\pi}$ is determined below). Since L is in power with probability 1-c, rational expectations implies $\pi^e=(1-c)\bar{\pi}$. Intuitively, when expected inflation is zero, both policymakers are deterred from inflating by the "punishment" of higher expected inflation in the next period. When expected inflation is positive, C disinflates but L does not, because he is not willing to create a recession.

Over time, the economy alternates between periods of high (positive) and low (non-positive) inflation. Policymakers try to prolong low inflation, but at some point a shock causes inflation to rise, and expected inflation rises in the following period. Inflation remains high as long as L is in power but returns to zero when C arrives. (In general, inflation could also return to zero through a large negative shock, but this is ruled out below.)[5]

As in Canzoneri, a rise in inflation caused by a shock must raise expected inflation because the shock is unobservable. If the public, believing that the rise is accidental, continues to expect low inflation -- that is, if there is no punishment -- then the Fed can gain by faking positive shocks. Thus it cannot be an equilibrium for expected inflation to stay low. (The public does ignore negative shocks, because the Fed has no incentive to cheat in that direction.) Note that the behavior of expectations is realistic: when actual inflation rises or falls, expectations follow.

Table I implies a positive relation between current inflation and uncertainty about next period's inflation. If π_t is non-positive, then next period's target, π^*_{t+1}, is sure to be zero. If π_t is positive, then π^*_{t+1} is zero with probability c and $\bar{\pi}$ with probability 1-c; its variance is $c(1-c)\bar{\pi}^2$.

In any period, the variance of unintentional inflation, $\pi - \pi^*$, is $q\sigma^2$ (the probability of a shock times its variance). Combining these results, the variance of next period's inflation is

$$(5) \quad E_t[(\pi_{t+1} - \pi^e_{t+1})^2] = q\sigma^2 \qquad \text{for } \pi_t \leq 0 ;$$
$$= q\sigma^2 + c(1-c)\bar{\pi}^2 \qquad \text{for } \pi_t > 0 .$$

The uncertainty arising from inflation shocks is constant, but policy uncertainty is greater at high inflation.

IV. WHEN IS IT AN EQUILIBRIUM?

This section derives conditions under which Table I is a perfect Nash equilibrium. There are a number of steps. Part A presents simplifying assumptions and Part B determines $\bar{\pi}$, L's inflation target when $\pi_{t-1}>0$. Part C determines the present values of policymakers' losses when they behave according to Table I. Part D computes the effects on these losses of deviations from the assumed behavior; Table I is a perfect Nash equilibrium if neither policymaker benefits from any deviation. Part E discusses the results, and Part F describes other possible equilibria.

A. Simplifying Assumptions

The behavior in Table I is simple; for example, π^* takes on only two values. To obtain this behavior, we must impose several restrictions on the parameters. Relaxing these restrictions leads to more complicated but qualitatively similar results. Here I present the simplifying assumptions and briefly preview their roles (which unfortunately are rather technical).

The assumptions are

(6) $\varepsilon \in \left[-\frac{1}{a_C + 1}, \frac{1}{a_C + 1}\right]$;

(7) $q < \bar{q}$;

(8) $c < 1 - \frac{1}{2\beta}$,

where $\bar{q}$ is a complicated expression (see (A8) in the Appendix). Assumption (6) limits the size of the inflation shock. It guarantees that inflation does not fall to zero accidentally when policymakers target positive inflation. (7) states that a shock is not too likely in a given period. As described below, this simplifies policymakers' choices of targets. Finally, (8) bounds the probability of a conservative policymaker (when the discount factor β is close to one, the bound is close to 1/2). If c is too large, then when π_{t-1} is high the public expects immediate disinflation. But if π^e_t is low even when π_{t-1} is high, there is little deterrent to surprise inflation, and Table I cannot be an equilibrium.[6]

B. Determination of $\bar{\pi}$

Here I complete Table I by determining $\bar{\pi}$, L's positive inflation target when $\pi_{t-1}>0$. The Appendix shows that if policymaker i chooses a positive target, he always chooses his "discretionary" (or "one-shot") inflation rate:

(9) $\pi^d_i = \frac{\pi^e + 1}{a_i + 1}$.

This inflation rate minimizes the one-period loss (3) for given π^e. Intuitively, any $\pi>0$ implies that next period's expected inflation is $(1-c)\bar{\pi}$. Since all $\pi>0$ have the same effect on future expectations, a policymaker considers only his current loss in choosing among them. (In general, the presence of inflation shocks could alter this result: a policymaker might reduce his target below π^d_i to increase the probability of accidental disinflation. The Appendix shows, however, that this complication is ruled out by assumptions (6) and (7).)

$\bar{\pi}$ in Table I is given by (9) with i=L. Combining this result with the fact that $\pi^e=(1-c)\bar{\pi}$ when $\pi_{t-1}>0$ yields

(10) $$\bar{\pi} = \frac{1}{a_L + c} .$$

C. Equilibrium Losses

Here I determine the expected present values of policymakers' losses when they behave according to Table I. Consider first the loss in one period. Equation (3) gives the loss in terms of expected and actual inflation. Call this expression $Z_i(\pi^e, \pi)$. Let $\hat{Z}_i(\pi^e, \pi^*)$ denote the expected loss given π^e, the target π^*, and the distribution of the inflation shock. One can show that

(11) $$\hat{Z}_i(\pi^e,\pi^*) = Z_i(\pi^e, \pi^*) + q(a_i+1)\sigma^2 .$$

The first term on the right is the loss when $\pi=\pi^*$ -- that is, when there is no shock -- and the second is the expected loss from shocks (shocks raise the expected loss because $Z_i(\cdot)$ is convex in π).

The present values of the losses depend on the initial level of inflation. Let V_i^+ and V_i^o be the expected present values of i's loss at the start of a period -- before the current policymaker is determined -- when previous inflation was positive and non-positive respectively. These losses are defined implicitly by

(12) $$V_i^o = R_i^o + \beta[\tfrac{q}{2} V_i^+ + (1 - \tfrac{q}{2})V_i^o] ;$$

(13) $$V_i^+ = R_i^+ + \beta[c(1 - \tfrac{q}{2})V_i^o + [1-c(1 - \tfrac{q}{2})]V_i^+] ,$$

where R_i^o and R_i^+ are the expected losses in the current period (derived below). The present value of the loss equals the current loss plus β (the discount factor) times the expected present value in the next period. The expected present value in the next period is an average of V_i^+ and V_i^o weighted by the probabilities that current inflation is positive and non-positive. If previous inflation was non-positive, so both policymakers target zero, current inflation is positive with probability $\frac{q}{2}$, the probability of a positive inflation shock. If previous inflation was positive, current inflation is non-positive with probability $c(1 - \frac{q}{2})$, the probability that C is in charge and there is no positive shock. (Assumption (6), the restriction on the size of shocks, guarantees that inflation is positive if L is in charge.)

The expected current losses are

$$(14) \quad R_i^o = \hat{Z}_i(0,0)$$

$$= 1 + q(a_i+1)\sigma^2 \;;$$

$$(15) \quad R_i^+ = c\hat{Z}_i((1-c)\bar{\pi},0) + (1-c)\hat{Z}_i((1-c)\bar{\pi},\bar{\pi})$$

$$= \frac{a_i(1-c) + a_L^2 + 2a_Lc + c}{(a_L + c)^2} + q(a_i+1)\sigma^2 \,.$$

R_i^o is the expected loss when π^e is zero and both policymakers target zero. R_i^+ is the expected loss when C and L target zero and $\bar{\pi}$ respectively. The second lines of the equations use (3), (10), and (11). Substituting (14)-(15) into (12)-(13) leads to solutions for V_i^o and V_i^+ in terms of underlying parameters (these complicated expressions are omitted).

D. Deviations

Table I is a perfect Nash equilibrium if neither policymaker can ever gain by deviating from it. Following the usual practice, I consider a policymaker's incentive to deviate in a single period given that he behaves according to Table I in all other periods.[7] As discussed above, a policymaker always targets either zero or his discretionary inflation rate π_i^d (the Appendix shows that this holds in any deviation as well as in equilibrium). Thus deviating from Table I means choosing π_i^d when the table dictates zero, or vice-versa. Policymaker i can deviate when $\pi_{t-1} \leq 0$ or when $\pi_{t-1} > 0$. Let Δ_i^o and Δ_i^+ be the effects of these deviations on the present value of i's loss; they are given by

$$(16) \quad \Delta_i^o = [\hat{Z}_i(0,\pi_i^d) - \hat{Z}_i(0,0)] + \beta(1 - \tfrac{q}{2})[V_i^+ - V_i^o] , \quad i=C,L ;$$

$$(17) \quad \Delta_L^+ = [\hat{Z}_L((1-c)\bar{\pi},0) - \hat{Z}_L((1-c)\bar{\pi},\pi_L^d)] + \beta(1 - \tfrac{q}{2})[V_L^o - V_L^+] ;$$

$$(18) \quad \Delta_C^+ = [\hat{Z}_C((1-c)\bar{\pi},\pi_C^d) - \hat{Z}_C((1-c)\bar{\pi},0)] + \beta(1 - \tfrac{q}{2})[V_C^+ - V_C^o] ,$$

where π_i^d is again given by (9). For either policymaker, there are two effects of deviating when $\pi_{t-1} \leq 0$ -- of choosing π_i^d rather than zero. First, the current loss changes by $\hat{Z}_i(0,\pi_i^d)-\hat{Z}_i(0,0)$, which is negative: the economy benefits from a boom. Second, with probability $1 - \frac{q}{2}$ the deviation moves the economy to the high inflation regime (with probability $\frac{q}{2}$ inflation rises even if the policymaker does not deviate). If L deviates when $\pi_{t-1} > 0$ -- if, contrary to Table I, he disinflates -- the current loss rises but with probability $1 - \frac{q}{2}$ the economy moves to low inflation. If C deviates when $\pi_{t-1} > 0$, which means not disinflating, there are opposite effects.

Table I is a perfect Nash equilibrium if Δ_i^+ and Δ_i^o are positive for i=C,L. To understand these conditions, it is useful to start with the relatively simple case of $q \to 0$: the probability of a shock is negligible. (In equilibrium, this means that once inflation falls to zero it stays there forever.) For this case, the Appendix establishes that

$$(19) \quad \Delta_i^o > 0, \qquad i=C,L;$$

$$(20) \quad \Delta_L^+ > 0 \text{ iff } a_L < \frac{1+\beta c^2-\beta}{2\beta-2\beta c-1};$$

$$(21) \quad \Delta_C^+ > 0 \text{ iff } a_C > \frac{\sqrt{4\beta(1-c)(1-\beta+\beta c)(a_L+1)^2+\beta^2(1-c)^4}}{2\beta(1-c)} - \frac{1+c}{2}.$$

(The denominator in (20) is positive by (8)). According to (19), neither policymaker ever gains by deviating when inflation is low. (20) and (21) give natural conditions under which the policymakers do not deviate when inflation is high. L does not disinflate as long as his cost of inflation, a_L, is not too large. And C does disinflate as long as a_C is not too small. (The bound on a_C depends on a_L, which determines the inflation rate that L will eventually choose if C does not disinflate.)

When q is strictly positive, the general conditions for $\Delta_i^o>0$ and $\Delta_i^+>0$ are too complicated to interpret. Numerical calculations show, however, that the conditions are qualitatively similar to (19)-(21). Consider, for example, the case of q=.1. I assume c=1/4, β=3/4 and determine the combinations of a_C and a_L for which Δ_i^o and Δ_i^+ are positive. As in the case of $q\to 0$, Δ_i^o is positive for all a_L and a_C. Figure 1 shows when Δ_L^+ and Δ_C^+ are positive. Δ_L^+ is positive if a_L lies below an upper bound, and Δ_C^+ is positive if a_C exceeds a lower bound that depends (positively) on a_L.[8]

E. Discussion

In Table I, C's behavior is simple: since he greatly dislikes inflation, he always targets zero inflation. L's behavior is more complicated. He does not dislike inflation enough to disinflate, but for $\pi_{t-1}\leq 0$ he resists the temptation to inflate. This behavior results from an asymmetry between rises and falls in inflation. Equations (16) and (17) imply that a necessary condition for L to behave as assumed is

$$(22) \quad \hat{Z}_L((1-c)\bar{\pi},0) - \hat{Z}_L((1-c)\bar{\pi},\pi_L^d) \;>\; \hat{Z}_L(0,0) - \hat{Z}_L(0,\pi_L^d) \;,$$

which always holds. (22) states that the current cost of disinflation exceeds the gain from surprise inflation -- that is, a recession raises L's loss by more than a boom reduces it. This result explains why L accepts inflation rather than create a recession, but does not inflate to create a boom.

Booms and recessions have asymmetric effects because the loss function (1) is convex in unemployment. Since the Phillips curve is linear, surprise inflation reduces unemployment by as much as disinflation raises it. But convexity implies that the fall in unemployment reduces the loss by less than the increase raises the loss. The convex loss function is realistic. Convexity means that policymakers prefer constant unemployment at the natural rate to symmetric fluctuations around the natural rate -- that policymakers would like to eliminate a symmetric business cycle.[9]

The asymmetry between booms and recessions would be strengthened by a natural modification of the model: a non-linear Phillips curve. If the Phillips curve is steeper at high inflation (the common view), then an unexpected rise in inflation has a smaller effect on unemployment than an equal fall. In this case, the gain from surprise inflation is smaller than the cost of disinflation both because the change in unemployment is smaller <u>and</u> because the loss function is convex. A non-linear Phillips curve is also realistic. The disinflation of 1979-82 raised unemployment by four percentage points, from six to ten percent. It is unlikely that an equal rise in inflation would have reduced unemployment from six to two percent.

Even though the gains from a boom are small, it is perhaps surprising that L resists the temptation to inflate for <u>all</u> values of a_L. Intuitively, it appears that a very small a_L would lead L to accept high inflation for even a small short run gain. Indeed, L <u>would</u> inflate for a_L sufficiently small if inflation remained high forever. But if L inflates, he is eventually replaced by C, who creates a costly recession to disinflate. Even if L does not view inflation as costly per se, he is deterred from creating it by the future cost of eliminating it.

F. Other Equilibria

This section concludes with a brief discussion of possible equilibria besides Table I. There are two issues. First, since Table I is an equilibrium only for certain parameter values, I ask what happens in other cases. Second, I describe equilibria that coexist with Table I.

Other Parameter Values: Not surprisingly, different ranges of parameter values imply different equilibria. One noteworthy possibility is presented in Table II. Here I label the two policymakers liberal (L) and radical (R), and assume that $a_L > a_R$. As in Table I, L prolongs low inflation but does not disinflate. R always inflates -- that is, he always sets $\pi^* = \pi^d_R$. He is so indifferent to inflation that when inflation is low he raises it to gain a one-period boom. Table II can be an equilibrium if a_L lies in a moderate range and a_R is very small. This equilibrium yields a <u>negative</u> relation between inflation and uncertainty: if inflation is high, both policymakers keep it high, while if inflation is low one policymaker keeps it low and the other inflates.[10]

This result shows that a positive inflation-uncertainty relation depends on assumptions about parameter values as well as on the basic model. However, the conditions for a negative relation -- in particular, the condition that a_R is very small -- appear unrealistic. It is unlikely that any Fed chairman would consider inflation so harmless that he would intentionally move the economy from low to high inflation. Policymakers disagree about the response to high inflation, but there is a consensus that low inflation should be prolonged.

Multiple Equilibria: As in other infinite-horizon models of monetary policy, there are many perfect Nash equilibria for given parameter values. This paper will not attempt a full analysis of the multiplicity problem, but one should note two equilibria that coexist with Table I. First, as usual there is an equilibrium in which policymakers always target their discretionary inflation rates, π_i^d. Since policymakers' behavior is constant, inflation uncertainty is constant. Second, as in Barro-Gordon (1983b) and Canzoneri, there can be equilibria with finite "punishment periods." When a shock raises inflation, expected inflation rises but then falls automatically after one or more periods: disinflation does not require a recession. (Temporary punishment is sufficient to deter surprise inflation.) If the punishment period is short and a_C is not huge, C accepts high inflation during the period to avoid the cost of immediate disinflation. L does the same, so there is little policy uncertainty.[11]

A reason for focusing on the equilibrium in Table I is realism. In Table I, changes in actual inflation lead to changes in expected inflation. This appears consistent with U.S. experience. It is unrealistic to assume that expected inflation is constant, as in the discretionary equilibrium, and very unrealistic to assume that it falls automatically after a punishment period.

V. COSTS OF UNCERTAINTY

A. Motivation

The last section assumes that policymakers attach a cost to the level of inflation. While this assumption is plausible, the subject of the paper suggests an alternative. Economists are interested in the inflation-uncertainty link largely because it helps to explain why inflation is costly. The costs of anticipated inflation, such as deadweight loss from the inflation tax, appear small. But if inflation causes uncertainty, there may be significant costs, such as greater risk in long-term nominal arrangements (Jaffee and Kleiman, 1977; Fischer and Modigliani, 1978). Motivated by this view, this section assumes that policymakers' losses depend on uncertainty about inflation as well as the current level. The effect of the current level can be small or even zero.

This version of the model raises a new issue. In the previous section, uncertainty arises from C's efforts to disinflate, along with L's resistance. C's motivation is his view that inflation is costly. But if the main cost of inflation is uncertainty, it appears that C creates the cost by trying to eliminate it! If C simply accepted high inflation, like L, then uncertainty would diminish. The major cost of inflation would be reduced, and no recession would be required. Why does C not take this course?

This section contains two results relevant to this issue. First, Table I, with its positive inflation-uncertainty relation, can be an equilibrium even when the model includes a cost of uncertainty. Second, while there is another equilibrium with high but stable inflation (the discretionary equilibrium), C may not prefer this equilibrium. As suggested by Fischer and Summers (1989), reducing the costs of inflation -- in this case by reducing uncertainty -- can raise the level of inflation so much that policymakers are worse off.

B. A Positive Inflation-Uncertainty Relation

Here I add a cost of uncertainty to policymakers' loss functions and show that the behavior in Table I can remain an equilibrium. Modify the loss function, (1), to be

$$(23) \quad Z_{it} = (U_t - U^O)^2 + a_i\pi_t^2 + b_iE_t[(\pi_{t+1} - \pi^e_{t+1})^2] \quad .$$

This specification attaches costs to both the current level of inflation and the variance of next period's inflation. The former can be interpreted as deadweight loss from the inflation tax, and the latter as increased risk in nominal contracts. One should think of a_i as small, so that $a_i\pi^2$ is small for moderate inflation rates.

We can determine when Table I is an equilibrium with the approach of the last section. $\bar{\pi}$ is again $1/(a_L+c)$. (The cost of uncertainty does not affect L's choice of $\bar{\pi}$ because uncertainty is the same for all $\pi>0$.) Once again, Table I is an equilibrium if policymakers cannot gain from any deviation: Δ_i^O, $\Delta_i^+ > 0$. Here, policymakers take account of the degree of uncertainty implied by positive and non-positive inflation (see (5)). For the case of $q\rightarrow 0$, calculations parallel to Section IV show that

$$(24) \quad \Delta_i^O > 0 , \qquad i=C, L .$$

$$(25) \quad \Delta_L^+ > 0 \qquad \text{iff} \quad a_L(2\beta-2\beta c-1) + b_Lc(1-c) < 1-\beta+\beta c^2 ;$$

$$(26) \quad \Delta_C^+ > 0 \qquad \text{iff} \quad a_C\beta(1-c^2) + a_C^2\beta(1-c) + b_Cc(1-c)(1+a_C) > (1-\beta+\beta c)(1+a_L)^2 - \beta(c-c^2) .$$

The results for $q>0$ are again qualitatively similar.

Conditions (24)-(26) are generalizations of (19)-(21), the corresponding conditions in the basic model. C and L never deviate from Table I when $\pi_{t-1}\leq 0$. For $\pi_{t-1}>0$, they do not deviate as long as their distastes for inflation are strong and weak enough respectively. Here, policymaker i's distaste for inflation is measured by a linear combination of a_i and b_i. Note that if $a_i=0$, (24)-(26) are satisfied for ranges of b_C and b_L. Thus the equilibrium in Table I survives even if uncertainty is the only cost of inflation.

As in the basic model, C disinflates because he views inflation as very costly. Here this result seems paradoxical, because the major cost of inflation -- uncertainty -- results from C's efforts to disinflate. Nonetheless this situation can be a perfect Nash equilibrium. When inflation is high, the public expects C to disinflate and L not to disinflate. The resulting uncertainty has large costs (e.g. there is less investment). Under Nash behavior, C takes expectations as given, and thus takes it as given that high inflation creates costly uncertainty. He disinflates to move the economy to the low-inflation regime, in which the public is certain of future policy.

C. Does C Prefer the Discretionary Equilibrium?

As in the basic model, many equilibria can coexist with Table I. In particular, as long as a_L and a_C are positive, there is an equilibrium in which policymakers always target their discretionary inflation rates, π_i^d. Here I compare C's losses in this equilibrium to his losses in Table I to see which equilibrium he prefers. It seems natural to focus on equilibria that policymakers prefer, and previous authors usually do. A loose but intuitively appealing justification is that policymakers can guide the economy to a desired equilibrium, for example through policy announcements. In most models, policymakers prefer equilibria like Table I, in which inflation is often low, to the discretionary equilibrium. In the current model, however, it may appear that C prefers the discretionary equilibrium, because his efforts to disinflate in Table I create costly uncertainty. This suggests that C will try to guide the economy to the discretionary equilibrium by publicly forswearing disinflation.[12]

Here I show that this argument need not lead us to reject the equilibrium in Table I. Even if C can influence the selection of an equilibrium, he may not choose the discretionary one: perhaps surprisingly, his losses may be lower in Table I. To show this, I derive the behavior of inflation in the discretionary equilibrium. Equation (9) defines π^d_L and π^d_C, which the policymakers target every period, in terms of π^e. Rational expectations implies $\pi^e = c\pi^d_C + (1-c)\pi^d_L$. Combining these conditions yields

$$(27) \qquad \pi^d_C = \frac{1 + a_C}{a_L a_C + (1-c)a_L + ca_C} \quad ;$$

$$(28) \qquad \pi^d_L = \frac{1 + a_L}{a_L a_C + (1-c)a_L + ca_C} \quad .$$

One can show that, since C does not disinflate, the variance of inflation implied by (27)-(28) is smaller than the variance when $\pi_{t-1}>0$ in Table I. A useful special case is $b_C>b_L$ but $a_C=a_L\equiv a$: C cares more about uncertainty, but the policymakers attach the same small cost to the inflation level. In this case, both π^d_L and π^d_C reduce to 1/a in the discretionary equilibrium, and policy uncertainty disappears completely.

Does reduced policy uncertainty mean that C prefers the discretionary equilibrium? Combining (27)-(28) and the loss function (23) leads to C's average loss per period in the discretionary equilibrium:

$$(29) \qquad Z^d_C = \frac{a_C c(1+a_C)^2 + a_C(1-c)(1+a_L)^2 + (b_C+1)c(1-c)(a_C-a_L)^2}{[a_L a_C + (1-c)a_L + ca_C]^2} + q\sigma^2(a_C + b_C + 1) + 1 \quad .$$

(When $a_C=a_L\equiv a$, (29) reduces to $Z^d_C = (1+a)/a + q\sigma^2(a+b_C+1)$.) One can determine which equilibrium C prefers by comparing the present value of this loss to C's losses in Table I, which are derived with an approach parallel to Section IVC.[13]

The relation between C's losses in Table I and in the discretionary equilibrium is ambiguous. Rather than present the general conditions for C to prefer Table I, I illustrate the possibility with two special cases. The first, which is not surprising, is $b_C=b_L=0$: as in the basic model, the cost of inflation depends only on its level. In this case (or for b_i close to zero), one can show that C prefers Table I because the level of inflation is often low. The second case, which is less obvious, is a_L, $a_C \rightarrow 0$. In this case, the expression in (29) approaches infinity. C's losses in Table I remain finite, so he prefers that equilibrium.

Thus C prefers Table I not only if the cost of inflation depends entirely on the level ($b_i=0$), but also if the cost of the level is small ($a_i \rightarrow 0$).[14] The second case is important because, as discussed above, small values of a_i are realistic. The explanation for this case is that small a_i imply very high inflation targets in the discretionary equilibrium (as a_L and a_C approach zero, the targets approach infinity). In Table I, by contrast, targets are always moderate: even when $\pi_{t-1}>0$, the possibility of disinflation holds down π^e, and hence L's target (as $a_i \rightarrow 0$, $\bar{\pi}$ approaches $1/c < \infty$). When a_L and a_C are small, moving from Table I to the discretionary equilibrium raises the level of inflation so much that C is worse off even though there is less uncertainty and the cost per unit of inflation is small. This result illustrates Fischer and Summers's (1989) point that trying to reduce the costs of inflation -- in this case by reducing the resulting uncertainty -- can be counterproductive.

This drawback to the discretionary equilibrium seems realistic. Suppose that Paul Volcker, hoping to reduce uncertainty, announced in 1979 that he would accept high inflation permanently rather than disinflate. This might have led to very high inflation: as Okun (1971) argues, inflation may rise considerably if the public believes that the Fed has given up the fight against inflation.

VI. CONCLUSION

This paper presents a model in which a rise in inflation raises uncertainty about future monetary policy, and thus about future inflation. When inflation is low, there is a consensus that the monetary authority will try to keep it low. When inflation is high, policymakers face a dilemma: they would like to disinflate, but fear the recession that would result. Since the public does not know the tastes of future policymakers, it does not know whether disinflation will occur.

Is policy uncertainty an important source of the inflation level-uncertainty relation in actual economies? In principle, the relation could arise instead from the reaction of the private economy to high inflation. Hasbrouck (1979) shows, for example, that high trend inflation can raise variability by making money demand more responsive to shocks. Ball, Mankiw, and Romer (1988) argue that high inflation reduces nominal rigidity and thus steepens the short run Phillips curve; a steeper Phillips curve implies that inflation varies more as demand fluctuates. Finally, it appears possible that high inflation destabilizes the relation between the money stock and the Fed's policy instruments, thereby magnifying monetary control errors.[15]

It seems unlikely, however, that these explanations for the level-uncertainty link are the whole story. The following may be a useful thought experiment. Suppose that a Constitutional Amendment imposes severe punishment on any Fed chairman who lets inflation deviate too much from x, and that everyone therefore knows that the Fed will try to produce x. Compare inflation uncertainty when x is zero to uncertainty when x is ten percent. It is possible that money demand or the money multiplier is less stable when the target is ten percent, and thus that actual inflation varies more. But with a firm commitment to the target, the variance is probably small in both cases. The important difference between zero and ten percent inflation in actual economies is not the Fed's ability to hit these targets if it wants to, but rather the degree of uncertainty about whether the target will change.

I conclude by pointing out a limitation of my model. In the model, high inflation creates uncertainty only about disinflation -- about whether inflation will return to a low level. In actual economies, it appears that high inflation also creates uncertainty about whether inflation will rise further. Okun argues that if the Fed accepts high inflation to accomodate a shock, the public fears that inflation will rise again if there is another shock. In contrast, a nonaccomodative policy shows that the Fed is committed to keeping inflation under control. Future research should try to formalize these ideas.

APPENDIX

A. Inflation Targets

Here I show that, as claimed in Sections IVB and IVD, a policymaker's inflation target is always either zero or his discretionary level π_i^d. As explained in the text, this result is trivial if there is no inflation shock: since all $\pi>0$ have the same effect on future expectations, the policymaker chooses only the one that minimizes his current loss. With a shock, we must rule out the possibility that a policymaker reduces π^* below π_i^d to increase the chance that π falls to zero accidentally. In addition, we must ask whether a policymaker chooses a <u>negative</u> target rather than zero to reduce the chance that π rises above zero accidentally. I show that a policymaker always targets zero or π_i^d if q, the probability of a shock, lies below a bound; this bound defines $\bar{q}$ in (7).

I first ask whether a policymaker prefers a zero target to a negative target. If policymaker i chooses a non-positive target π^* in a given period, the present value of his loss is

$$\text{(A1)} \quad W_i(\pi^*) = \hat{Z}_i(\pi^e,\pi^*) + \beta[pV_i^+ + (1-p)V_i^o] ,$$

where V_i^o and V_i^+ are defined by (12)-(13) and p is the probability that current inflation is positive.[16] p is given by

$$\text{(A2)} \quad p = q[1 - F(-\pi^*)] ,$$

where $F(\cdot)$ is the c.d.f. of the inflation shock. In (A2), q is the probability of a shock and $1-F(-\pi^*)$ is the probability that the shock is large enough to produce positive inflation.

Substituting (A2) into (A1) and differentiating yields

$$\text{(A3)}\quad \frac{dW_i}{d\pi^*} = \frac{d\hat{Z}_i(\pi^*,\pi^e)}{d\pi^*} + \beta q f(-\pi^*)[V_i^+ - V_i^o] ,$$

where $f(\cdot)$ is the density function of the shock. For $\pi^*\leq 0$, this derivative is greatest at $\pi^*=0$, since $d\hat{Z}_i/d\pi^*$ is increasing in π^* and $f(\varepsilon)$ is greatest at $\varepsilon=0$. Thus if $dW_i/d\pi^*$ is negative at $\pi^*=0$, it is negative for all $\pi^*\leq 0$, and the policymaker prefers $\pi^*=0$ to $\pi^*<0$. At $\pi^*=0$, $d\hat{Z}_i/d\pi^*$ equals $-2(\pi^e+1)$; since the lowest π^e in Table I is zero, $d\hat{Z}_i/d\pi^*$ is no greater than -2. Along with (A3), this implies that $dW_i/d\pi^*$ is negative at $\pi^*=0$ if

$$\text{(A4)}\quad q < \frac{2}{\beta f(0)[V_i^+ - V_i^o]} .$$

(A4) guarantees that the policymaker prefers $\pi^*=0$ to $\pi^*<0$.

I now ask whether a policymaker prefers $\pi^*=\pi_i^d$ to another positive target. For $\pi^*>0$, the policymaker's loss is given by (A1) with

$$\text{(A5)}\quad p = (1-q) + q[1-F(-\pi^*)] .$$

The probability that inflation is positive is the probability of no shock plus the probability of a shock greater than $-\pi^*$.

Assumption (6) implies that $-\pi_i^d$ lies below the lower bound on ε. Thus $F(-\pi_i^d)=0$, and $p=1$ for $\pi^*=\pi_i^d$. Along with (A1), this implies

$$\text{(A6)}\quad W_i(\pi_i^d) = \hat{Z}_i(\pi^e,\pi_i^d) + \beta V_i^+ .$$

Equations (A1) and (A5) define $W_i(\tilde{\pi})$ for an arbitrary $\tilde{\pi}>0$. Using (A6), one can show that $W_i(\pi_i^d)\leq W_i(\tilde{\pi})$ if

$$\text{(A7)}\quad q < \frac{\hat{Z}_i(0,\tilde{\pi}) - \hat{Z}_i(0,\pi_i^d)}{\beta F(-\tilde{\pi})[V_i^+ - V_i^o]} .$$

(In (A7), I again set π^e to zero, its lowest value in Table I, to obtain the lowest bound.)

If a policymaker prefers zero to any negative target and π_i^d to any other positive target, then he chooses either zero or π_i^d. Thus he chooses zero or π_i^d if (A4) is satisfied and (A7) is satisfied for all $\tilde{\pi}>0$. One can show that both conditions are more restrictive for i=C than for i=L (the conservative is more tempted to reduce π^* below zero or π_i^d). Thus both conditions hold for both policymakers if

$$\text{(A8)} \qquad q < \bar{q} ,$$

$$\bar{q} = \min\left\{ \frac{2}{\beta f(0)[V_C^+ - V_C^o]} , \frac{\hat{Z}_C(0,\tilde{\tilde{\pi}}) - \hat{Z}_C(0,\pi_C^d)}{\beta F(-\tilde{\tilde{\pi}})[V_C^+ - V_C^o]} \right\} ,$$

where $\tilde{\tilde{\pi}}$ is the positive value of $\tilde{\pi}$ that minimizes the right side of (A7). The shape of F(·) determines the value of $\tilde{\tilde{\pi}}$ and which of the expressions inside the min is smaller. (A8) defines $\bar{q}$ in (7). (The bound on q is defined implicitly, because q affects $\bar{q}$ through V_C^o and V_C^+. The bound is satisfied for q sufficiently small, because $\bar{q}$ remains strictly positive as q approaches zero.)

B. The Case of $q \to 0$

Here I outline the derivation of (19)-(21), the conditions for Table I to be an equilibrium when $q \to 0$. When $q \to 0$, (12) and (13) imply

$$\text{(B1)} \qquad V_i^o = \frac{R_i^o}{(1-\beta)} ;$$

$$\text{(B2)} \qquad V_i^+ = \frac{R_i^+ + \frac{\beta c}{1-\beta} R_i^o}{1-\beta+\beta c} .$$

Substituting the formula for $\hat{Z}_i(\cdot)$ into (16)-(18) yields

$$\text{(B5)} \quad \Delta_i^o = \frac{-1}{a_i+1} + \beta[V_i^+ - V_i^o] ;$$

$$\text{(B6)} \quad \Delta_L^+ = \frac{1+a_L}{(a_L+c)^2} - \beta[V_L^+ - V_L^o] ;$$

$$\text{(B7)} \quad \Delta_C^+ = -\frac{(1+a_L)^2}{(1+a_C)(a_L+c)^2} + \beta[V_C^+ - V_C^o] ,$$

where, from (B1)-(B2) and (14)-(15),

$$\text{(B8)} \quad V_i^+ - V_i^o = \frac{(a_i+c)(1-c)}{(a_L+c)^2(1-\beta+\beta c)} .$$

Using the assumptions that $a_C > a_L$ and $c < 1 - 1/2\beta$, one can show that Δ_i^o is always positive and that Δ_L^+ and Δ_C^+ are positive under the conditions in (20)-(21).

Table I

The Proposed Equilibrium

	π_t^e	π_t^* if C	π_t^* if L
$\pi_{t-1} \leq 0$	0	0	0
$\pi_{t-1} > 0$	$(1-c)\bar{\pi}$	0	$\bar{\pi} > 0$

Table II

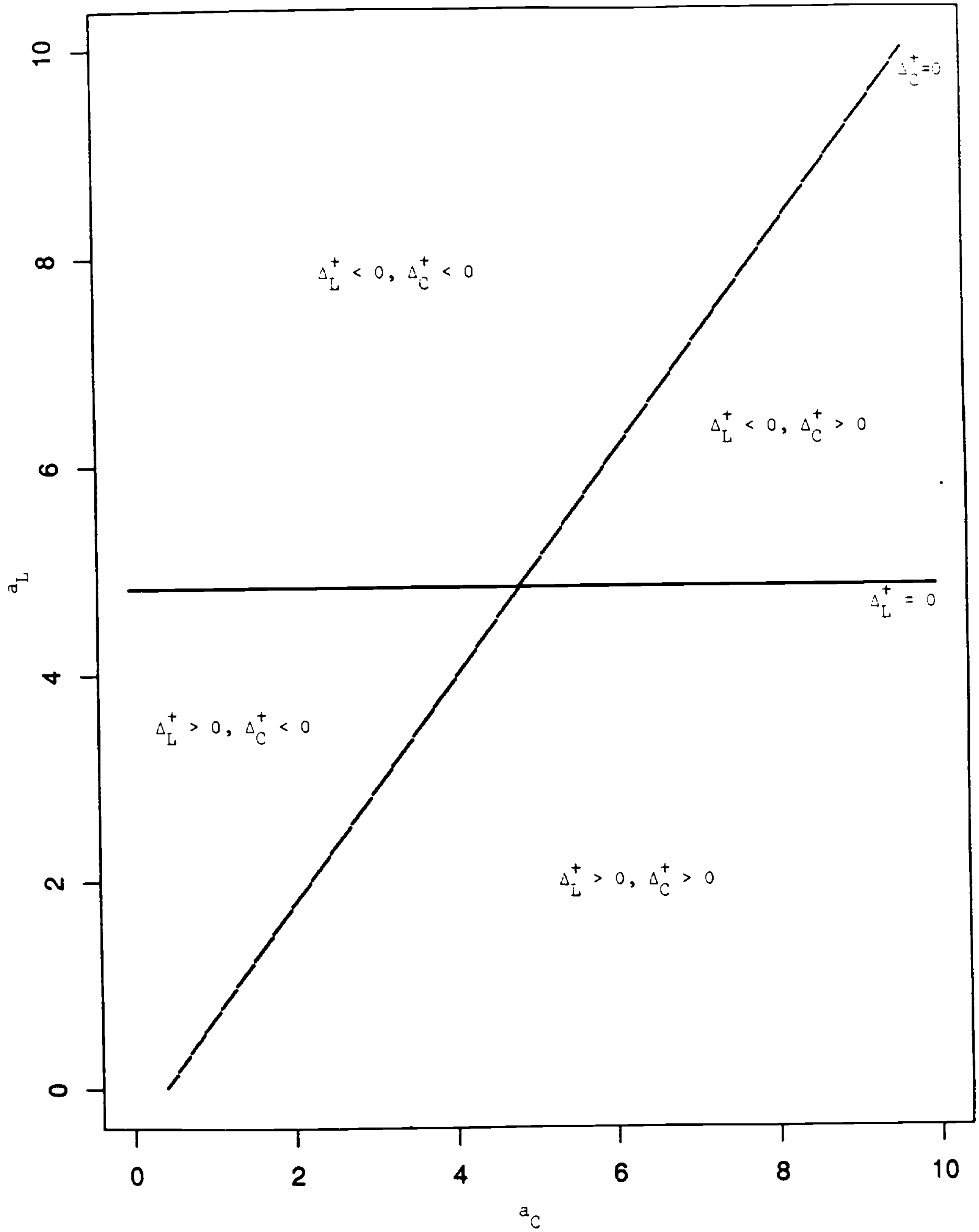
Another Possible Equilibrium

	π_t^* if L	π_t^* if R
$\pi_{t-1} \leq 0$	0	π_R^d
$\pi_{t-1} > 0$	π_L^d	π_R^d

Figure 1

Combinations of a_L and a_C for which Δ_L^+, $\Delta_C^+ > 0$

($q=.1$, $c=\frac{1}{4}$, $\beta=\frac{3}{4}$)



NOTES

1. Evidence of an inflation-uncertainty link is presented by Okun (1971), Logue and Willet (1976), Jaffee and Kleiman (1977), and Taylor (1981). While the evidence is not conclusive (see Engle [1983]), it appears to be widely accepted. In any case, this paper treats the inflation-uncertainty link as a fact to be explained. Cukierman and Meltzer (1986) and Devereux (1989) present other recent explanations; these papers are discussed below.

2. As this example suggests, the model is meant to apply primarily to moderate-inflation countries like the U.S. The experience of high inflation countries (e.g. in Latin America) depends largely on factors that I ignore, such as the use of seignorage to finance budget deficits.

3. It would be realistic to introduce serial correlation in who is in charge, or to let c depend on the state of the economy. But these modifications would greatly complicate the analysis.

4. This specification is a simplification of Canzoneri's model. In Canzoneri, a shock arrives every period. In addition, the inflation shock is derived by assuming that the Fed chooses the money stock and that money demand is stochastic. The money demand shock is observable -- the public infers it from the money stock and the price level -- but the Fed has a forecast of the shock that is private information. Adopting this more sophisticated approach would not change my main results.

5. The result that inflation remains high until C creates a recession is a departure from Barro-Gordon and Canzoneri. In those papers, inflation falls costlessly after a brief "punishment period." This difference is discussed in Section IVF.

6. If policymakers alternate in power according to a Markov process, (8) can be replaced by the assumption that the transition probabilities are small. In this case it is not necessary to restrict the unconditional probability that C is in power. This approach introduces other complications, however.

7. For a class of repeated games including the one considered here, Sorin (1988) shows that a set of strategies is a perfect equilibrium if one can rule out single-period deviations.

8. Ceterus paribus, raising q increases the range of parameters for which $\Delta_L^+>0$ and decreases the range for which $\Delta_C^+>0$. That is, it makes both policymakers more likely to prolong high inflation. A large q makes disinflation less attractive because disinflation is quickly reversed through a positive inflation shock.

Recall that assumption (7) restricts q to lie below the bound $\bar{q}$. For q strictly positive, the sufficient conditions for Table I to be an equilibrium include this restriction as well as Δ_i^0, $\Delta_i^+>0$. ($\bar{q}$ depends on all the parameters and the density function for the inflation shock. Thus, for a given q>0, the bound may be satisfied in some cases and not in others.)

9. The asymmetry between rises and falls in unexpected inflation is discussed by Hoshi (1988). In his model, the asymmetry can lead to multiple equilibria for the level of inflation.

10. In the equilibrium in Table I, L does not create surprise inflation even if a_L is very small, because inflation leads to a recession when C disinflates. In Table II, R does inflate for small a_R because he knows that nobody will disinflate.

11. For further discussion of these equilibria and others, see Fischer (1986) and Rogoff (1987).

12. This idea is informal because there is no formal theory of how announcements move the economy from one Nash equilibrium to another. Taylor (1983) argues that the economy is likely to arrive at an equilibrium that policymakers prefer. Rogoff (1987) expresses doubts. Other authors often focus on desirable equilibria without providing a justification.

13. For the results below, it does not matter whether one assumes an initial state of $\pi_{t-1} \leq 0$ or $\pi_{t-1} > 0$ in calculating the present value of the loss in Table I.

14. C may prefer the discretionary equilibrium to Table I if both a_C and b_C are large -- that is, if he strongly dislikes both a high level of inflation and a high variance.

15. Cukierman and Meltzer (1986) and Devereux (1989) present other theories of the inflation-uncertainty link. These papers, like the current one, use models of time-consistent policy in the Barro-Gordon tradition. In both papers, an exogenous increase in the variance of a shock, which raises the variance of inflation, also raises average inflation in the discretionary equilibrium. In Cukierman-Meltzer, a larger variance of monetary control errors makes it harder for the public to detect an intentional increase in inflation. This raises a policymaker's gain from inflating, and thus raises equilibrium inflation. In Devereux, a higher variance of real shocks reduces equilibrium wage indexation, which increases the temptation to inflate by increasing the real effects of inflation surprises. In both models, as in Hasbrouck and Ball-Mankiw-Romer, inflation varies more around a policymaker's target when the average target is high. In my model, high inflation raises uncertainty about whether the target itself will change (see the discussion below).

16. The assumption that V_i^+ and V_i^o are given by (12)-(13) means that the policymakers obey Table I in all future periods. That is, as in the text I consider a single-period deviation from the equilibrium.

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